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Geo-Spatial Sketches

1. Introduction

Few people learn how to sketch at school or during their professional education, but still, most everybody is able to draw a sketch or to understand a scene that was sketched by somebody else. This is sometimes even more astonishing, because people's sketching habits and techniques can differ considerably from one person to another. Nevertheless, we believe that sketches contain reoccurring structures, pattern, and symbols and that there are certain drawing strategies that are commonly used to generate sketches. The intention of our survey and its subsequent analysis is, therefore, to detect such typical characteristics in sketches and to study what kind of approaches people choose to translate their mental images into a two-dimensional sketched representation.

The focus of our investigations is on sketches that represent geo-spatial scenarios. Despite this, we expect that there is a significant correlation between sketches containing primarily geographical objects and sketches generated in other domains, which would allow a transfer of our results to other application fields as well. The primary reason for studying the generic sketching behavior of people is that a thorough understanding of the way people sketch is an essential requirement for the development of methods and techniques that allow an automated interpretation of freehand sketches. The survey and the report are, therefore, specifically designed to provide the required base knowledge for the development of such applications.

1.1 Motivation and Goal

This technical report emerged from the need to know more about the way people sketch and to understand people's sketching behavior in general. This knowledge is fundamental to be able to anticipate a user's intention when using an intelligent sketching device that is able to perceive a user's sketched intention, such as the one described in the Spatial-Query-by-Sketch project (Egenhofer 1996; Blaser 1997; Blaser 1997). Theoretical or introspective reasoning about people's sketching habits provide only limited and more or less subjective insight into important issues of the sketching process. A survey is, therefore, the only way to obtain realistic information that can be used as a base to categorize sketched objects or relations and to detect reoccurring sketching patterns or sketching strategies, which is in turn essential for the formulization of a model that captures the way people sketch.

Before analyzing the survey, we had compiled a set of questions for that we expected to find satisfactory answers. In the first place we were interested in *how*, *when* and *where* people draw their sketch objects. This resulted in questions, such as *Do people always use the same simple symbols to represent their objects in a sketch or is each object entirely different from the rest?* and many more. A subsequent, but non the less important issue concerned relations among different kinds of objects. Here we wanted to know more about the topological aspects or the temporal sequence between sketched objects. Beside pure object to object relations we were also interested in object to sketch relations, such as the orientation of an object in reference to the main sketching orientation for instance.

There are many more issues that caught our attention during the analysis of the survey, such as the distribution of objects in a sketch, how and when people make annotations, or how consistently a constant scale is applied throughout a sketch. This great number of involved parameters and characteristics that had to be considered led to an extended and quite complex analysis of our survey, which was also the reason why the report become much bigger than we initially expected. However, thanks to a preliminary study involving a subset of the surveyed sketches, we think that were able to address and asses the majority of important characteristics of freehand sketches describing geo-spatial scenarios. With this analysis, we believe that we have reached our goal to compile a comprehensive description of how people sketch and with it laying the foundation for a subsequent formulization of a model capable of capturing the essence of a freehand sketch.

1.2 Methodology

This results presented in this report are based on a survey that required each of the selected subjects to draw three sketches and to complete a short questionnaire with questions. A total of 51 surveys have been send out. Five of these surveys have been sent prior to the actual survey in order to assess the understandability of the survey. Although only minor changes were necessary non of these five initial surveys have been included into the quantitative interpretation of the survey.

The selected group of subjects can be further divided into those that are familiar with geographic information systems (GIS) and those that are not necessarily acquainted with. The primary group consists of students and faculty of the Department of Spatial Information Science and Engineering here in Orono. The secondary group includes individuals from the US, Germany, Switzerland, and India with various professional and cultural backgrounds. Age and gender of both groups is also quite heterogeneous–The age of the subjects ranges from 25 to 57 years, including 11 female and 20 male subjects (subjects, who's survey has been analyzed). A total of 32 surveys has been completed and returned, this does not include the five preliminary surveys. Of those 32 surveys there was only one survey that could not be processed, because all three sketches were undecipherable and, therefore, inappropriate for further considerations. Hence of the possible total of 96 sketches we finally interpreted 91 sketches. The 5 missing sketches were either not drawn or inadequate for an interpretation. A further statistical analysis and categorization can be found in the Appendix Section 11.1.

The survey was prepared in English and German with identical content. This was necessary, because of the international setup and that every subject was able to read the survey in one of his or her mother languages. The survey includes the following elements:

- A *cover letter* with a general description and an explanation of the purpose of the survey.
- A page with *general instructions* that explained how to complete the survey (Appendix 11.2.1)
- Separate and written descriptions of three *sketching problems.* This page includes six short sketch related questions and it provides space to note the *sequence* with that the sketch objects are drawn as well as space for *additional comments* (Appendix 11.7.3)
- Three *printed screens,* emulating a sketch-based user interface (Appendix 11.2.3)
- One page with *general questions* about the survey and about sketching in general (Appendix 11.7.1)

The three sketching problems, where the participating subjects had to sketch a situation based on a written description are the core part of the survey. The accompanying questions, associated with each sketching problem and the questionnaire at the end of the survey were primarily intended to distract the subjects from the true purpose of the survey in that they suggested that time is an important issue. Besides this, the questions were also meant to persuade the subjects to sketch their sketches and keep them from painting. At the end, however, the answers to these questions turned out to be quite informative as well.

To establish equal conditions for each subject, there was–beside the information in the cover letter and in the sketching instructions–no other information concerning the survey.

1.2.1 Thematic of the sketching Problems

The three sketching problems are all structured the same way. Each problem includes a description of the scenario that has to be sketched by the subject, space to specify the chronological sequence in which objects are sketched, six questions about drawing this particular sketch, and finally space for additional comments. The subjects are asked to proceed in this same sequence that is: first reading the description, then drawing the sketch, then noting the sketching sequence, then answering the questions, and then adding comments if necessary. In contrast to the structure of the sketching problems that was chosen equal for all problems, the individual assignments are clearly distinct. The first scenario involves sketching a situation that the subject is very well aquatinted with. Conversely in the second scenario, where the subject is asked to draw a situation that he or she is not familiar with. The last problem, finally, consists of drawing an imaginary spatial scene that the subject only knows from reading the description. The original text of the three sketching problems can be found in the Appendix Section 11.2.2.

These three scenarios represent three significantly different approaches for sketching a spatial scenario. In the first problem the subject knows much more than he or she will actually draw in a sketch. Such a sketch is most likely to contain only a set of selected, prominent objects that are helpful for a description so that one could anticipate a very meaningful, consistent, and reliable sketch. This is not true for the second problem, where the subject has only fragmental knowledge of the spatial scene because he or she is not familiar with this environment. The type of sketched landmarks are most likely to differ considerably from those that are drawn in the first problem (Lynch 1960). It can also be expected that errors occur more frequently within the setup of problem number two. The last sketching problem, finally, urges the subject to build up a whole new mental image of the scenario that is based only on the description of the problem. This transformation of a written scene description into a sketch is very interesting and revealing, because the description is ambiguous in that is lacks some information about relations between involved objects and because the overall orientation of the scenario is unclear. The task is further complicated, because the description includes some unusual objects, such as topographical elements (e.g. mountain) and time indications that convey distances. This setup requires the subjects, therefore, to use a great deal of imagination.

1.2.2 Analysis of the Survey

There is almost an infinite amount of things to analyze in surveys based on sketches. This is above all, because sketching, unlike any spoken language, has no definite and standardized grammar or syntax. Almost every technique is allowed as long as it is appropriate to convey the intended message: Symbols, schemas, perspectives, annotations, and much more can be freely arranged and mixed in a two-dimensional setup. The fact that people are able to extract information from such a conglomerate of items is truly a sign for the high inference capabilities of the human mind and it might as well be an indication that people are rather used to think in some sort of images than in words or phrases like some research (Koffka 1935; Gibson 1979; Johnson 1987).

To reduce the initial complexity of the analysis of our survey we focus primarily on elementary structures, such as objects, binary relations, and object annotations. The three sketches of every subject are analyzed one after another, on an object by object base. To facilitate the study of the sketches and speed up the data collection phase we have created a simple MS Access database with four tables and forms that simplify the input. The main table contains information about each detected object, there is a total of 44 records for each object to hold this information, four records hold pointers to the other tables. Each object can have many written annotations, which are all stored in a separate table. All objects in a sketch are connected through a table that holds general information about this specific sketch and, finally, all sketches of a person are linked to each other with the forth table that stores also the subject's answers on the questionnaire. The database schema and the description of the content of the various records is described in Appendix Section 11.3.

All surveys were examined by the same person. This has two reasons: First we expect that eventual variations concerning the interpretation of the sketches are smaller if only one person is involved in assessing the surveys. The second reason is that it takes a considerable amount of time to thoroughly examine sketches that contained in our case up to 55 distinguishable objects, not counting annotations. However, we think it would be advantageous for a sketch interpretation if multiple people would go through a survey of this kind, because this would level of the subjective component of an interpretation significantly. For the interpretation of the results of the examination we used SQL-based query tools provided by MS Access and the visualization was done with MS Excel and MathCAD.

1.2.3 Structure of the Survey

The report is structured into five major parts, covering sketch objects, relations, and annotations as well as general characteristics of sketches and an analysis of the sketching questionnaire. During the first phase that is focused on sketched objects we analyze different object classes and object types and study their distribution and how they are represented by the sketching subjects. A further sub-chapter of this part reasons about the role and the purpose of objects in a sketch. The second chapter about relations in a sketch investigates various relations between objects, the entire sketch, and the drawing device. Issues of concern are topology, location, orientation, direction, as well as the temporal and spatial sequence with that objects are drawn in respect to each other. The third chapter looks at object annotations and other written statements that have been made in the scope of the sketches. Beside the form and the typical use of annotations we examine spatial and temporal aspects of annotations that is we look where annotations are placed and when objects are annotated.

The subsequent chapter is concerned about general characteristics of a sketch, such as orientation, scale, and internal structures in a sketch. The last chapter, finally, is looking at answers from the sketching questionnaire. The subjects were asked about the survey and about the functionality of a hypothetical electronic sketching device, if one were available. A discussion and interpretation of our observations closes, thereafter, the report. Tables and figures containing extended and additional information can be found in the Appendix (Chapter 11).

Before we start with the first part of our analysis, we will briefly introduce the three basic elements in a sketch in the following chapter.

2. Ingredients of a Sketch

Before we can delve further into the topic we will have to define the ingredients or elements of a sketch. Although there is no general rule of how to make a sketch, we can divide all sketch elements into the following three categories:

- Object,
- Relation, and
- Annotation

Definition of an object:

An object is a logical instance or entity in a sketch. Objects can be composed of multiple intersecting or non-intersecting strokes. It is also possible that an object contains no drawn elements and that it is defined by an annotation alone (refer to the definition of annotation below). Because objects are logical entities, an object may enclose multiple independent *sub-objects*. In analogy to object-oriented programming such objects that are hosting other objects are referred to as *base-objects*. An example of a base-object is a town containing houses, where the houses are the sub-objects. It depends on how objects are drawn that they are considered sub-objects or autonomous objects. Multiple levels of objects are possible, such a hierarchy of objects can be associated for example between a country, a town, and a house.

The referencing system–the drawing surface or any other delimited or virtual area–to which objects are related can be considered as an object too. And since objects can be in reference to one or more referencing systems the total number of objects is not necessarily equal to the number of actual objects in a sketch. In many geographical related sketches there is only one referencing system in which case the total number of objects equals the number of actual object plus one.

Definition of a relation:

A relation is the link between two or more objects. A binary relation includes only two objects. Multiple objects are only involved when a group of objects is brought into relation with a single object, such as when a poplar tree in an avenue is related to the rest of trees as standing *in line* with the other trees. But since a group of objects can be considered itself as an object on a higher level, most relations involving multiple objects can be reduced to a two object relationship. We can specify the number of possible binary relations in a sketch as:

$$\frac{n!}{k!(n-k)!}$$

with n equals the number of drawn objects in a sketch and k the number of objects involved in a single relations–for binary relations this is $k=2$. The number of possible relations (including binary and multi relations) can only be determined with knowledge about the distribution, affiliation, and aggregation of objects in respect to the various referencing systems and to other objects. However, beside the entire set of possible relations in a sketch there is a subset of relevant relations that is essential to describe a sketch. This subset of relevant relations is much more difficult to evaluate but it contains in return more substantial information about the sketch.

Definition of an annotation:

> An annotation is a written or spoken verbal note specifying, describing, or defining an object, a group of objects, a relation between two objects, or properties of objects or relations. If an annotation is used without referring to an object, it can be seen as a virtual object (Example: Referring to a town with just writing its name on the sketch, e.g. Boston). Annotations are frequently used to describe characteristics of an object that can not be formulated graphically, such as an address or a name of a building. Annotations can also be used to specify specific properties of a relation between two objects, such as the time or distance to get from A to B. Annotation are in general used as a complement in a sketch, but they can also be used in a contradicting sense, although this is less likely.

Every sketch can be split up into sets according to these basic elements. Annotations are not essential parts of a sketch, objects are mandatory and relations are implied when more than one object is drawn. The main advantage of subdividing a sketch into atomic elements is that elements or small structures of elements are much easier to handle and process than an entire sketch. This is especially critical if a sketch must be analyzed and interpreted by a computer.

The next chapters take a closer look at the three basic elements of a sketch: Object, relation, and annotation. Although our interpretation is based primarily on our survey which involves geo-spatial objects only, we try to be as general as possible when making statements about people's sketching habits and strategies.

3. Objects

Drawn objects are the primary elements in a sketch; they can be seen as the meat of a sketch and knowledge about them can reveal what the sketch is concerned about. Hence, simply by acquiring knowledge about the type of objects in a sketch it seems to be possible to obtain some insight about the semantic or meaning of a sketch as well. In this context objects can be seen as metadata of a sketch.

The term sketch-object stands for a multitude of different drawn and non-drawn representations in a sketch and there are no rules how to represent certain real world objects. Everything is allowed, as long as the sketch remains understandable for the interpreting person. Hence, one's home could be circumscribe with a perceptively drawn house, a circle, a square, a front view, or one could just write *my house* without further drawn indication. All these representations would be legal placeholders for the same thing: *my house*. This example shows that it is not trivial to perceive the meaning of sketched objects without some basic knowledge of how people sketch, and on the other hand it implies that there must exist some common patterns in how people sketch, because otherwise nobody would be capable to interpret other people's sketches.

To investigate these commonly agreed principles that describe how objects in sketches can be drawn, we have analyzed our surveys on an object by object base. Each object was interpreted and classified on behalf of an a priori fixed assessment scheme and the results were fed into a database. The following sections describe the results of this interpretation.

3.1 Classes and Types of Sketched Objects

We define an object class as a category of objects having similar characteristics or being of the same sort. Each object class can have one or more sub-categories, object types, that allow a more specific description. A priori knowledge about object classes and types, such as the frequency or the typical shape of an object, is very valuable, because it can be used to help determining the type of an object if the meaning of such an unidentified sketched object is not clear from the context alone. For instance, if a user draws a rectangle, our experience tells us that this is most likely a building and not a swimming pool that could have the same representation as well. Our *experience* in this case is nothing else as an evaluation of the frequency in which such objects–in this case an non-annotated rectangle–occur. This knowledge about the occurrence frequency of specific objects in sketches is also essential for the design of automated processes that use sketches as input source. Beside considerations concerning the likelihood of specific objects there is also the question of object representation. Despite the fact that there is in theory an infinite number of possibilities to describe the same objects in a sketch, we believe that there is a strong similarity between these representations and that most people tend to use a rather small set of object types in their sketches. Of course the set of frequently used object types and classes may vary from domain to domain.

3.1.1 Object Classes

The initial step of our analysis involves a query that generated a list of the entire set of object classes (or categories) that were used in our survey. Some of these categories were defined dynamically while analyzing the survey and, therefore, were not known a priori. Our evaluations in respect to composition and frequency of object classes and object types exclude all objects of the third sketching problem (Appendix 11.2.2), because in this example there was explicitly specified what objects had to be drawn. The two other sketching problems (Problem 1 and 2, Appendix 11.2.2) are less biases by the problem description. The total number of objects is 832 (69% of all objects analyzed in the survey) and their distribution on the 19 object classes is depicted in Figure 1.

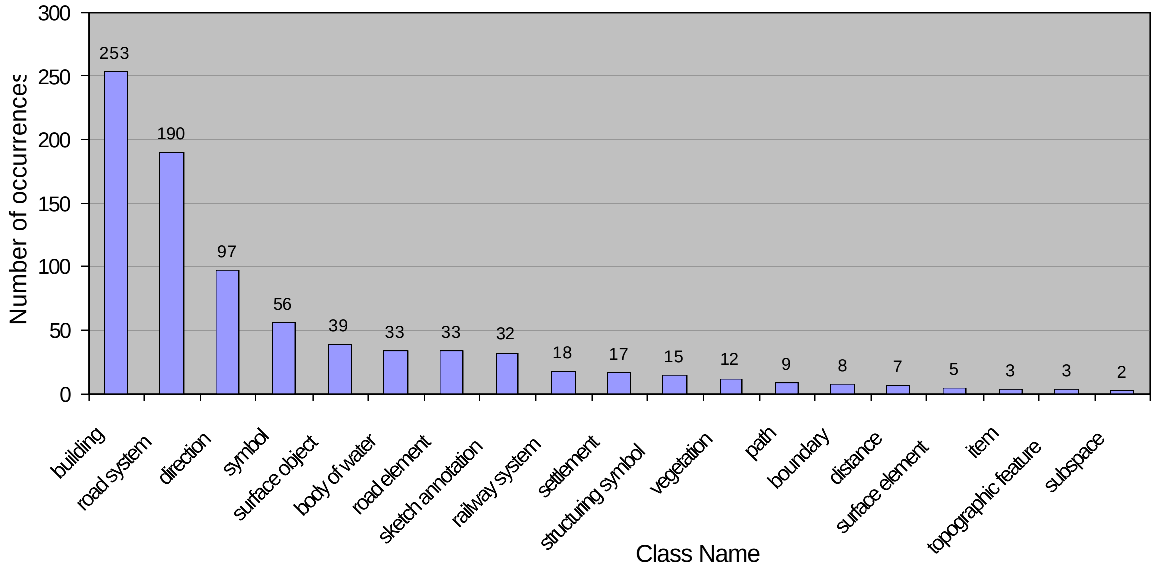


Figure 1 Population of the 19 arbitrary defined classes, sorted by the number of contained objects (Scenario 1 & 2).

It is remarkable that the sum of objects belonging to the two most frequently used classes (building and road system) alone covers 53% of all sketched objects and that the first nine classes (buildings - railway system) make up 90% of all objects. Dependent on the field of application and the context of the sketch these classes will, of course, vary. However, we believe that for a specific field of application there is only a relatively small number of object classes and that these classes are sufficiently comprehensive to allow a sketch-based communication in this domain. Beside such domain or application specific sets of expressions, there is most likely also a generic standard terminology that is included in all sketches. This standard set of object classes may include generic symbols, such as arrows or simple lines, it may include gestures, such as underlining to emphasize an object, or other techniques that are common throughout sketches in general.

The referencing system to which the sketch is linked plays a major role for the definition of the used classes. This is because sketches normally refer to their referencing system by describing a small portion of it in order to create the link between sketch and reality. The actual message of a sketch sits on top of this description that defines the scope of a sketch and can have many forms, such as a path to follow, an object in question, a set of way points, or the definition of a new structure within an existing system. Because of their link to the real world we can assume that applications that use a geo-spatial context and our environment as their primary referencing system are very likely to use similar object classes to describe basic structure in a sketched representation. These assumptions seems to be supported by the relatively small set of classes described in Figure 1.

3.1.2 Objects Types

Figure 2 shows object types grouped by classes. Object types with only five or less occurrences are not listed. While some object classes, such as the building class are represented by as many as 11 different types, there are other important classes that do not show such a great diversification. The road system class (streets) and the body of water class (rivers) are two examples. One reason for this observation could be that people are more concerned about buildings than about objects with line characteristics, such as streets or rivers. The reason for this may be that buildings are more dominant in our environment and that they are convenient to use as landmarks. Another explanation may be rooted in the formulation of the sketching problems that focuses rather on buildings (e.g. start and end point of a route) than on streets (path or route). Yet another explanation is that we perceive and use line-shaped objects, such as road systems, more like connecting links between different object types and that we emphasis this linking character in our mental images and such taking less notice of other characteristics, such as width, shape, or proportion.

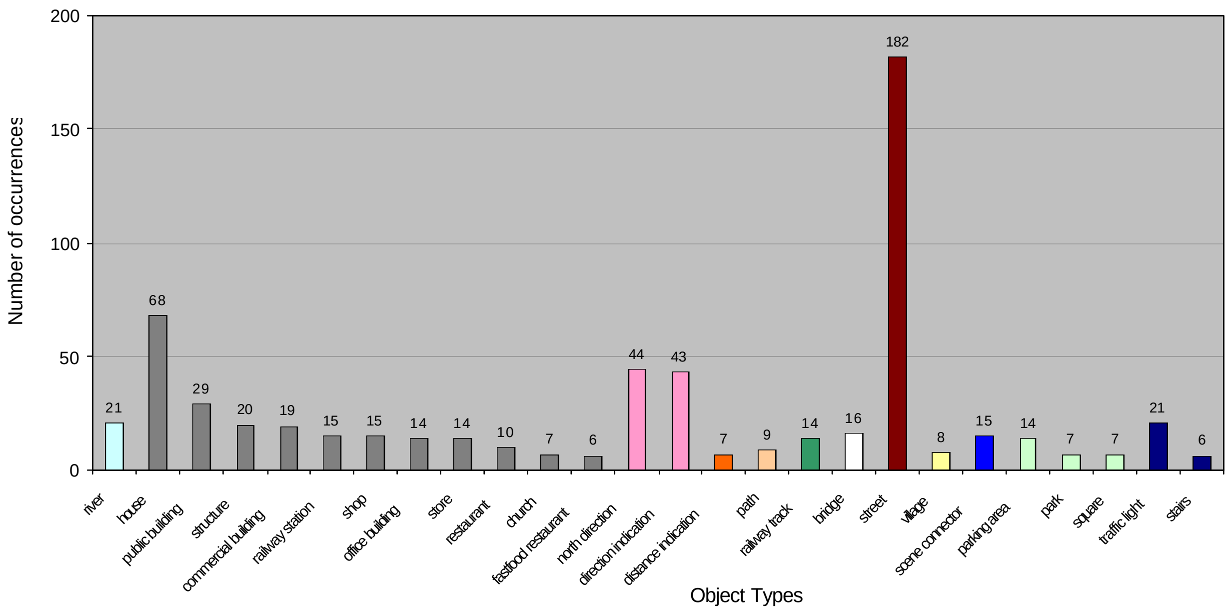


Figure 2 Object types that had more than five occurrences within the first two sketching scenarios. Object types are grouped and color coded by classes (Scenario 1 & 2).

Based on these observations we can assume that people use objects with line characteristics primarily as some sort of "sketch-glue" to keep and link objects together, to orient a sketched scene, and to indicate a from-to relation. Conversely objects with no line characteristics, such as buildings: Here the emphasis is on an object's specification or description, such as its name, address, or its purpose while other characteristics, such as its orientation play a less significant role. Later observations, as we will see, will further support these assumptions.

3.1.3 Various Observations

Natural objects, such as body of water (4%) or vegetation (1%) make only a remarkable small part of the entire set of objects found in scenario one and two, while artificial objects, such as buildings (30%) or roads (23%) occur much more frequently. Again, this could be because of a particular constellation in the sketching problems that focus primarily on urban areas, but it is also feasible that this is the way people memorize their environment and that most artificial objects are thought to make up more reliable and better landmarks or guides then natural objects. That the actual environment plays a significant role can be seen in differences between sketches made by Europeans and Americans: While there are as many as 32 train related objects in sketches that are made by Europeans, there is only one such object within all sketches made by Americans. Conversely there were only two fast food restaurants on sketches made by Europeans, while there were five in the American sketches [Figure 2 shows a total of six fast food restaurants that is one less than just mentioned. The reason for this discrepancy is due to the fact that one fast food restaurant was classified as symbol and not as building]. Therefore, we can assume that there are other factors beside the field of application and the reference frame that influence the composition and frequency of object classes and types in sketch. Cultural background or knowledge are examples.

Also not explicitly perceptible from Figure 2 alone we found a strong agreement among the subjects of how to indicate the north direction. In 44 sketches (73% of a total of 60 sketches in scenario one and two) this prominent direction was indicated by a directional arrow pointing North and annotated with a capital letter *N* or the word *North*. Only in 7 cases the north direction was annotated differently. This observation reflects, how easily we adopt and learn common symbologies of our environment–in this case the north arrow on maps–that suggest the use of symbols or methods to describe the world around us. A similar consent as with the North direction can be observed for other directions or paths. These directions were almost without exception expressed with simple directional arrows, again an observation that supports the theory that there is only a small set of symbols that covers most people's sketching needs. We will learn more about directions and direction indicators in Sub-chapter 4.5 and Section and 6.1.1.

Another interesting observation can be made in respect to objects conveying metric information. Only 8 objects (seven pure distances and one direction indicating a distance as well) or less than 1% out of a total of 832 objects in scenario one and two are concerned about explicit metric aspect, all other sketches use mainly topology and the arrangement of objects to describe a specific situation. This is a very important observation and it seems to prove the statement that topology matters and metric refines (Egenhofer and Mark 1995).

Into a similar category falls that there are only three objects (less than 4‰) that describe topographic structures with a prominent 3D component, such as a hill or a valley. That these three objects belong to a single sketch amplifies this statement even more. Hence, it seems that, like with objects defining metrical aspect in a sketch, objects that describe the third dimension are rarely used in people's everyday sketches. A similar observation can be made with common maps, where contour lines, hill shadings, or other means to represent topographical structures are frequently considered to be secondary information. We assume that this neglecting approach in respect to topographical structures is due to the fact that people use primarily topological structures to get a rough impression of a spatial situation. But it might as well be that people have no appropriate representations for these kinds of objects and, consequently, try to avoid them.

While this sub-chapter has focused on issues concerning *what* kind of objects are drawn in a sketch, the next sub-chapter will focus on *how* objects are represented in a sketch.

3.2 Representation of Sketched Objects

Objects in a sketch are generalized to an extend that they are often barely recognizable without the context provided by the sketch or without a written or spoken annotation. That people can make sense of sketches is because they are able to comprehend sketched objects as well as their annotations and bring them into meaningful relation with each other and the referencing system. Although sketched objects are in general drawn with very few strokes and, therefore, have a simplistic or symbolic character, sketched objects can still have many distinguishing characteristics, such as shape, type of outline, or drawing perspective. In order to be able to automatically retrieve sketched objects, it is of interest to investigate these characteristics. To learn more about the various visual characteristics of objects in sketches we have examined all 1208 objects from the three sketching scenarios concerning their form of representation. This means that this time we have included the third scenario for our studies as well. The third sketching problem (Appendix 11.2.2), as a reminder, describes a virtual scene with predefined objects that intentionally include vegetation and topographical objects, as well as some metric constraints. This was done by purpose in order to study people's sketching technologies with these otherwise rarely used objects and specifications.

3.2.1 Dimensionality

We define the dimension of an object as the basic type of representation. With this definition, we can have zero, one, and two-dimensional objects. A zero dimensional object is an object that is only defined by an annotation or by an annotation with an arrow. Sketch annotations that define a sketch object or that are not connected to the entire sketch, such as the legend or the title of a sketch, are also considered as zero dimensional objects. Figure 3 shows two examples of zero-dimensional objects.

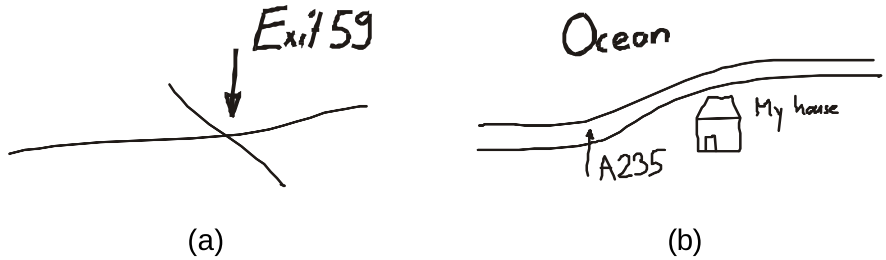


Figure 3 The exit in (a) and the ocean in (b) represent both a zero dimensional object in a sketch. Note that the *arrow* and the annotation *Exit 59* in (a) belong to the object annotation, therefore, the arrow is not listed as an autonomous directional symbol.

An object in a sketch is one-dimensional if it has a pronounced line-characteristics (object length >> object width). Objects of this category are not limited to single lines, also double lines qualify for one-dimensional objects. Objects such as rivers, roads, or boundaries are, therefore, in general one-dimensional. The set of two-dimensional objects contains accordingly all objects that have an area character, such as buildings, squares, or settlement areas.

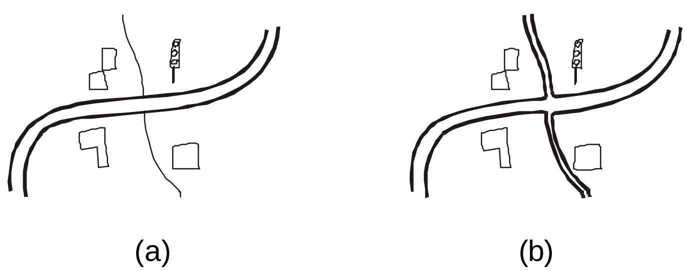


Figure 4 Both sketches depict the same intersection, but (a) involves two intersecting one-dimensional road objects, while in (b) the intersection is part of a two-dimensional object of the road system class.

Depending on the style people use to represent sketch objects, these objects can be of different dimensions. Figure 4 shows two semantically identical scenes. But while the intersection of the two streets in (a) is caused by two intersection one-dimensional roads, the same intersection is part of the two-dimensionally drawn road system in (b), because here the two intersecting streets are sketched as one sketch element including the intersection. The fact that an object belongs to the road systems class is, therefore, not necessarily an indication that the object is one-dimensional, because this depends how the object is drawn. However, the distribution between one and two-dimensional objects of the road system class was about 5:2, which indicates a preference for one-dimensional street objects (Figure 5).

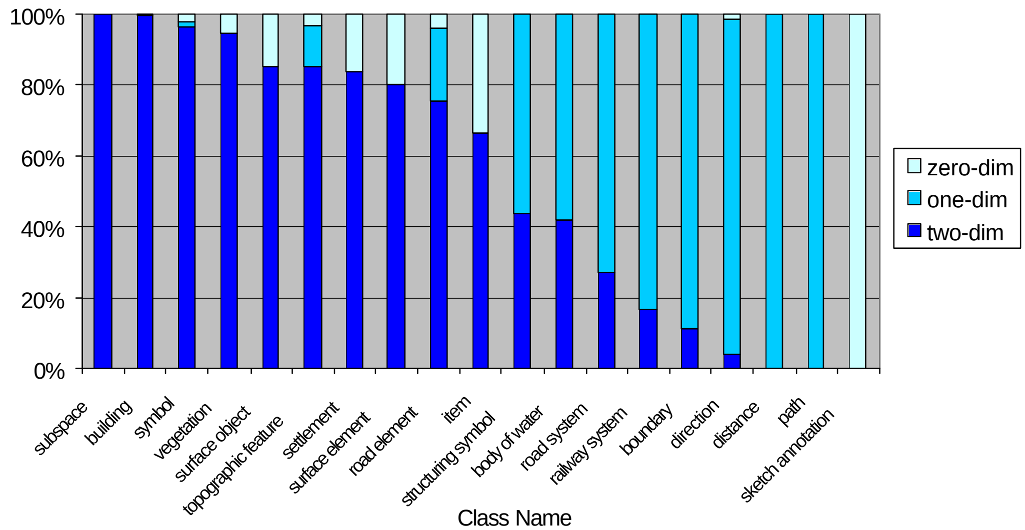


Figure 5 Distribution in respect to the dimensionality of objects for all object classes (Scenarios 1, 2 & 3).

Figure 5 depicts for all object classes the distribution of objects into the three dimension-types. This provides an indication about how objects of the individual classes are drawn. The analysis is based on all objects of all three scenarios. As a comparison between Table 1 (a) and 1 (b) suggest, there is only a small variation between taking all scenarios (a) or taking only the first and the second scenario (b) into account, the essential ratio remains the same. If we consider and compare single object classes then these variations are slightly higher. However, we can still assume that the distribution is relatively constant even for different sketch content. Table 1 indicates that in general roughly $^3/_5$ of all objects have a two dimensional character, while those objects with line characteristics are clearly less used. As we will see in a subsequent section we will have to slightly adjust this statement. Zero-dimensional objects, however, seem to play only a marginal role. Figures 61, 62, and 63 in the Appendix show the dominant object classes for all three dimension types in detail.

Dimensionality	Num	%
Zero-dimensional	67	6%
One-dimensional	448	37%
Two-dimensional	693	57%

(a)

Dimensionality	Num	%
Zero-dimensional	43	5%
One-dimensional	297	36%
Two-dimensional	492	59%

(b)

Table 1 Table (a) shows the distribution of the dimensionality of objects for all three scenarios. Table (b) includes only objects from the first two scenarios.

The conclusion that can be made from these numbers is that people prefer to sketch an object over just specifying an object by an annotation. Some objects with line-characteristics, such as rivers or streets can be represented by two-dimensional objects as well, although this is less frequent. Which form of representation is chosen by a subject seems to depend beside on issues of scale on personal preferences. Considering the numerical distribution of objects we have found so far that objects with a two-dimensional character are predominant compared with one- and zero-dimensional objects.

3.2.2 Shape

Shape is a rather complex property of an object and it is very difficult to come up with an expressive and precise notification of shape. The standard approach is to define the shape of an object as the polygon of its outline. While this can be accomplished with adequate computer algorithms (see edge detection (Agouris 1995)) it is challenging, at least, to obtain the actual meaning of a sketched object, solely based on its outline. In the scope of our survey we have investigated how objects are represented in respect of their shape. We have classified all non zero-dimensional objects into the following three main shape categories:

Symbolic,

Semi-symbolic, and

Realistic

Objects are considered *symbolic*, if their representation is based on a symbolic representation of an object that has nothing in common with the actual look of the object in reality. The fast food restaurant and the airport on Figure 6 (a) and 6 (d) are two examples. Here the association between sketched object and the original object is made over a symbol and not over the shape of the sketched object. *Realistic* objects, conversely, try to capture reality with the expression of unique or distinguishing features of an object, such as depict on the example on Figure 6 (c) and (f). Those objects which have both symbolic and realistic characteristics fall into the *semi-symbolic* category (Figure 6 (b) (e)).

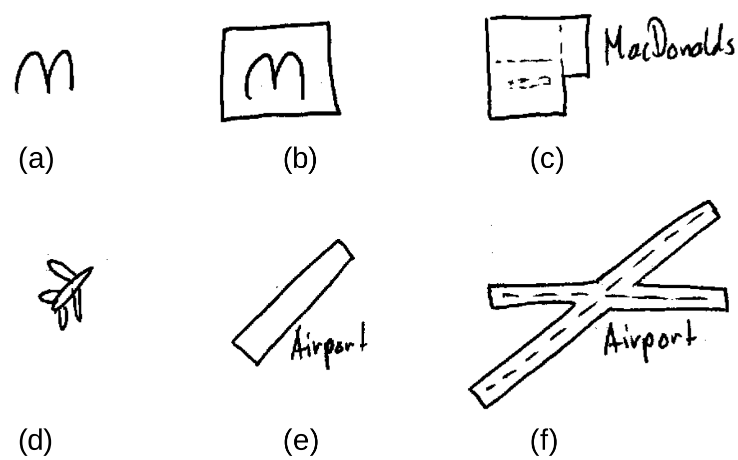


Figure 6 Two sequences of sketched objects with the same semantic but different representations.

Tables 36 and 37 in the Appendix show the distribution of objects into the three shape categories and depicts how objects are most frequently represented. Without going into much detail we can observe that the global ratio between symbolic, semi-symbolic, and realistic shapes is about 23:31:1. This ratio does not change significantly if the third scenario is included in the examination, which suggests that this distribution of symbolic, semi-symbolic, and realistic shapes is relatively generic for sketches in a geo-spatial context.

Based on these observations we can assume that most sketches have a semi-symbolic character and that most shapes keep some identifying but symbolic features of the original object. Realistic representations with many details, however, are rare and it seems that most objects maintain only as much detail as necessary in order to be recognized in the context of the sketch. Based on this observation we can infer that most people intentionally renounce sophisticated details and realism within sketches. We can, therefore, assume that a clear composition of objects within a proper context is more important for the perception and interpretation of a sketch than the detail or the look of objects. We think that this is, because people seem to build their mental image of a sketched scene, based on the content and the meaning of a sketch, but not based on pure visual perception of a sketched scene.

Consequently and because most people appear not to perceive a sketch as an image, there is also no need for high levels of detail in a sketched representation.

Beside qualitatively dividing sketches into one of these three object shapes classes we have defined two other possible subdivisions that address the type of shape. According to their overall shape, the entire set of objects is split into *1D-type* and *2D-type* objects. The 1D-type focuses primarily on objects with line characteristics and features three possibilities:

Straight, Curved, and *Complex*

Objects with 2D-type shapes are in general objects with characteristics of regions and they can fall into one of the following categories:

Square, Box, Circle, Oval, Cross, and *Complex*

Under certain circumstances it is possible for objects to qualify for both groups. This is when a single object has components that belong to either of the two categories. We initially assumed that for this analysis we can again refer to all objects of all three scenarios. But, as a preliminary comparison between all scenarios and the two first scenarios revealed, object shapes of scenario three are significantly different from those used in the two other scenarios. We found that the major difference in the third scenario was that people started to draw rather than to sketch, which resulted in more complex shapes. There are many possible explanation for this observation. Maybe the most likely assumption is that people were uncertain how to draw uncommon objects, such as the ones described in this scenario and, therefore, started to draw unusually detailed objects. However, and because it was not our intention to investigate peoples painting methods, we limit our examination for this section to the first two scenarios.

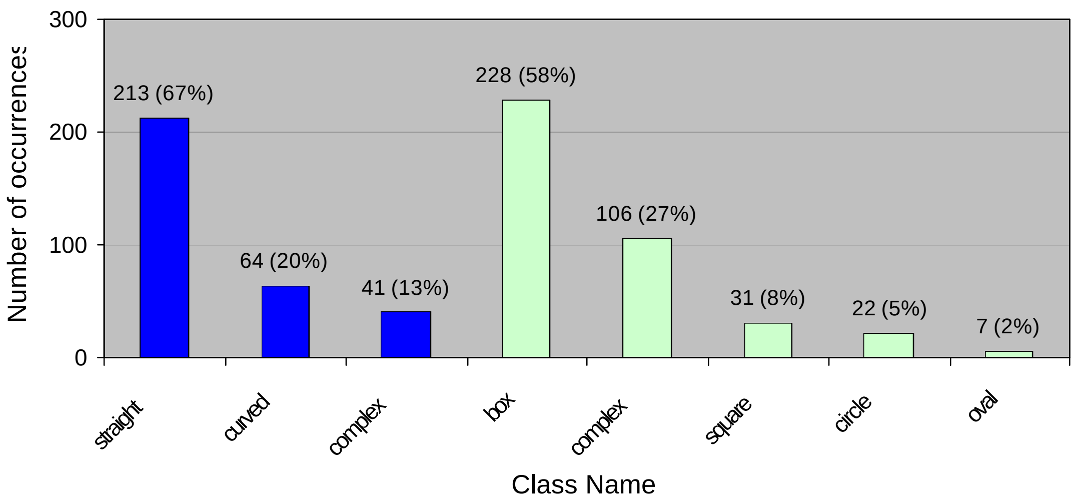


Figure 7 This graph shows the frequency of the different 1D-type (columns 1 to 3) and 2D-type object shapes (columns 4 to 8).

Figures 7 and 8 provide some interesting details about the distribution of object shapes. The most remarkable observation that can be made from Figure 7 is that more than half of all objects of scenarios one and two are represented by simple object forms, such as straight lines or boxes (56% of all objects with a classifiable shape). Squares, circles, and ovals are used in a much less frequent manner. While only 13% of all objects with a 1D-type shape are classified as complex, there are 27% objects with 2D-type shape characteristics that qualify as complex. We have analyzed the reason for this relatively great number of complex 2D-type objects and found that 67% of these objects were classified as buildings, symbols, or road systems. Symbols are per se more complex and need no further explanation and also for buildings it is quite obvious that only a small change in shape can result in a complex 2D-type object. A good example is a L-shaped house. Finally we found that objects of type road system that are classified as complex 2D-type are frequently drawn in a manner similar to Figure 4 (b), where objects are built based on the principle of successive adding street-boundaries instead of drawing in a street-by-street manner.

Figure 7 is a combined chart that depicts the frequency in which both, 1D-type and 2D-type shapes occur. If we exclude shape categories that contain complex structures, we can reduce the set of possible object shapes to line, curved line, box, square, circle, and oval and cover 72% of all sketched objects in scenario one and two. This observation is of major significance, because it is another important indication that people tend to keep their sketches simple and their objects abstract, suggesting on the other hand that the context and the actual configuration of a sketch is more important than the representation of single objects. Figure 8 shows the distribution of combined-shape objects that seem not to play a significant role in sketches, however.

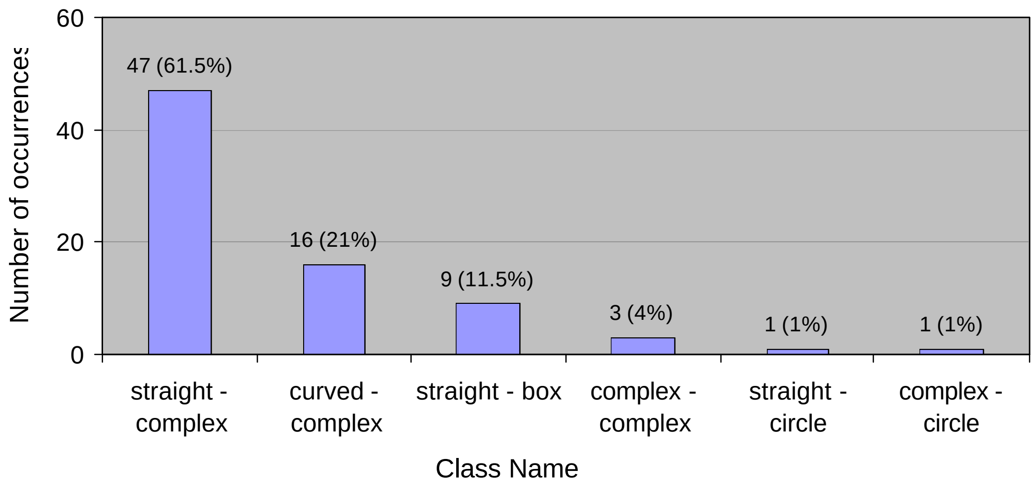


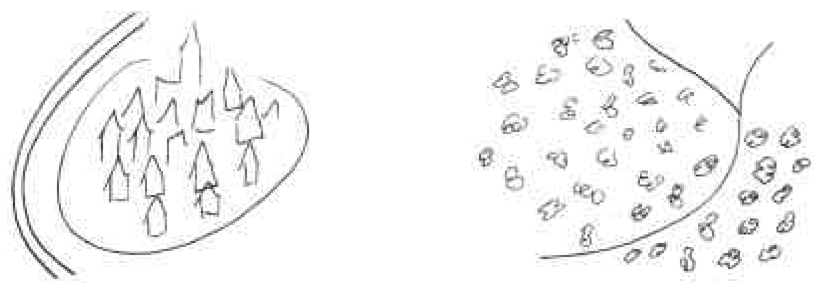
Figure 8 Frequency of the different combined object shapes (1D-type *and* 2D-type). (Scenario 1 & 2).

Conversely to objects that can clearly be assigned to one of the shape type classes, sketched objects with characteristics of both shape types are in general more complex. Therefore, they often contain more detail and their structure is relatively heterogeneous. However, these types of objects make up only 10% in respect of the total number of sketched objects in our survey which supports the interpretation that detailed objects are comparably rare in sketches.

It is important to be reminded at this point that the analysis of our survey was conducted on a manual basis and that our classification of sketched objects is based on pure visual features. It is obvious that this can be delicate, because such manually conducted interpretations tend to be subjective. In order to keep this subjective component as small as possible and to minimize variations of the interpretation we have defined and declared the possible classification schema before we actually analyzed the sketches in our survey (based on the five preliminary assessed surveys). Thus, and considering the fact that the survey was carried out by only one person, we think that this approach leads to a relatively consistent analysis of the sketches in hand. However, it would certainly be beneficial for the stability of the final results if multiple persons could go through the entire user-data so that their interpretations could be compared.

3.2.3 Composition / Structure

In our analysis we have distinguished between the composition and the structure of an object. A sketched object is considered to be a *composite object*, if it has multiple *sub-objects* that were not considered as autonomous objects. Hence, such sub-objects make only sense when they are grouped or combined with other sub-objects. Figure 9 presents two examples of composite object. Figure (a) shows a town, consisting of several house-shaped objects, a church, and bounding line, while in example (b) there is no such line but the forest as a unit can still be perceived as an accumulation of tree symbols.



(a) (b)

Figure 9 Two composite objects. Figure (a) represents a road that goes along a town, and (b) shows a forest with an intersecting street.

Composite Objects

Composite objects make up around 20% of all objects in our survey. The ratio is about 17% if the third scenario is excluded and increases to 25% if it is taken into account. The reason for this accumulation of composite objects in scenario three is again that people seem to be uncertain about how to draw uncommon objects and, therefore, start to draw more detailed. The second reason is that we explicitly asked people to draw objects of type forest and settlement in the third scenario and that these objects are very frequently sketched in a composite manner (50%). Figure 9 in the Appendix shows the number of composite objects in each object class and the ratio between composite and non-composite objects of each class. For the three most used object classes (road systems, buildings, and directions) the ratio is like the overall average around 20%.

In the scope of composite objects we examined also if composed objects have an independent boundary, such as the town on Figure 9 (a). We found that only 22 or 8% of our composite objects have such a bounding structure, all other compound objects consisted of a loosely connected formation of sub-objects, such as the forest in Figure 9 (b).

Sub-Structure of Objects

A *sub-structure* of an object is defined as a drawing inside of an object. These drawings must not be considered as sub-objects and they can have a texture or symbol like appearance. Textural sub-structures are referred to as *texture* in this context. An example of a texture is a box filled with a scribble or hatch and an example for a symbolic sub-structure is a river with wavy lines indicating flowing water. In our analysis we differentiate eight different types of textures, their frequency is listed in Figure 10 below.

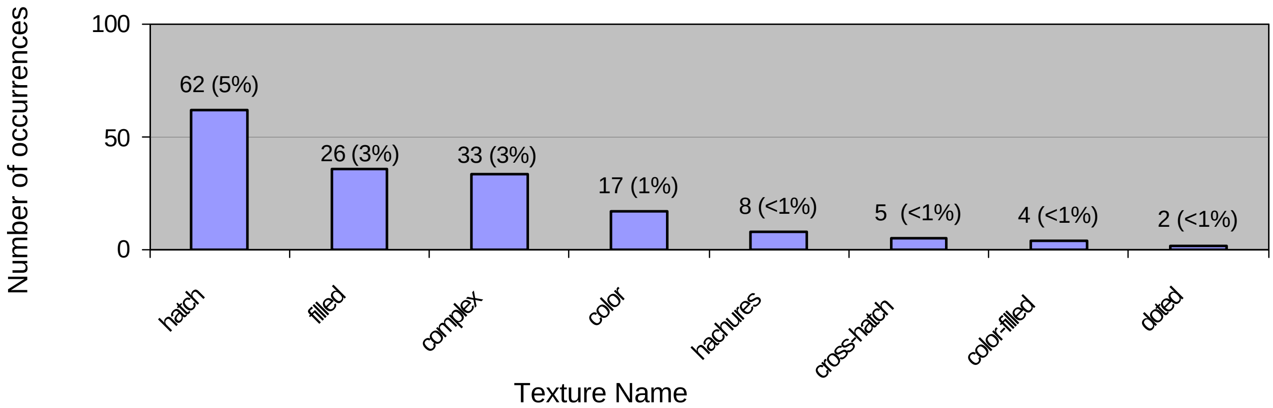


Figure 10 Different texture types that have been distinguished in the survey. (Scenarios 1, 2 & 3).

The numbers in parentheses indicate the percentage compared to the total number of sketched objects. For instance there are 62 object with a hatch in our survey and this represents 5% of all sketched objects. This analysis is based on all objects of our survey, because all three scenarios showed about the same distribution.

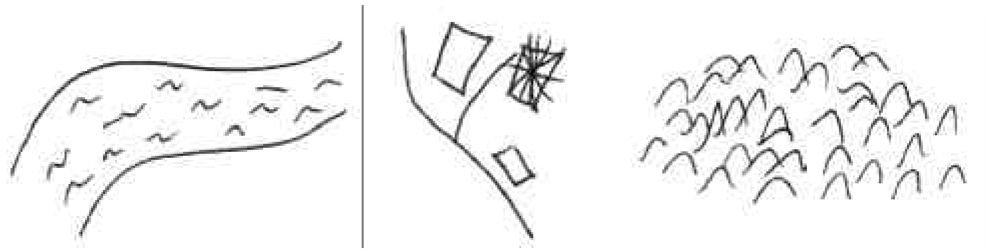
About 86% of all objects do not have a texture. Of those that have a sub-structure hatch is the most frequently used type (5%), followed by objects that are filled or that have a more complex filling pattern. That people rarely used sub-structures is another indication that people try to keep their sketches simple in that they use primarily outlines of objects. However, if we look at Figure 65 in the Appendix, we can observe that the number of objects with a texture increases it these objects have a specific purpose. Objects with a start, end, or way-points purpose, for instance, have a higher likelihood to have a texture than sketched objects in general. From this observation we can infer that sub-structures can be used to emphasize an object within the context of otherwise non-textured objects. This interpretation is supported by Figure 66 in the Appendix, which demonstrates that of those 65% sketches that contained textured objects the actual number of textured objects per sketch is relatively low. Only 21% of all sketches have more than 3 objects with a texture.

Beside textural sub-structures that underline and mark objects there are sub-structures that assert a certain meaning to an object. These sub-structures have mostly a symbolic character. Wavy lines, for example, stand for water waves and indicate in general a body of water. It is hard to define distinct classes for such sub-structures, because they can differ considerably. They are also to numerous for a detailed examination in the scope of this report and, therefore, we have only retrieved and listed the most frequently used symbolic sub-structures in Table 2 below.

Count	Sub-Structure
84	arrow(s)
35	cross
32	wavy line(s) or ripple(s)
29	char N
14	tree(s)
10	street(s)
8	star

Table 2 Table with the most frequently used symbolic sub-structures of objects in the survey. (Scenarios 1, 2 & 3).

Some sub-structures consist of multiple instances, such as a set of single arrows that indicate the direction along a route, while other sub-structures emphasize an object, such as a cross over a box-shaped object. Some symbolic sub-structures have an unambiguous meaning, such as trees, but others can have different meanings, such as a cross or a star. The cross, for example, is frequently used to annotate the starting or end point of a route. In our survey we counted 7 crosses for starting points (20% of all start points) and 21 crosses for end points (60% of all end points), an observation that suggest that end points or objectives of a sketch enjoy a higher significance than starting points which are in general more open and frequently omitted.



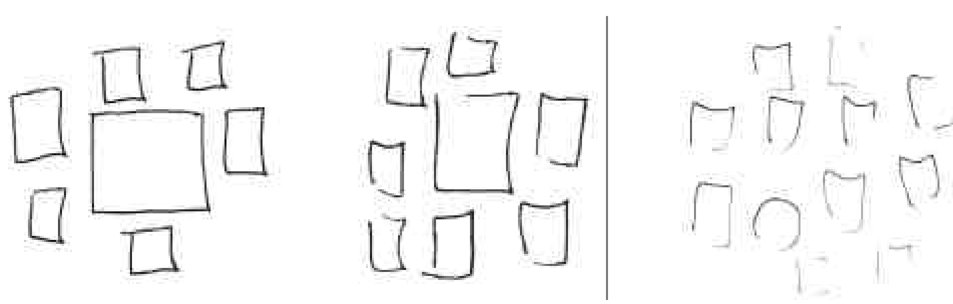
(a) (b) (c)

Figure 11 Wavy lines of a river, a star emphasizing a house, and little hooks symbolizing a forest.

There is certainly much more to explore concerning textures and symbolic sub-structures in sketches, but this would be beyond the scope of this report. The important observation that we can extract from our brief analysis is that people make frequent use of graphical annotations, such as textures and symbolic sub-structures. They seem to do this in order to emphasis certain sketched objects or to give objects a certain meaning. The use of textures seems to be fairly standardized–most textures involve either a hatch or a filling pattern (between 60% and 70% of all used textures). The set of possible symbolic sub-structures, conversely, is much larger, because people are quite creative in this respect. Despite this, there is a number of symbolic sub-structures that appear to occur more frequently in sketches(Table 2).

Completeness of Objects

Another criteria in the scope of our sketch object analysis was concerned about the completeness of drawn objects. Despite that there is obviously no simple rule that defines, when an object must be considered complete or incomplete, we believe it is important to analyze how conscientious objects are drawn. Our simple classification scheme includes only three possible categories: complete, partial complete, and incomplete. To qualify for one of these categories an object has to have drawn elements, hence, zero-dimensional objects have no value for completeness assigned. Figure 12 shows three scenes with sketched houses, each with a different grade of completeness according to our definition and Table 3 list the results from our survey.



(a) (b) (c)

Figure 12 Figure with three different complete representations of houses: (a) complete, (b) partial complete, and (c) incomplete.

Count	%	Category
538	50%	complete
487	45%	partial complete
53	5%	incomplete

Table 3 This table shows the average distribution of drawn objects in our survey in respect to our classification of completeness. (Scenarios 1, 2 & 3).

If we refer to Table 3 or to the more detailed Table 40 in the Appendix we can observe that people draw in general sufficiently careful so that sketched objects are easy to perceive as more or less complete entities. Conversely there are only about 5% of objects in the scope of our survey that we considered being incomplete. The *complete* and *partial complete* category in Table 40 in the Appendix have an unusually high variance, this indicates that the completeness of drawn objects is rather individual among users and that some people tend to sketch more carefully then others. The comparable low variance of incomplete objects on the other hand shows that people, even if they have a sluggish sketching style, try to minimize the number of such objects that make a sketch difficult to understand. Therefore, in our survey there is no sketch with more 18% of incomplete objects.

		Completeness					
		Complete		Partial complete		Incomplete	
Sketch No	1	234	52%	199	44%	15	3%
	2	139	47%	132	45%	24	8%
	3	165	49%	156	47%	14	4%

Table 4 Comparison of the different levels of completeness accordingly to the type of sketching problem (Scenarios 1, 2 & 3).

Table 4 compares the number of objects with a different level of completeness for each sketching problem individually. Despite some small differences, the distribution is remarkably constant and only minor trends can be noticed. For instance, people seem to sketch more frequently incomplete objects if they are not familiar with an environment, such as in scenario two. An interpretation of this observation is that people want to express their uncertainty with incomplete sketchy objects so that their sketches become relaxed and vague, which is important in order not to block certain views of interpretation. This interpretation is further supported by scenario one, where people are well acquainted with the environment and where the relative number of complete objects is highest.

Number of Strokes of Sketched Objects

There are two numbers of interest concerning sketched strokes in sketches: the first point of interest is the number of *strokes per sketch* and the second point the number of *strokes per objects*. Both values might provide insight how dense and how complex sketches are composed and how much “drawing effort” is necessary to convey a message with a sketch.

The number of strokes per object is represented on Figure 13. This graph includes all sketched objects in the survey and shows that most objects consist of only two strokes, while the average number of strokes is between 5 and 8 strokes per object (Table 5). The graphs representing the three individual sketching problems are very similar, all experience a peak at two strokes per objects and show a steep decrease in frequency thereafter. We can, therefore, assume that the average distribution of strokes per object is relatively independent in respect to the sketching problem. However, this distribution may very well be dependent on individual preferences of a sketching subject, such as the liking for detailed representations.

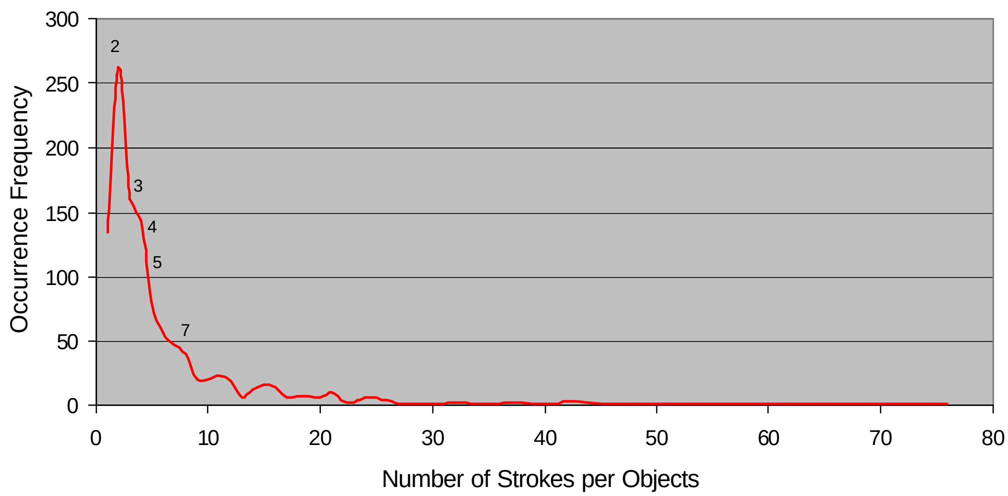


Figure 13 Histogram representing the distribution for the number of strokes per objects over the entire survey. (Scenarios 1, 2 & 3).

Despite the general distribution being the same for all three sketching problems, there are some differences between the average numbers of strokes per object between the three sketching problems, as can be observed in Table 5 The first and second problem show an average of 5.5 strokes per object, while the average of the third scenario is more than two strokes higher. The reason for this discrepancy is probably the same that was responsible for other variations in previous examinations. People are not used to sketch uncommon objects, such as a suspension bridge or a mountain and begin to paint rather than to sketch. In addition we have to acknowledge that some objects in the third scenario are hard to draw with only view strokes and that the two first sketching problems are more open for simple objects, such as houses that can easily be represented by a box. The effect of uncertainty manifests also in the higher standard deviation of the third sketching problem.

Summarizing the above observation we can make the four general assumptions:

- Most objects in a sketch are drawn using only two strokes
- The average number of strokes of an object is around six strokes for a sketch with an average complexity.
- The number of strokes per object increases, if the sketch complexity increases or if unusual objects have to been drawn.
- Reciprocally the number of strokes per object decreases if sketches are simple, for instance, because they contain standard structures or common symbols, or because people are uncertain about the correctness of the sketch.

If we consider the number of strokes per object as being constant, then the number of strokes per sketch depends primarily on the number of objects, which in turn seems to depend on the complexity of the sketched scenario. Looking at Table 5 we can observe that there are significant differences how people translate a task into a sketch. A high standard deviation is an indication for such divergent behavior. Task related differences are indicated by varying numbers of average values between the three sketching scenarios.

The first sketching problem shows a relatively high average number of sketched objects (17.9) and also a relatively high standard deviation (47% of the average number). This suggests that people have different points of view of how many objects must be drawn to make the sketch understandable. If we take a look at Figure 67 and 68 in the Appendix, we can distinguish two groups of subjects for the first scenario. One class (15 subjects) used an average number of 13 objects per sketch; this is about the same as the average for scenarios one and two. Conversely the second group of people (12 subjects) that used a significantly higher average of 24 objects per sketch to describe the first scene. The only difference between the two groups is that in the second group the percentage of female subjects is higher than in the survey in general–58% instead of 35%–all other recorded characteristics were average. A larger study would have to prove if this observation is pure chance or if women have indeed the tendency to draw more objects per sketch.

Sketching problem two involves users to recall a scenario from long term memory. This results in a relatively low average number of objects per sketch (11.7) and also a remarkably low standard deviation (32% of the average). Sketching problem three, finally, has the smallest standard deviation, because the number of sketched objects was explicitly given by the problem statement.

	Sketch Problem No			All
	1	2	3	
Average Number of Objects per Sketch	**17.9**	**11.7**	**13.0**	**14.3**
Standard Deviation	8.4	3.7	3.3	3.3
Standard Deviation per Sketch (%)	47%	32%	25%	23%
Average Number Strokes per Object	**5.7**	**5.5**	**7.9**	**6.5**
Standard Deviation per Object	2.6	2.6	6.0	3.5
Standard Deviation per Object (%)	45%	47%	77%	53%
Average Number of Strokes per Sketch	**97.1**	**65.9**	**100.6**	**89.9**
Standard Deviation	50.1	43.3	65.7	45.0
Standard Deviation per Sketch (%)	52%	66%	65%	50%

Table 5 Average numbers for objects per sketch, strokes per sketch, and strokes per object.

Combining these findings with observations made based on the histograms on the Figures 67 and 68 in the Appendix, we can amend the list above by the following hypothesis:

- Most sketches of an average complexity contain between 5 and 25 sketched objects.

This hypothesis covers all but one sketch (98.8%) in our survey.–However, and as stated before, our observations may only be considered as trends or first guidelines that have to be confirmed and proven by additional and more comprehensive human subject tests that are out of the scope of this survey.

Color

The subjects were allowed to used any mean to express themselves in a sketch, this included also color. But only five subject chose to use a secondary color to draw the sketch and no subject chose to use more than two colors. In those cases where color was used it was applied to emphasis certain aspects, to chose a natural color for an object (river = blue) or to explicitly specify a route or a path (often in red, orange, or yellow). Red was the color that prevailed if a secondary color was chosen. This observation allows the conclusion that color is secondary for most sketches, but when color is applied in an appropriate fashion, it can be a powerful tool to mark or distinguish drawn objects (Imhof 1982).

3.2.4 Type of Outline

Based on our preliminary review of sketches, we came up with a classification for object outlines that included six distinct types of outlines: *simple line, 2D-line, multi-stroke line, mixed line, dashed line,* and *doted line*. Examples of these outline types are depicted below on Figure 14. The naming is straightforward and only two outline types need some further explanation. The 2D-line type belongs in general to a one-dimensional object type that has two lines that are parallel and not individually interrupted (refer also to Figure 4 (a)). A *multi-stroke line* is defined as a line consisting of multiple small, mostly sketchy strokes that are often slightly out of line with each other. Multi-stroke lines must not be confused with single lines that may consist as well of multiple strokes, but in this case the individual line segments are well aligned and the individual line segments tend in general to be longer.

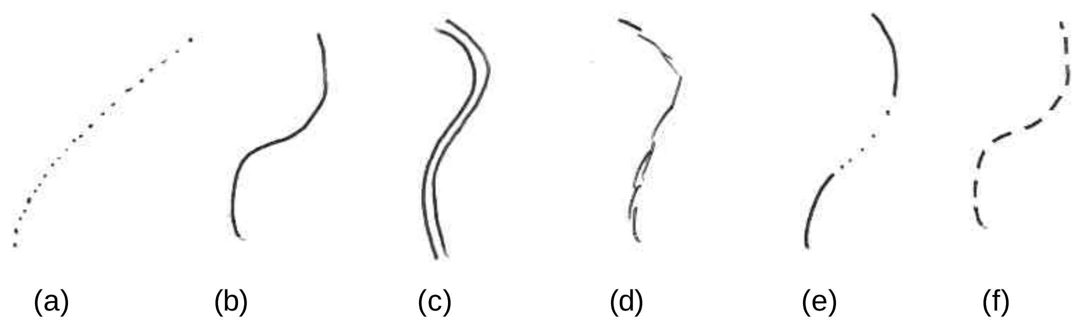


Figure 14 The six different outline styles: (a) doted, (b) simple line, (c) 2D-line, (d) multi-stroke line, (e) mixed, and (f) dashed.

The graph on Figure 15 shows the distribution of the six different outline types over the entire survey. The simple line tops this chart, as expected. It is followed by the 2D-line with a remarkable 9% of all drawn objects. Simple lines are used for objects throughout the entire spectrum of object classes. For all other line types this depends on the object type. 2D-line, for instance, are frequently use for waterways but never for boundary. Multi-stroke lines are in so far special in that they are frequently expressing individual drawing styles without being so much dependent on the object itself.

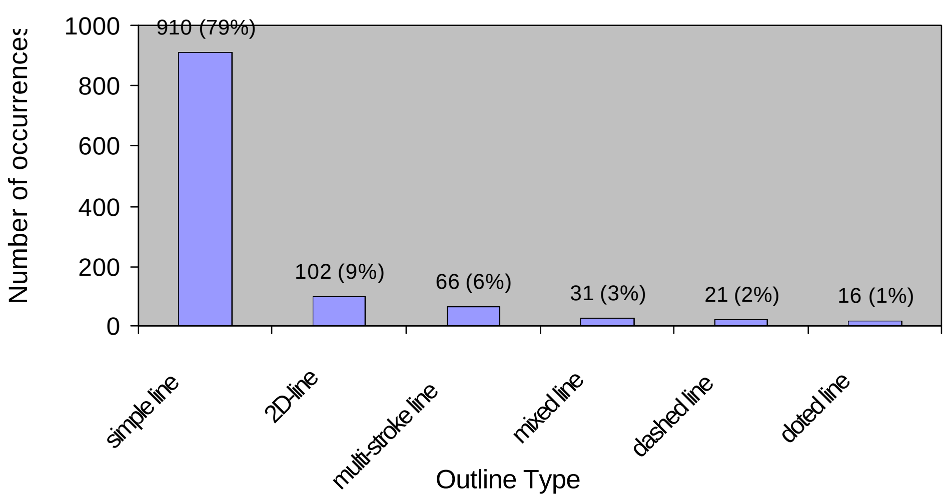


Figure 15 Histogram showing the use of different outline-types for sketched objects over the entire survey. (Scenarios 1, 2 & 3).

Looking at Table 6 we can observe that despite the predominance of simple lines there are other outline types that for certain object classes have a significant higher than average frequency. Table 6 excludes simple lines and lists all combinations of object classes and outline types that have a higher than 20% overall frequency in this class. So for instance we can infer that the 2D-lines are used in 37% of all cases when a body of water–in this case a river, brook, or any other type of floating water–is sketched. The-2D line is also relatively often used when road or rail systems are drawn. Another observation from Table 6 is that objects from the path and boundary object classes are often represented as dashed lines alternatively to being drawn as simple lines. This seems realistic, because objects of both classes are frequently represented as dashed lines on maps and charts too.

Number of Objects	Class of Objects	Type of Outline	Total of Objects	Percentage of Total
31	body of water	2D-line	84	37%
2	boundary	dashed line	9	22%
4	path	dashed line	13	31%
5	railway system	2D-line	18	28%
54	road system	2D-line	224	24%
1	surface element	multi-stroke line	4	25%

Table 6 This table shows all *object class* - *outline type* combinations that make up more than 20% for one object class. (Scenarios 1, 2 & 3).

3.2.5 Perspective

When people sketch they keep objects and their sketches in general simple and in general two-dimensional. But during the study of sketches of our survey we have experienced that there are also more dimensional approaches to represent object in sketches. For a first categorization we have come up with three types in addition to the usual flat, ground plan, or map like object types. These are: *front elevation type*, *perspective 3D*, and *mixed representation*. The first two types are pure representations, while objects sketched using a mixed perspective representation can contain elements of various perspective types. Figure 16 shows three examples for each of the perspective types. The type of objects differ, because it is unlikely for some objects to be drawn, for instance, in a 3D perspective.

(a) (b) (c)

Figure 16 Examples for the three different perspective types that have been distinguished in our survey: (a) front elevation type, (b) perspective 3D, and (c) mixed representation.

Table 7 shows the ratio between objects drawn with a perspective and flat objects for each of the three scenarios. The last scenario, as usual, stand out in that it shows a much higher percentage of objects with a perspective, in average almost every forth object was drawn this way.

Another interesting interpretation is that people tend to construct a spatial representation that is similar to a three dimensional scene or a film instead of a flat map, when they interpret a read or told story. However, this is just a speculation that would need to be proven.

Count	Scenario	%
21	1	**4%**
19	2	**6%**
83	3	**23%**

Table 7 Distribution of objects that have a perspective component in respect to the three sketching scenarios. The last column depicts the percentage of objects that are drawn with a perspective compared to the total number of objects in the particular scenario.

The flat front view or elevation dominates all three possible forms of perspective representations (Table 8 (a) and 8 (b) below). This dominance is even more obvious when only the first two sketching scenarios are considered. Here the ratio between *Elevation* and *3D-Perspective* is 4:1. The mixed perspective representation plays an inferior role, only 11 objects are depict this way and most of those objects belonged to the topographic feature object class.

Scenario 1, 2 & 3		
Count	**Type of Persp.**	**%**
75	Elevation	61%
37	3D Perspective	30%
11	Mixed Perspective	9%
123	?	

(a)

Scenario 1 & 2		
Count	**Type of Persp.**	**%**
32	Elevation	80%
8	3D Perspective	20%
-	Mixed Perspective	-
40	?	

(b)

Table 8 Table (a) and (b) show the number of objects with a perspective component divided into the three possible perspective classes. The difference between the two tables is that Table (a) contains objects from all three sketching scenarios, while (b) involves only those from scenario 1 and 2.

An other interesting question concerns the frequency, type, and purpose of objects that were drawn with a perspective. About every third sketch in the first two scenarios (30%) contain at least one perspective object, while in the third scenario, there is a boosting 82% of all sketches that have such objects. The average number of perspective objects per sketch for sketches with at least one such object lies between 2.5 and 3. This is valid for all scenarios and suggests, therefore, that if people sketch in perspective, then they frequently draw more than one object in this particular way. (Figure 69 in the Appendix).

An interpretation regarding affiliations of perspective objects to object classes is, due to the small number of such objects, relatively difficult. However, people seem to increasingly draw objects in a perspective when there are otherwise no simple and convincing symbols available (such as symbols found on maps). Another reason why people might depict some objects in a perspective is that people experience certain objects in their daily life from a particular perspective and that this perspective is most likely different from the top–down view induced by maps. Examples are cars, trains, traffic lights, or topographic structures, such as mountains. In respect to the purpose of drawn objects, we found that the majority of objects that have a perspective are classified as *landmark*, *detail*, or *orientation help* (in this order). Astonishingly only few objects with a perspective are classified as *start* or *end* points. This is surprising, because we originally expected an increased use of this representation for these types of objects.

We can, therefore, conclude that perspective objects are primarily used to depict important features in a sketch that are difficult to formulate in words or that have a prominent perspective component. However, perspectives seem to be less often used when expressive and common symbols of objects are available. Of the three classified perspective types we found that the front elevation type is the most often used perspective. Finally, we have found that with an average number of perspective objects per sketch of only about 5% this form of visual representation can be considered as relatively rare.

3.2.6 Metric and Directional Object Descriptors

Descriptors that denote direction or metric are important components of a sketch as they can emphasize or define properties, such as orientation, flow direction, distance between objects, or indicate the scale of a sketched representation. Descriptors can be used in a qualitative or quantitative way and they can become substantial when a sketch contains otherwise insufficient or inconsistent information. Such situations can arise, because a sketch is a subjective interpretation of somebody, conversely to maps that are in general much more objective (Monmonier 1991).

Direction

When we refer to direction in this context we are concerned about one or multiple directions that are explicitly specified by the user. We are less focused on the actual (quantitative) direction, this will be covered in Sub-chapter 4.5. This discussion does also exclude arrows that are used to link written annotation with sketched objects, because such arrows will be analyzed in a later section about object annotations (Sub-chapter 5.4).

If people specify direction in their everyday live, they are often applying gestures using their hands, such as for instance pointing in a specific direction, or they make a verbal statement of a direction. When drawing a sketch there are fewer possibilities to express a direction. We found that the method of choice is drawing an arrow. This technique was applied by all subjects in our survey. An other metaphor for direction was the use of sign-like symbols, but this method was only used by one single subject. As a result, we distinguish between three types of sketched directions: *single arrow*, *double arrow*, and *multiple arrows*. Examples for all three cases are shown below on Figure 17.

(a) (b) (c)

Figure 17 Three different direction types of directions that have been distinguished in the analysis of our survey: (a) *single arrow*, (b) *double arrow*, and (c) *multiple arrows*.

Signs of direction that are independent of the referring object are classified as objects of their own, but if such signs are integrated into an object, such as the flow direction of a river then the object inherits the direction and the direction symbol (e.g. an arrow) is considered part of the global object. Sketched direction indicators can be used for different purposes. Considering the primary geo-spatial objective of this survey we have found the following situations where people have used sketched direction indicators in our survey:

- Definition of the North direction
- Reference to places outside the scope of the sketch
- Indication of the flow direction of rivers, brooks, etc

- Specification of a path or a route from A to B
- Link between two spatial scenes, or provision of a shortcut from one scene to another
- Indication of a view direction
- Emphasizing an object, e.g. the end point of a path

This list may not be complete, but it shows that many objects can be associated with a direction and it lets assume that they often play a central role in a sketch. In average there were about 25% objects with an explicit indicated direction (Table 9 below). However, in sketches that have no path or specific route in their context this percentage of directional objects may be lower. In our survey, the path-less scenario two scored 14% directional objects, while scenario one and three showed with 31% respectively 26% a significantly higher ratio of objects with a directional component.

	Count	Direction Type
	910	no direction
25%	214	single arrow
	15	double arrow
	69	multiple arrows
	1208	?

Table 9 Ratio between objects with and without a directional component and their distribution over the entire survey. (Scenarios 1, 2 & 3).

The most frequently used type of direction indicator is the single arrow, followed by multiple arrows and the double arrow. Table 41 in the Appendix shows the distribution of objects with a directional component in respect to their affiliation to object classes. Single and double arrows are taken together, because of their similarity and because double arrows are relatively rarely used. As was to be expected, the majority of objects of the direction object class are specified using arrows or multiple arrows (94%). The same holds true for objects of the path object class. There 92% of all path objects have an explicit direction. We can further observe that road system objects (41%) and body of water objects (26%) are also frequently associated with an explicit direction. Interesting is also the high number of objects that indicate distance and direction at the same time (48% of all object in the distance object class). This leads to the assumption that people frequently assign both, distance and direction when they make a quantitative metric statement, such as a distance indication in a sketch.

This examination is certainly not exhaustive, but it demonstrates the relevance of directions in sketches and shows that some object classes have a significantly higher likelihood to be affiliated with an explicit direction. We have also seen that that the single arrow is people's metaphor of choice for specifying directions.

Distance

In general distances can be expressed in two ways. The direct way to answer the question *How far away is Orono from Boston?* is to provide a metric statement such as 244 Miles or 393 Kilometers. But there is also another approach which takes the mean of transportation and the time traveled into account. For the distance in the question above this is typically a car and, therefore, the answer would be about four and a half hours. The use of time for a distance indication implies knowledge about the traveled speed what makes the statement much more sensitive about the context. e.g. asking a pilot of a regional air carrier the answer would more likely be about an hour. Such indirect distance specifications that make a detour over travel time are often used for longer distances, because time seems to be easier to remember and in most cases accurate enough. Another reason for an indirect statement might be that the asking person is more interested in the time traveled than in the distance itself. Shorter distances, on the contrary, seem to be specified more often in a direct way, which is a more specific indication and which leaves the interpretation to the information consumer.

To explore the way people apply distance information in their sketches we have intentionally conditioned two of our sketching scenarios so that people had to express some metric and time bound components in their sketches. As a reminder: the first scenario involved the description of a route or path for somebody unacquainted to a place. This is, depending on the interpretation, an implicitly invitation to specify some time and/or distance descriptors. The second scenario was free of such influencing control, whereas in the third scenario there were four explicit distance statements involving direct and indirect distance statements (3 time, 1 distance). To capture sketched distance indications we distinguished three different distance types: *time*, *distance*, and *mixed*. The mixed type was never used. The results are presented on Table 10.

	Scenario		
Type	**1**	**2**	**3**
time	1	0	42
distance	12	5	5
%	3%	2%	13%

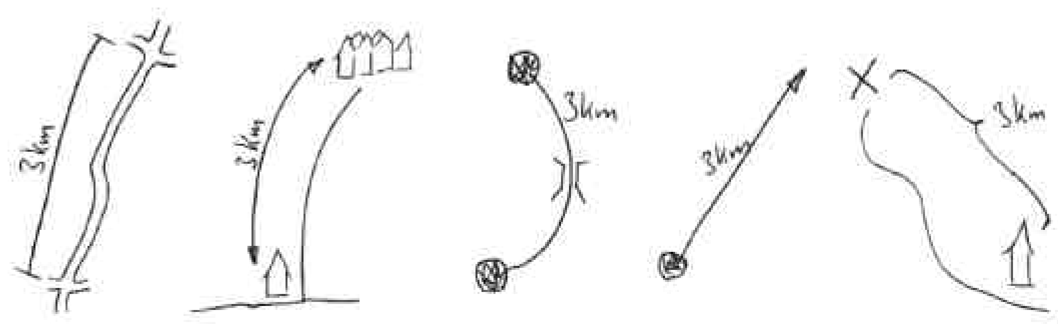
Table 10 Frequency of the two encountered distance types in dependence of the sketching scenarios. The percentage in the lowest row represents the overall occurrence frequency of distances per scenario.

Much to our surprise we can observe that distances are only very sparingly used in sketches. This observation leads to the assumption that explicit metrical information is of secondary importance in sketches. People seem to express metric rather through size and proportion of objects and the overall composition of objects in a sketch than by explicitly specifying distances. Such the final interpretation of a sketch's scale is left to the information receiver. These findings support claims that *Topology maters and metric refines* (Egenhofer and Mark 1995) or that people are better in remembering topological features of a scene than in recalling its metric (Allen 1997). A typical sketch seems, therefore, to rely primarily on topology and the relative composition of objects. Sketch elements that indicate a distance on the other hand seem to be used only if scale or metric are unclear or if there is a special focus on distance related issues in the sketch. An example for such a case is a sketch that is made with the purpose to convey shape and dimension of real estate property.

Distances have only been used within five sketches in the scope of scenario two (16% of all sketches of scenario two). When a path description is involved, such as in scenario one, we can observe a slightly increased use of distances. But because all 13 distance notifications in scenario one have been made by only four subjects the actual percentage of people that have used distances to reinforce their sketches drops to 15%, which is similar to the ratio for scenario two (16%). There seems to be also no clear correlation between subject that have used distances in scenario one and subjects that have done so in scenario two, only two subjects used distance annotations in both scenarios.

An other observation that came to our surprise was that distances in sketches are indicated above all in a direct form as concrete distances. Hence, only one out of 18 distance indications in the first two–in this respect relatively unbiased–sketching scenarios uses time to specify a distance. This big difference between the use of explicit and implicit distance annotations might be attributed to the relationship of sketches with maps, where distances are usually expressed in a direct form or over a map's scale. Another explanation for the low use of indirect distance indications might be that people did not have to express long distances in our survey.

Throughout our survey we have experienced various forms of distance annotations, some are demonstrated in Figure 18 below. However, people have used primary two methods to link a distance to an object. The first technique is to use an additional object, such as in Figure 18 (a), (b), or (e) and the second method is to annotate an objects directly by writing the appropriate distance notification close to the sketched object (c) and (d). In the scope of our survey, people seemed to use both methods with similar preferences. However, it is important to notice that the annotation of a distance explicitly requires the use of a written or verbal statement, because a distance can not be expressed by visual means alone, e.g. by a symbol. This is essential and distinguishes distances from other sketch elements, such as directions that can be specified by symbols alone.



(a) (b) (c) (d) (e)

Figure 18 Some examples how distances were specified in our survey.

Summarizing this sub-section we found that distance annotations in sketches are sparingly used. People seem, therefore, to convey spatial information on a sketch primarily by visual means, using explicit metric information only in cases where topology and the arrangement of objects are not expressive or consistent enough. If distances are specified it seems that this is done almost exclusively by direct annotations of distance and not indirectly over time (travel time). About half of all distance annotations in our survey are attached directly to objects with line-characteristics, such as streets or roads. The other half is expressed with additional, but independent symbols. The combination of distance and direction into one symbol, e.g. an arrow with a distance indication, seems to be intuitive when a path or a route has to be specified–as stated in the previous sub-section.

3.2.7 Virtual Objects

We have already briefly mentioned the term *Virtual Object* in Chapter 2 (The Ingredients of a Sketch). In this scope we have defined a virtual object as an object that is solely based on a written annotation and that, therefore, has no graphical representation within a sketch. This definition can be extended to entirely virtual objects if verbal annotations (talking) are allowed. A verbal expression during the sketching process, such as *Bangor is north of this house*, perhaps combined with a gesture pointing to a sketched object, but without actually sketching objects, marks the creation of such a virtual object.

Because we were unable to record verbal statements in our survey we concentrate on written annotations only. Over the entire survey we have encountered 54 virtual objects (~4.5% of all sketched objects). 24 subjects (77%) have used at least one virtual object within their sketches and virtual objects were distributed over 36 of a total of 81 sketches (38%). There was no sketch with more than 3 virtual objects and the average was at 1.5 virtual objects per sketch if virtual objects were used at all (? = 0.6). These numbers show that virtual objects are frequently used in sketches, but that their density per sketch is rather low. The reason for this observation is most likely that too many virtual objects are confusing and that the structure of a sketch becomes unclear if virtual objects are dominant.

Table 14 in the Appendix shows the distribution of virtual objects depending on object classes and object types. In addition to the classification done during the analysis of the sketches, we found four groups of virtual objects with similar characteristics. The first group contains real world objects that have flat or area-like features. These objects are often composite objects, such as a town or a forest and their horizontal extension is in general greater than their vertical range. Such objects are, due to these characteristics, hard to specify within a graphical context. In this case, as well as opposite to the Chinese belief: *one word is more than 1000 lines.* An example is a big town, such as New York that is much easier to circumscribe by a textual description than by drawing, for instance, the Statue of Liberty.

The next group of virtual objects consists of global sketch annotations, such as comments, descriptions, or legends. A legend is certainly an atypical element within a sketch, but we think it can be explained by the familiarity of people with maps and attributed to the fact that our subjects had no possibility for verbal annotations, which would be much easier and less cumbersome, because verbal annotations can be made during the sketching process. In the scope of our survey we consider global sketch annotations as single objects, even if they consist of multiple textual and graphical sub-objects. Similar to the expression of distances, this group of virtual objects relies on text-based descriptions, because it is difficult to convey this kind of global information otherwise.

A third group of virtual objects consists of objects that are in general much smaller than the average object in a sketch, so that they are difficult to draw in the same scale and easier to reference by an annotation. Similar with objects that are framed by other objects or objects that have no exact boundary, these are also often specified as virtual objects. An example is shown in Figure 18, where the virtual object *ideal site* is defined by a written statement and an annotation arrow pointing to an approximate location of the object between road and brook.

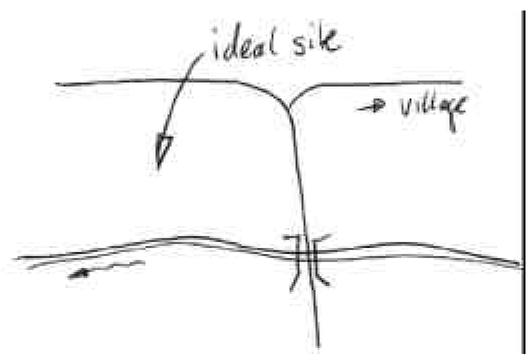


Figure 19 The object described by the annotation *ideal site* is a virtual object because the arrow establishes no link to a drawn object and nor is the arrow indicating a direction.

Yet another group of virtual objects is concerned about direction and orientation. Objects in this group are either reference places beyond the scope of the sketch, such as a far away town, or one of the cardinal directions north, west, east, or south. Such directions are often indicated solely by writing the name of the direction onto the periphery of the sketch. Objects of this category have no directional arrow, otherwise they would have been classified as directional objects. The borderline between objects represented under this group and objects of the first group (objects with flat or area-like features) is often unclear, because it depends on the actual real world location of these objects and indirectly on the factor of distortion of a sketch, information that is not necessarily known. Virtual objects of both groups are, therefore, interchangeable under certain conditions.

Concluding this section, we have found that virtual objects are frequently but moderately used in sketches. Virtual objects are well suitable to specify extended area-like objects that may be composed of different sub-objects. They are, therefore, also appropriate to specify real world objects that would otherwise be difficult to describe. Global textual annotations that apply to the entire sketch or to some portions of it are also considered virtual objects. Finally, virtual objects can also be used to orient a sketch by providing a reference direction with a statement of a far away place.–With this section we close the sub-chapter about representations of real world objects in sketches and move on to explore the role and purpose of sketched objects.

3.3 Role and Purpose of Sketched Objects

This sub-chapter is concerned about the role and purpose of sketched objects in the context of geo-spatial sketches. The sub-chapter is also the last part of our analysis, where we focus on objects, without taking their relationship to other objects or groups of objects into consideration. The purpose and role of a sketched object are, admittedly, often hard to define, because they depend on the context of a sketch and because there are frequently multiple feasible ways of interpretation. The term context on the other hand implies some sort of dependence of an object on its environment. Therefore, we consider this sub-chapter as a footbridge of transition to the next chapter, where we take a look at relations within a sketch.

The *purpose* of sketched objects has already been introduced previously (3.2.3 Sub-structures of objects and 3.2.5 Perspectives). This sub-chapter analyzes the frequency with that objects with different purposes occur and reasons about the generic composition of a geo-spatial sketch in respect to object purpose. For the specific context of this survey we have defined 15 different purpose categories. A detailed description of all categories can be found in the Appendix (11.4.11). Similar to other definitions in this survey and in contrary to unambiguous mathematical definitions, it is important to be reminded that definitions in the context of sketches do rather have a character of guidelines or general rules than of exact definitions. Objects could, therefore, be classified differently, depending on who does an interpretation.

However, we think it is important to make this first rough assessment even if it is biased by the interpreting person. The indicated trends will help in future stages of sketch interpretation to focus on important and relevant issues of sketches and will lead to a better understanding of how people sketch.

The graph on Figure 20 below shows the relation between the normalized occurrence frequencies of the 15 purpose categories for each to the three sketching scenarios and the average over all three scenarios (dashed line).

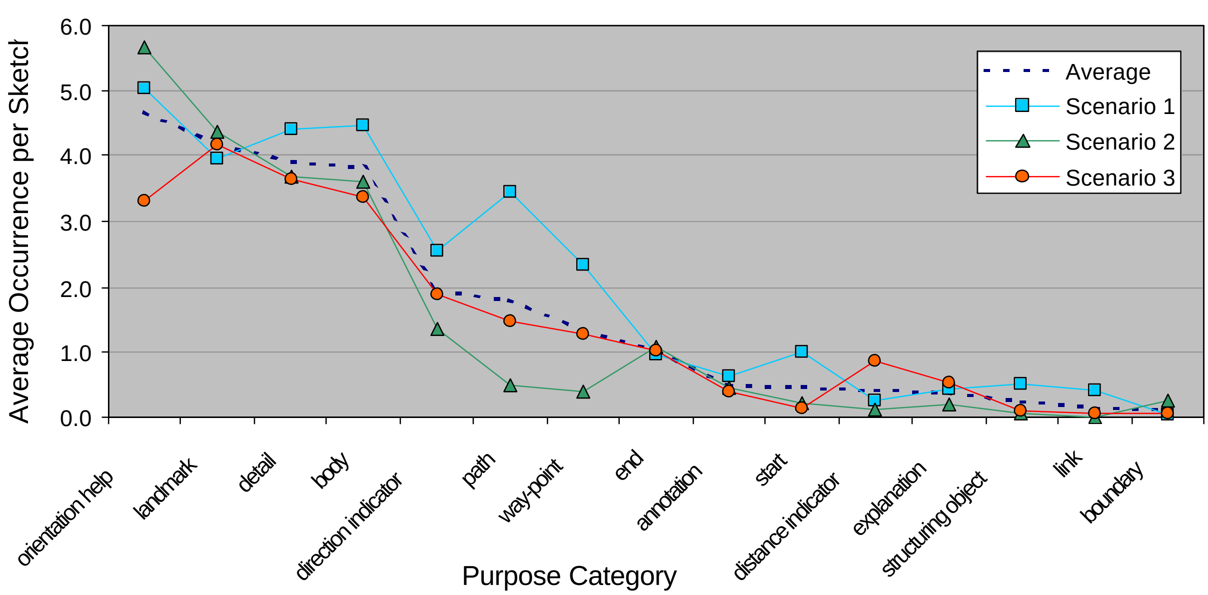


Figure 20 Normalized distribution of objects with a specific purpose per sketch for all three scenarios in reference to the average frequency (doted line).

Each sketched object has at least one purpose tag and the total number of purpose tags in our survey is 2021, resulting in an average of 1.7 purpose tags per object. This number was constant over all three scenarios. Looking at Figure 20, the first thing that surprises is that the distribution of objects with a specific purpose is relatively constant for all three scenarios. Geo-spatial sketches appear, therefore, to share some sort of a common framework or a global structure that is independent from the sketching task. However, there are some deviations from the dashed average distribution on Figure 20, but they are relatively easy to explain.

Scenario one, for instance, has a significantly higher number of path related objects (*start*, *path*, and *way-point*) than in the other scenarios, because the task in this scenario was to sketch a route. That the subjects are more knowledgeable about the drawn spatial situation of scenario one can be derived from the fact that complex and refining objects from categories, such as *detail*, *structuring object*, or *links* are used more frequently. We made the same observation when we analyzed the object type composition in sub-chapter 3.2.3. Scenario three scores highest for *distance* related objects and lowest for *orientation-help* related objects. This is due to the description of this scenario that implied the use of distances and which was not very detailed about objects that help orient a sketch. In fact it was our very intention to be vague in this respect to see how people deal with this situation.

Based on these observations we can assume that there is a set of task related objects that is superimposed over a generic set of objects found in the majority of geo-spatial sketches. The largest group that makes up alone around 50% of all objects, for instance, focuses primarily on defining and orienting the sketching space. This group includes objects with *orientation help*, *landmark*, and *body*-purpose tags. Other objects are used to refine this global sketching framework (e.g. objects with a *detail* or *annotation*-purpose) and still others are used to convey the actual message (e.g. *end*-purpose objects).

Table 44 in the Appendix shows a detailed analysis of the distribution of Figure 20 and adds standard deviation and an other statistical parameter. If we assume that the distribution is similar in each sketch and if we consider that an object can have multiple purposes, then it is possible to estimate a rough average number of object with a specific purpose per sketch.

- ~5 orientation-help or landmarks objects
- ~4 body or details objects
- ~2 direction objects
- ~1 end, goal, or focus object
- eventually one sketched annotation and
- eventually one textual explanation

If a path related task is involved then a generic sketch may contain additionally:

- ~5 path or way-point objects
- eventually one starting point

Depending on the context of the sketch, this composition of objects may, of course, vary. However, but we believe that the distribution of object with specific purposes is relatively constant within a specific application domain.

With these observations and findings about the purpose of objects we are at the end of Chapter 3 that focused objects without regard to their environment. In the following chapter we will go one step further, looking at neighboring objects and take the reference system of a sketch into account.

4. Relations

Introduction

Theories about spatial relations and relations between things in general are quite complex, often contradicting, and their definition is challenging at least. Much of this can be attributed to the fact that the definition of the word *relation* in Indo-European and Romance languages is vague about the *kind* of relationship between involved objects. Relations are in general based on people's perception of reality. This makes many types of relations highly subjective, because reality itself depends beside perception also on their interpretation.

Philosophers have been studying reality, perception, and the inferred knowledge for a long time, Nagarjuna (AD ~150-250, Indian Buddhist and monk-philosopher), Descartes (1596-1650, a French philosopher, mathematician, and scientist), Berkeley (1685-1753, an Irish prelate and philosopher), Hume (1711-1776, a British philosopher and historian), and Kant (1724-1804, a German idealist and philosopher) are some more famous examples (Encyclopaedia Britannica 1993). The Appendix 11.5.1 contains some further thought about philosophical aspects of relations. On the mathematical side there was the introduction of set theory that made exhaustive use of relations between sets of objects. The first axiomatization of set theory dates back to 1908 and was given by Zermelo, a German mathematician. Eventually, the increased interest and development of spatial databases directed attention towards spatial relations in general and their formulation. A very successful approach to describe binary topological relations between spatial objects was proposed by Egenhofer (Egenhofer 1989).

In the scope of this chapter we will make a simplistic approach of defining spatial relations and we will not delve further into philosophical aspects. Hence, we assume that the interpretation of a relation is unambiguous and that, therefore, everybody perceives a relation between objects the same way. A relation can, therefore, be defined as:

> *A relation is a natural, logical, or virtual association between two or more things, relevant one to another.*

Things in this context are sketched objects that can be visually distinguished.

Using a metaphor, we can compare sketched objects in a sketch with words in a sentence: Each single word has a typical meaning by itself. This meaning may not be expressive and it may be restricted to a supporting function, such as typical to prepositions. When taking two or more words together–words that are not necessarily next to each other–then the meaning can be extended in that it is possible to perceive basic substructures of a sentence. The final meaning of a sentence, however, can not be extracted without taking all words within their local context into account. Exactly the same is true for a sketch: We simply have to substitute words with sketched objects and the sentence with a sketch. A sketch can, therefore, also be paraphrased with a two dimensional sentence (Blaser 1997). For reasons of complexity we consider only binary relations in our analysis about sketched object relations and such disregarding the existence of relations that involve more than two objects. We are aware that this general setup is only the first step of an exhaustive exploration of relations in peoples sketches. However, we see our study as a first assessment of relations between discernible sketched objects in people's sketches that can be used as a base for later more sophisticated studies.

Relations between sketched objects

We have already mentioned that sketched object relations can be split into binary relations and relations that involve more than two objects. Beside these two forms, there is an other type of relation that plays an essential role for the interpretation of a sketch. This specific form of relation is also binary, but conversely to a typical binary relation which involves two sketched objects, it establishes a link between a sketched object and the referencing system. The referencing system in this context is a piece of paper or the drawing device. Hence we can consider the referencing system as a kind of *special object*. Another special object is the sketched scene itself. It qualifies as special object, because it can have a main orientation, a flow direction, or a specific location in relation to the drawing device or the global referencing system. The external referencing system (the world) can be considered to be yet another special object—Such, we have a sketched object, in a sketch, on a sketching device, which is in a specific relationship with its environment—.An object that is frequently used to link a sketch with the external referencing system is an arrow that indicates the North direction. Finally, the last relation that we want to mention at this point is the temporal relation between objects. This type of relation takes the drawing sequence of sketched objects into account and provides further insight about the structure of a sketch.

This leads to the following seven types of relations:

- Binary relations between ordinary objects
- Relations between ordinary objects and the sketched scene
- Relations between ordinary objects and the drawing surface/device
- Relations between ordinary objects and the external referencing system of the sketch
- Relation(s) between the sketched scene(s) and the drawing surface/device
- Relation(s) between the sketched scene(s) and the external referencing system of the sketch
- Temporal relation between objects or drawing sequence of sketched objects

As stated above, we focused primarily on a specific set of binary relations in our analysis. The main reason for this choice is the insurmountable complexity that arises when all possible relations are taken into consideration. The number of possible binary relations in a sketch is *n!/(n-k)!*, with *n* equal the number of sketched objects and *k* equal the number of objects involved in a relation, which is obviously two for a binary relation. In an average sketch with 14 objects this results already in 91 binary relations (We have to divide the result by two, because each relation is counted twice. Our formula is, therefore, actually *n!/2*(n-2)!*). Allowing relations between more than two objects leads to an immediate explosion of possible relations, because *n!* grows very quickly in comparison to the denominator. Beside this, it is much easier to process and interpret binary relations, than it is to do the same with relations that extend over multiple objects.

A manual examination of relations between sketched objects is in so far simpler than an automatic interpretation as that only a small subset of all possible relations are really relevant to understand or describe a sketched problem. It seems further that people have no problems to perceive this subset of important relations. However, and in order to keep our analysis in a manageable scope, we have focused our attention during the assessment of our survey on the relations listed below:

- binary topological relations between single objects, such as overlap, meet, or contains
- rough position of sketched objects in reference to the drawing surface,
- orientation of sketched objects in reference to the drawing surface
- direction of sketched objects if this is applicable (object must have an explicitly indicated direction)
- parallelity or rectangularity of sketched objects to other objects, if applicable

- temporal sequence with that object are drawn in relation to each other
- orientation of the sketched scene in reference to the drawing device and the external referencing system, if provided by the sketching subject.

The following sub-chapters describe our findings in respect to these particular relationships.

4.2 Topology

Topology is per definition the branch of mathematics concerned with those properties of geometric figures that are invariant under continuous transformations. A continuous transformation in this sense is a one-to-one correspondence between the points of one figure and the points of another figure such that points that are arbitrarily close on one figure are transformed into points that are also arbitrarily close on the other figure. Hence, two figures are topologically equivalent if one can be deformed into the other by bending, stretching, twisting, or the like, but not by tearing, cutting, or folding(Columbia University Press 1995). Egenhofer and Herring developed a method to formally describe all possible topological relations between two regions in 2D space. The model is based on 3x3 matrix that states the topological condition between interior, boundary, and exterior of two regions (Egenhofer and Herring 1990). The result are eight topologically different relations, shown in Figure 21.

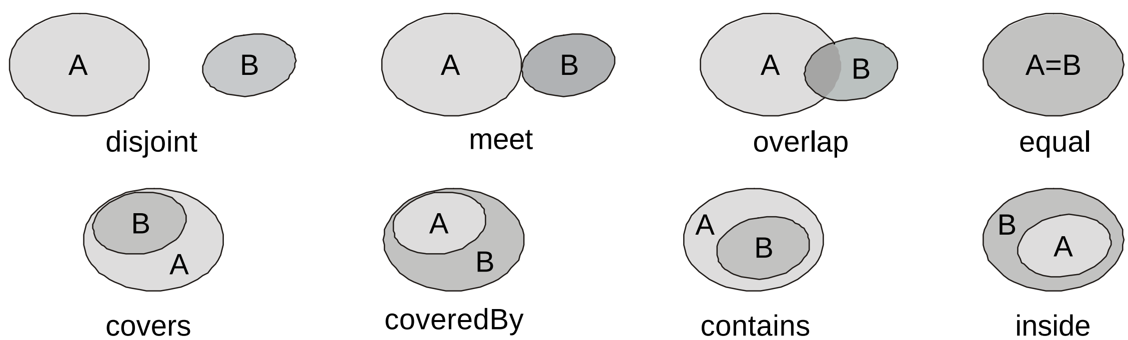


Figure 21 The eight topological relations that can be realized between two spatial regions and their verbal definitions.

Similar as for region-region relations it is possible to define sets of possible topological relations for all binary combinations between points, lines and regions. The 9-Intersection model is easy to apply on set theoretic objects and the verbal descriptions of the eight topological region-region relations are commonly used in natural language. This is true for regions, lines and points. Hence we adopt this taxonomy for the classification of binary object relations in our survey. To simplify the process we use only the following subset of the relations from Figure 21:

overlap, meet, contain, inside (contained by), and *equal*

If we consider relations on an object to object base, we can deduct the other three possible relations from these five relations as follows:

disjoint := if none of the above relations holds true

covers := if *meet* and *contain* hold true

coveredBy := if *meet* and *inside* hold true

However, in our case we evaluated relations on a one-object to n-object basis, which means that we counted all occurring relations per object, independent of how many objects were involved. Hence, relation of type *covers* and *coveredBy* are integrated in the categories *contain*, respectively *inside*.

Although this simplification might not be absolutely consistent, in regard to set theory, it works fine for a sketch analysis. Our approach can be justified, because of the nature of a freehand sketch that is often inexact and unclear. One manifestation of this vagueness is for instance that the boundary between the *disjoint*-, *meet*-, and *overlap*-relations are fluent. The advantage of our simple method of assessment is that there are only five points per relation to consider and that the method works as well for regions as for points and lines. In addition to the type of relation we obtain also the number of occurrences per sketched object in a single approach. For example if an object overlaps three other objects, then this number was recorded too. In the case of ambiguous situations, such as when two objects almost touch, but if there is still a small space in between, we try to bear the subjects intention in mind and formulate a verbal analogy to that relation, which we then translate into one of the five possible relations.

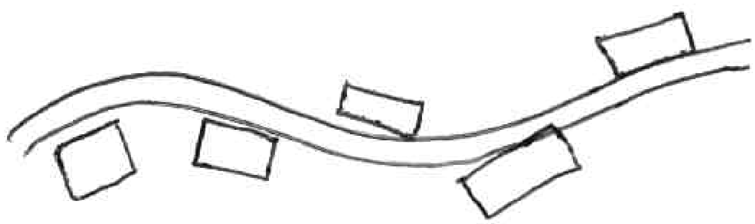


Figure 22 Sketch with five houses along a road, four of them qualify for a *meet* condition (b) - (e).

Based on this approach the road in Figure 22 meets with four houses, even if the houses meet only marginally (c) or if they are very close, but do not actually touch (b) the road, and even if they overlap a little bit. House (a) is considered disjoint, but it still carries the attributes along and parallel (Sub-chapter 4.7). For this analysis about topology we have once again excluded all sketches of scenario three, because the choice of objects and their relations was too much influenced by the problem description.

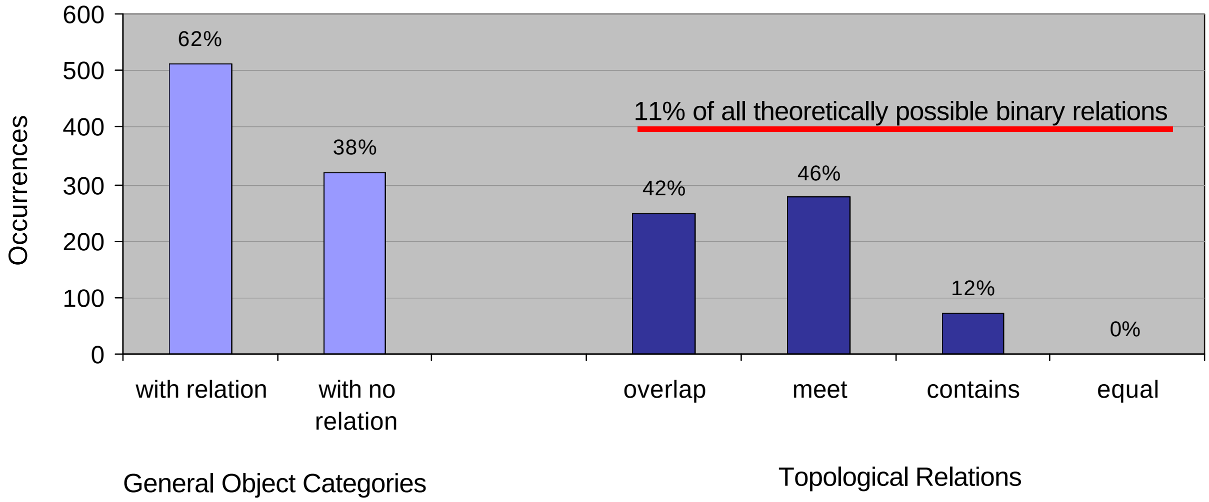


Figure 23 Graph with two parts: The left side shows the ratio between objects that have one or more relations (*in relation*) and objects that have no recorded relation (*disjoint*). The right four columns show the distribution of binary relations that were recorded in our survey (scenario 1 and 2) and make up 11% of all theoretically possible binary topological relations.

The chart on Figure 23 integrates two representations concerning topological relations in the two first sketching scenarios. The first part on the left of the graph shows the ratio between the number of objects that have no single topological relation (*disjoint*) and the number of objects that have at least one binary relation (*in relation*). The right side of the figure depicts the distribution of topological relation into four topological categories. The numbers in this part of the graph reveal the true count of relations. This means that only one relation per object pair was counted. For symmetric relations, such as *overlap*, *meet*, and *equal* the true number of relations is evaluated by counting all occurrences and dividing them by two. The dependent relations *contain* and *inside* produce the same numbers and can be used as is. However, to be able to compare topological categories, we have to merge the categories *contain* and *inside* into one category, which we called in this case *contains*.

Looking at the left portion of Figure 23 we can infer that almost two third of all objects have one or more binary topological relation other than disjoint associated. Hence, a big part of a sketch can be considered as a topologically inter-linked system of partial drawings, which means that the majority of objects belong to a connected topological framework. Considering only scenario one and two, we get an average of between 15 and 16 objects per sketch. Doing the same for topological relations we obtain an average value of 11.2 topological relations per sketch, not including of course disjoint relations. Comparing the number of classified topological relations with the theoretically possible number of relations we can observe that in average only about 11% of all possible binary relations have been classified to be non-disjoint. However, we have to assume that also some disjoint relationships are important to understand the meaning of a sketch. But despite this we believe that the number of relevant topological relations, including non-disjoint and disjoint relations as well, is relatively small when compared with the possible number of binary relations. Admittedly, we would have to prove that with another study.

Referring to the right portion of Figure 23 and reasoning about the distribution of topological relations, it is remarkable that there are relatively many *overlap* and *meet* relations in comparison to the total number of topological relations. This observation may be interpreted for instance, as an indication that people tend to sketch connected rather than disjoint sketches. Figure 23 suggests also that *containment* plays an inferior role and that containment is less important than *overlap* and *meet* relations. This on the other hand justifies our simplification concerning the reduced set of categories used to classify topological relations in our survey. *Similarity* finally appears to have no measurable importance for the drawing of a sketch. However, this might also be partially due to the fact that an object with multiple different annotations was still treated as only one object.

Table 11 compares the distribution of object relations concerning objects type. We can infer that the most common type of topological relation is a crossing of lines and that area and line objects frequently meet. The case that regions overlap other regions or lines occurs less frequently, but it is still quite common. The role of regions concerning containment is as expected. That lines are eligible to be listed as a host for a *contain* relation can be attributed to the existence of 2D lines, which can in fact contain other objects. Unfortunately we can not explore these issues any further, because we did only record the type of the of relation but not the involved secondary object. Table 11 lists, therefore, only the total number of objects with a specific topological relation divided in the two categories line and area objects. However, with some reasoning about possible combinations it is still possible to derive some interesting information like the statements made above.

	Relation Category				
Object Type	overlap	meet	contain	inside	equal
line	324	259	12	25	0
area	173	295	58	45	0

Table 11 This table compares line and area object types concerning topological relations. (Scenarios 1 & 2).

Summarizing our analysis about the simplified topology in a sketch, we found that people seem to draw objects in a connected way, using primarily *meet* and *overlap* relations between objects. Topologically disconnected objects make about one third of all objects and it can be expected that the majority of these objects are connected through alternative relations to the rest of the framework. *Containment* was considered of lesser importance and *similarity* has had no influence in our survey.

For an additional study of topological relations in sketches, it would be interesting to look at relations at a lower level of granularity that would include more parameters per recorded relation. Questions, such as *what are the involved objects?* or *what parameter characterizes this particular topological relation?* would be very helpful for an interpretation. Because such a detailed examination is almost impossible on a manual base, we would strongly recommend that such an analysis would be based on an automated approach.

4.3 Location/Position

In this sub-chapter we examine the distribution with that objects are positioned on the drawing surface. For this purpose we have recorded for each object its rough position by assigning the object to one or more quadrants. The drawing surface measures 26,1 by 16,8 cm ($10^{5/16}$" x $6^{5/8}$") and it is evenly divided into 16 quadrants of the same size. The distribution and the order of the quadrants can be seen on Figure 24 below.

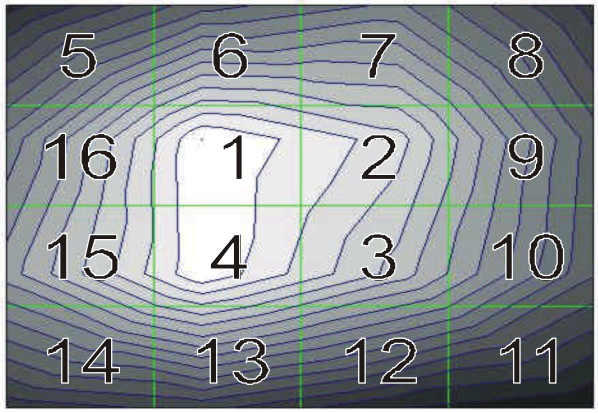
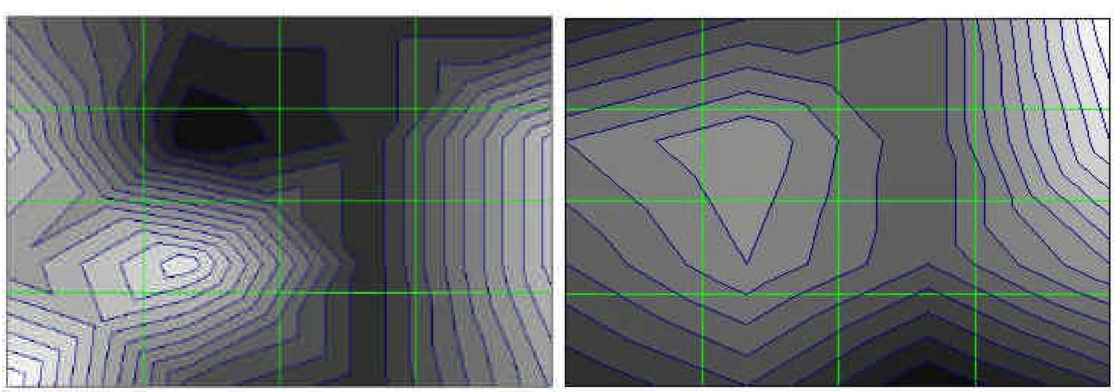


Figure 24 Contour plot of the frequency with that objects were drawn, averaged over all three scenarios. Light parts indicate a high and dark parts a low occurrence frequency. The numbers stand for the specific quadrants.

The location of an object is defined by the set of identification numbers of all quadrants that the objects overlaps (e.g. The position of an object in the lower right corner could be defined with the set *10,11*). The frequency and distribution of objects is most easily presented with a 2D contour chart; in the representation on Figure 24 the scale goes from red (high frequency) to dark blue (low frequency). This Figure shows the overall distribution of all objects in all sketches. As could be expected, the distribution is relatively concentric and there is a concentration of drawn objects in the middle of the drawing surface. However, it seems that most objects are drawn in quadrants 1 and 4, which is most likely because of the western style of writing and drawing that teaches people to start on the left and continue to the right. This left-right tendency can also be experienced if we compare the graphs for the individual scenarios in the Appendix (Figure 71).

Beside taking the entire set of objects as a base for an analysis of the local distribution it seems interesting to consider only objects with particular characteristics. Although it would be desirable to look at the spatial distribution of the entire spectrum of possible objects properties, this is unfortunately out of the scope of this technical report. The purpose of objects appeared to be an interesting characteristic in respect of the spatial distribution of sketched objects. We selected 8 purpose classes that seemed to be particularly responsive to a specific spatial location: *body, start, end, orientation-help, landmark, detail,* and *direction*. In addition we looked at objects indicating the North direction.



(a) (b)

Figure 25 Contour plot showing the frequency of objects that indicated a starting point (a) and an end or goal (b) within a sketch. (Scenarios 1, 2 & 3).

Five of the investigated object purposes shows no significant different spatial distribution compared to the average distribution (Appendix Figure 72 (a) - 72 (e)). However, for three object purposes this is different. As we can infer from Figure 25 and Figure 26 below the obtained frequency graphs for objects representing *start* and *end* points and for objects indicating the *north direction* diverge significantly from the average graph in Figure 26.

Similar to the general observation that most people have a left to right tendency, we can infer from Figure 25 (a) that most people also seem to have a preference for the lower left corner to position points of departure. The second highest accumulation of starting points can be found in quadrant 4, which can be explained by subjects that did not use the entire drawing space. Above average frequencies in other regions, such as the right and left side, can be interpreted as noise, because there was only a total of 47 starting points in our survey, which results in a rather loose distribution. A further explanation could be that some subjects tried to orient their sketches to the north direction (like maps: North is up) and, therefore, positioned their starting points in one of the boundary quadrants. The distribution of end points or goals on Figure 25 (b) is even more remarkable. The great majority of people seems to agree that the upper right side of the drawing surface represents the best place to locate the end point or goal in a sketch. There is a secondary accumulation of object of the end/goal type in quadrant one and four. This anomaly is most likely because of non-path oriented sketches which do not necessarily have an end point on the boundary of a sketch, but more a goal somewhere in the middle of the sketch. This explanation is consistent with the observation for sketched objects in general that seem to concentrate in the same quadrants (one and four).

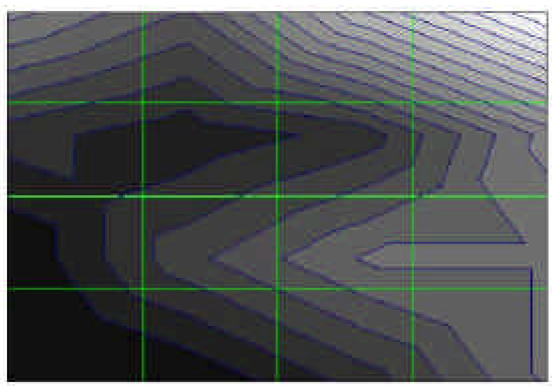


Figure 26 The majority of North direction is drawn in the upper right corner of the sketching device. (Scenarios 1, 2 & 3).

The local frequency for objects indicating the North direction is represented in Figure 26. This Figure is another prove that people are influenced by the environment they live in, their experience, and in this case by maps, which frequently have the North symbol in just this location.

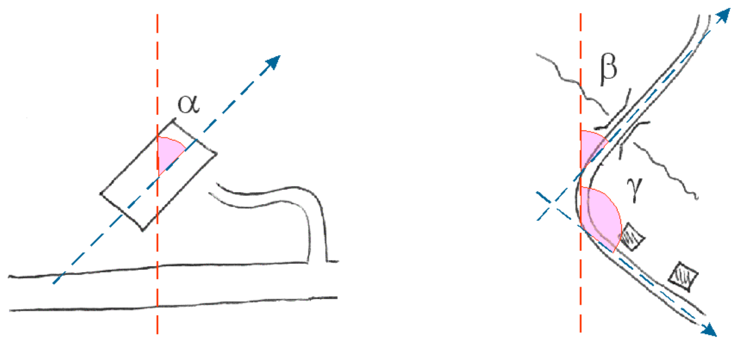
Taking all figures in this sub-chapter into account and trying to summarize our findings we can state that the majority of sketched objects are located slightly left of the center of the drawing device. It appears that many people that are used to write in a western style from left to right seem to proceed in this same manner when sketching. That the majority of objects classified as starting points are placed on the lower left corner and that the highest accumulation of end points is in the upper right corner of the drawing surface seems to support this theory. Another observation, which is related to this left-right flow concerns the tendency that the average sketch in our survey seems to be slightly tilted (Figure 22, 23 (a), (b), and Figure 71 (a) and 71 (c) in the Appendix). This observation too can be attributed to the frequently noticeable tendency that people are tempted to write slightly upwards. Simple and uncertain sketches are in general more symmetric and their object distribution more regular (e.g. Scenario two, Figure 71 (b) in the Appendix). They are also located more to the center of the drawing surface. More complex scenarios or scenarios with greater detail show a greater variety and are less regular. We found some special objects that have a preferred location on the drawing surface: the North direction indicator is an example. Most likely there are other objects that have a object-specific distribution as well.

4.4 Orientation

The term orientation always involves some sort of referencing system. In the case of sketches, an object's orientation can be brought into relation with the following three referencing systems

- Drawing device
- Main sketch orientation
- Other objects or groups of objects

The orientation concerning the drawing device is relatively easy to evaluate, because the orientation of the drawing device is fixed, hence the problem is reduced to get the main orientation of the object, which we defined as the angle between twelve o'clock of the drawing device and the main direction the object is pointing to. If the object's main direction is more than 180° then it is reduced by 180° so that the orientation is always between 0° and 170°. Objects that have no visible orientation have a special tag and are excluded from the examinations. The orientation of an object was recorded in steps of 10°, which is adequate considering eventual uncertainties when measuring a direction manually. If an object has more than one main direction then all directions are recorded separately. Figure 27$ below shows two examples.



(a) (b)

Figure 27 The house in (a) has the orientation of ? ; the street in (b) has two orientations: ? and ?.

The next Figure 28$ shows a graph with a logarithmic scale that indicates how people preferably oriented their objects. As could be expected the North-South and East-West orientation were the prevailing orientations. The distribution is relatively regular in respect to symmetry and the two principal axis. The difference between objects with an orientation from 0° to 90° and those from 90° to 180° is relatively small (14:11) but the deviation seems to confirm our findings from the previous sub-chapter that many people in the Western world have the tendency to write or draw slightly upwards from down left to up right (✍ larger number of objects with an orientation 0° to 90°). Comparing the two main axis only, there are about 40% more objects with a East-West bearing than objects with a North-South orientation. It is hard to say if that is due to the orientation of the sketching surface or if landscape is people's preferred object orientation–a survey based on a square-shaped sketching device would certainly help to find an answer for this question.–Of the 1208 objects analyzed in our survey, 993 objects or 82% had at least one prominent orientation, the average number of orientations per objects was 1.2.

Object Orientation	Count	%
0°	**312**	**26%**
10°	40	3%
20°	40	3%
30°	27	2%
40°	16	1%
50°	24	2%
60°	20	2%
70°	35	3%
80°	42	4%
90°	**438**	**37%**
100°	41	3%
110°	22	2%
120°	32	3%
130°	16	1%
140°	19	2%
150°	20	2%
160°	16	1%
170°	26	2%

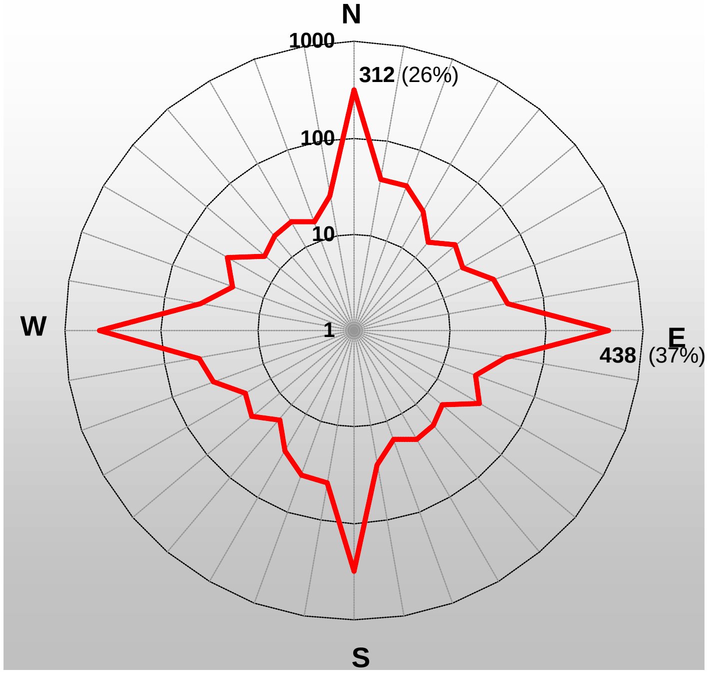


Figure 28 This graph shows the frequency with that objects are drawn with a specific orientation. The scale is logarithmic and the analysis includes the entire set of objects of the survey. The graph is symmetric that is it uses the same data between 180° and 360° as between 0° to 180°to better visualize the distribution.

The orientation of sketched objects in respect to the main sketch orientation is the angle between both orientations. Because each object and each sketch can have multiple orientation it is not a trivial task to calculate this specific object orientation. This is also the reason why we skipped this particular relationship in our analysis. However, a study of this issue in an upcoming, automated survey could be promising, because it could provide evidence that people tilt their objects in the same manner as that they tilt their sketches–similar to people's handwriting on a unruled sheet of paper. Having such information about the systematic tilting of objects and sketches could prove very useful for the calibration of sketches and for the generation of user profiles.

The last of the three object orientations–the orientation of an object in relation to other objects or groups of objects–is even more complex to evaluate, because it requires knowledge about the set of objects in the vicinity of each object and because each object is allowed to have multiple orientations. As a result it was not possible to address this issue in the scope of this manual analysis. Observations concerning the similarity of orientations among neighboring objects could be used to guess on the affiliation of objects to groups of objects. For instance houses along a street are frequently aligned with the street and, therefore, they have also often the same orientation. We would have now two clues that link these houses to the street: first their closeness to the street and secondarily the similarity of orientation between houses and street. Other characteristics, such as object alongness could be inferred from object orientations as well.

This sub-chapter addressed the orientation of objects in a sketch. There are three primary referencing systems with that sketched objects can be compared: The drawing device, the main orientation of the sketch, and groups of sketched objects. Due to the manual method of examination to assess characteristics of sketched objects, we have focused on the drawing device as the sole referencing system. Our findings show that people have a clear tendency to orient their objects either in reference to the North-South axis or to the East-West axis. The frequency of objects that are parallel to the East-West axis is about 1.4 times higher than the frequency of objects that are parallel North-South axis; an observation that eventually may be attributed to the general set-up of the drawing device, which oriented the same way.

4.5 Direction

In this sub-chapter we examine objects concerning their pointing direction. To qualify for this examination an object must have one or more associated direction indicators. This group of objects with an indicated direction is a sub-set of those objects with an orientation (previous sub-chapter), because an object direction automatically implies an orientation. In total there were 323 or 27% objects that qualified for this analysis, this includes also objects that have a deduced direction, for instance, because they inherited a direction from an associated arrow. The four examples of Figure 29$ show some possible configurations with objects that have an indicated direction. Example (d) is particularly interesting, because it is ambiguous. The place named *Boston* could be at the end of the arrow but it is also feasible that Boston is out of scope of the sketch in this particular direction.

(a) (b) (c) (d)

Figure 29 Four examples of objects that have an indicated direction: (a) a typical north arrow, (b) a street with an indicated flow or path direction, a view symbol indicating the direction of the view (c), and a virtual object with a indicated direction (d).

The orientation of the referencing system that we will use in all our examples reflects the orientation of the drawing device, that is, the top of the device represents twelve o’clock, respectively the North direction of the drawing surface. Other valid referencing systems are the main sketching direction or if indicated, the North direction. The reason why we use the drawing device as our primary frame of reference is the same as in the previous sub-chapter about object orientation, it is the most logical and simplest choice.

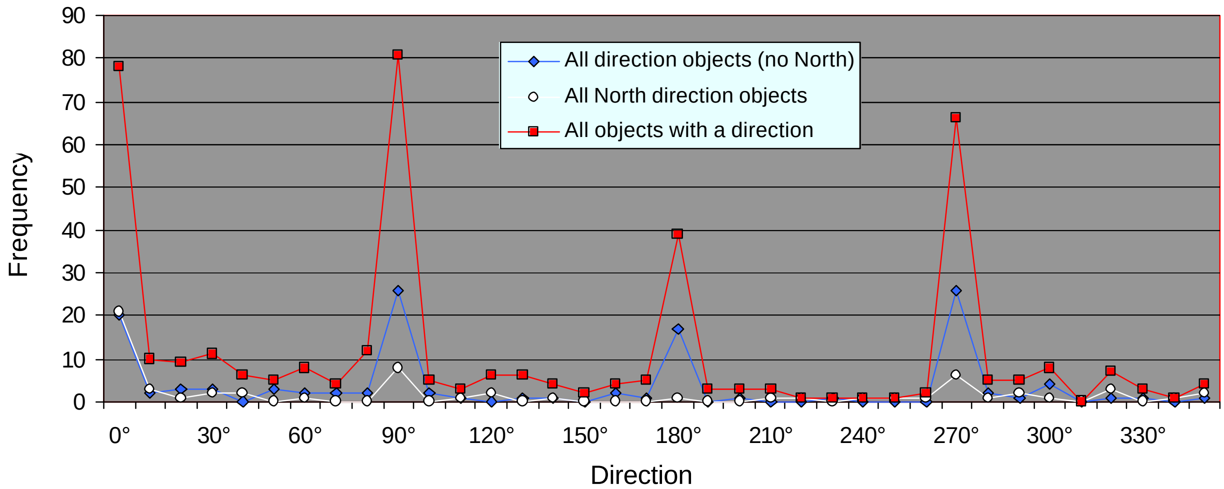


Figure 30 Frequency for all objects with an indicated direction (red), all objects of the direction object class, not including north directions (blue), and all objects indicating the North direction (white). (Scenarios 1, 2 & 3)

Figure 30 shows the 36 possible object directions and the frequency with that they have been used. To reflect the different characteristics of objects with an indicated direction, we distinguish between three different types of objects: The red line represents all objects with an indicated direction, the blue line depicts those objects that belong to the direction object class, not including objects indicating the North direction. Objects indicating the North direction are, finally, represented by the white line. The red line is the reference to Figure 74$ in the Appendix.

Looking at all objects with an indicated direction in general it is apparent that cardinal directions show a significant higher frequency than all other directions–objects that point in one of the four cardinal directions make up 64% of the total number of objects with an indicated direction.–Objects pointing to the North and to the East are twice as frequently used than objects pointing to the South, those objects with a westerly direction scored somewhere in between. This is also similar to the distribution experienced with object orientations in the previous sub-chapter. The difference between orientation and direction is that object are more frequently oriented towards one of the cardinal axis if they indicate a specific direction than if they have no implicit or explicit direction (Compare Figure 28$ and Figure 74$ in the Appendix). This decline of frequency is even more significant for directions with a bearing from 180° to 270° (only 3% of all objects with an indicated direction). The preferred non-cardinal directions lie between 0° and 90° (12%), while the two remaining sectors score a mere 6% of the total number of directions. This observation supports our assumptions that–beside the predominating desire to adjust object orientation or direction to the principal axis–many people have a tendency to write and sketch objects slightly tilted upwards from left to right.

Focusing on North directions (green line Figure 30) it becomes evident that most of our subjects seem to agree in orienting their sketches by providing a north direction that points towards twelve o'clock (33% directly North and 41% with a maximal deviation of +/- 10°). There is a smaller percentage to the East and West (13% respectively 9%) and there are practically no objects pointing to the South (2%). This is an indication that North arrows pointing downwards appear to most people quite unusual. The distribution of ordinary (not North) directions within the *direction* class (blue) is much more symmetric compared to the distribution of objects indicating the North direction. The number of objects pointing to the East and to the West are very similar and objects with northerly and southerly bearings are slightly less frequent. There are only few objects pointing into other than these principle directions.

All observations made in this sub-chapter seem to confirm that people generally tend to adjust sketched objects to the common cardinal referencing system in that they try to align drawn objects either to the North-South or East-West axis. Beside this, we have again experienced a slight upwards tendency that leads to an increased use of directions pointing towards directions between 0° and 90°. We found also that there is an important difference between objects that indicate the North direction and objects of the direction object class in general: Those objects that indicate the North direction show a exceptional high frequency for twelve o'clock, a moderate frequency for three and nine o'clock, but there is practically no North direction pointing at six o'clock. All other objects of the *direction* class, in contrast, show a much more symmetric distribution, which includes directions to six o'clock. Finally, if we compare the behavior of objects concerning orientation and direction we can observe that–although both parameters show a strong tendency for an alignment to the four principal directions–the orientation of an objects seem to be less bound to the cardinal referencing system than this seems to be the case for objects that indicate directions.

4.6 Sequence

Conversely to a photograph which records an entire scene all at once and in one single step, a sketch develops over time. A sketch has, therefore, a history and sketched objects can be analyzed by their temporal sequence in respect to the beginning of a sketch and its end. There are mainly two reasons why this temporal component–which is gone by the time the sketch is finished if the sequence is not recorded–provides very valuable information for an analysis of a sketch. On one hand it can be observed that sketched objects are in general drawn in a single step; that is, people tend to finish drawing an object before they start to draw the next object. Although this is not an iron rule, most people seem to stick to this sketching strategy and the number of objects that are created in one go seem to prevail in most sketches. This observation and the fact that it is impossible to draw multiple objects simultaneously makes it much easier to detect objects in a sketch than on a snapshot like representation without any time-bound information.

We do also believe that objects are sketched with specific chronological patterns, which can reflects a subjects thoughts during the sketching process. Therefore, if it is possible to perceive and formalize such sketching pattern it may as well be possible to obtain another indication that helps to understand the generic structure of a sketch. In this context we have three major points of interest:

- The relative position of sketched objects in regard to neighboring objects that are in temporal sequence.
- The pattern of objects that are in temporal sequence considering their affiliation to object classes.
- The pattern of objects that are in temporal sequence in regard to their purposes.

We have briefly addressed issues concerning the absolute location of objects in Sub-chapter 4.2$ when we addressed the position of objects in respect to the drawing device. These reflections were made from a more static point of view. Here we focus rather on the dynamic generation of a sketch and its genesis.

To assess the chronological object sequence in a sketch we have asked the subjects to make a timely ordered list including all sketched objects. This list had to be done after the sketch in order not to interfere with the sketching procedure. Although clearly stated in the description of the survey, many people were very vague and imprecise in describing the sequence in which they had drawn their objects. This resulted partially in incomplete and inaccurate statements. Some sequences were even obviously wrong, as they expressed a sequence that did not match with the graphical representation. The consequence for future surveys with a similar setup is an automation of this step that relieves the subjects from recording the sketching sequence or from other inferring activities. Such a procedure would certainly be less biased and more expressive, but unfortunately it was not available for our analysis. However, we have carefully studied the all declared object sequences and checked for their plausibility.

To further ensure a correct handling of the topic we analyzed only those sketches that were made in the scope of scenario one and two. This measure became necessary, because many people used the indicated sequence of the third scenario description to draw their sketch.

The spatial location of an object is defined as the geometrical center of all cells that it covers (each cell is $^{1}/_{16}$ of the size of the drawing device). To eliminate errors of location we have excluded objects that extend over more than three cells in a row or that occupied more than four cells in total. We are aware that this is a rather rough approximation of the location of a sketched object, but considering the fact that the analysis of the survey was based on a manual examination and looking at our results as a first assessment we think that our method will sufficiently describe object locations within sketches. In subsequent surveys, however, it would be desirable and a big advantage to have an automated method to retrieve the position of sketched objects.

4.6.1 Spatial Object Sequence

In order to asses and visualize the spatial sequence of objects in a sketch we connected the center-points of all objects in a sketch in the sequence of their creation. The result is one single, non-branched, and unidirectional polygon per sketch, containing each a start and an end point. The next step involved a visual examination of all polygons resulting in our definition of a simple classification scheme for the spatial sequence of objects. Apart from the fact that different spatial scenarios inevitably lead to different geometrical representations and despite the fact that no two polygons are identical we found five basic types of sketching strategies:

- *Looped* path (regularly clockwise or counter clockwise looping)
- *Zigzag* path (back and forth in a random manner)
- *S-shaped* (changing orientation while looping, meandering over the sketching surface)
- *Straight-curved* path (not intersecting, and keeping more or less one direction)
- *Random* path (going from object to object in a random manner that is not going to neighboring objects in the first place)

These five strategies are depict in a pure form on Figure 31 below. During the analysis of our survey it became obvious that many subjects used also mixed forms of these strategies, in which cases the strategy that came closest was selected. Section 11.5.5 in the Appendix depicts all 50 polygons that were used for our analysis. 22 subjects were represented with a valid sketch in both scenarios, but only 6 (27%) subjects applied the same strategy in both sketches. Although this number is slightly above the theoretical value of 4.4 (20%), it seems insufficient evidence that people use the same strategy over multiple sketches. This observation is converse to the experience made during the interpretation of the survey, where it was often possible to visually associate all three sketches of a subject.

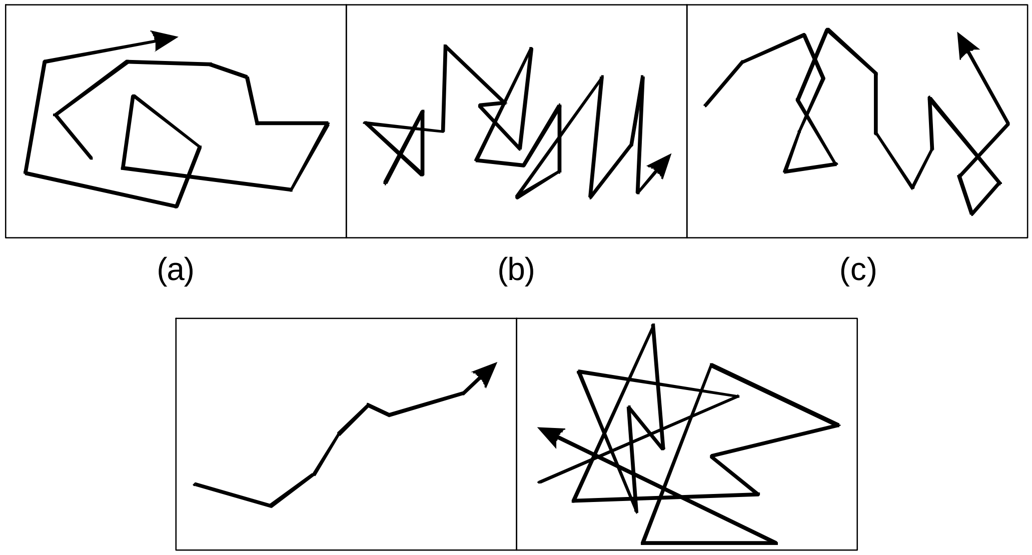


Figure 31 These five graphs show the predominant sketching strategies, in regard of temporal object sequence that we have found in our survey.
Looped path (a), *Zigzag* path (b), *S-shaped* path (c), *straight-curved* path (d), and *random* path (e).

	Scenario 1	%	Scenario 2	%	Scenario 1&2	%
Looped Path	9	33%	7	30%	16	32%
Zig-Zag Path	6	22%	2	9%	8	16%
S-shaped Path	5	19%	9	39%	14	28%
Straight/Curved Path	2	7%	4	17%	6	12%
Random Path	5	19%	1	4%	6	12%

Table 12 Frequency of the different sketching strategies for the scenario one and two separately and for both scenarios together.

Table 12 lists the occurrence frequency of the different sketching strategies for scenario one and two and for both scenarios together. The *looped* path and *S-shaped* path strategies seem to be very popular. Using these strategies the subject goes from one object to a neighboring object in a looping manner, gradually building up a sketched scene. These two strategies are closely related and sometimes hard to distinguish. A possible explanation for their popularity is that people in general do not want to run out of space while sketching and that they, therefore, try to sense the dimension of the device by positioning their objects in a looping manner that covers a big part of the drawing device. It would be interesting in this context to analyze that impact a sizable and panable sketching device would have on such sketching strategies.

A phenomenon that can be observed with all but the *random* path strategy is that people tend to sketch the subsequent (n+1) object relatively close the previous object (n). We can call this observation the *neighboring effect*? 88% of all sketches were generated like this. This observation is helpful while building up a virtual image of a sketch, because we can assume that objects that are drawn in sequence have a stronger relationship to each other than objects that are out of sequence. An other reason that supports this statement is that the drawing subject may infer new objects from preceding objects and hence that there is a logical connection between objects that are sketched in sequence.

The *random* path strategy is mainly characterized by neighboring objects not being sketched in sequence. Inferring thereupon that there is no logical connection between objects in chronological sequence in such sketches proofed to be wrong, as it seems rather that in these cases the objects are connected thematically. That is, objects of the same or similar classes are drawn one after another (e.g. all streets or all houses are drawn in a chronological sequence). Based solely on this hypothesis we were able to identify four out of six sketches with a random strategy. The examination involved all 50 sketch paths and resulted in a total of six misclassifications. This number of falsely classified sketch strategies seems high at first glance, but if we consider that four of these sketches were of type *zigzag*–a sketching form that seems to be related to the *random* path strategy–then this number appears in a better light.

A further observation concerning both scenarios is that if the last drawn object happens to be a direction indicator, such as the north direction, then the location of this last objects is somewhat out of order what often leads to a longer than usual last segment of the polygon. This observation can be made with other types of objects too, for instance with legends and other written annotations that are drawn at the end of the sketching process and that traditionally have preferred locations in a sketch, such as the North arrow which is preferably positioned in the top right corner.

The major reason why we decided to analyze the scenario one and two separately was, because we did expect significant differences between the two thematically varying scenarios. Hence, before we had done our analysis we thought that for the path oriented first scenario mainly the *straight-curved* and *S-shaped* path strategies are being used. This assumption was based on the idea that a well known path would be rather drawn gradually than in a random manner. But the results were different. There were only 25% of all sketches (in scenario one) drawn according to these two strategies, which is actually less than half of the number of sketches drawn with the same two strategies in scenario two. One explanation for this observation could be that it poses no problem for people to virtually jump from object to object in a familiar environment, because they can "look" at an internal representation of the scene that provides enough clues to guess from one object to another in a spatially non-sequential manner. However, there may be other object characteristics that the user mentally connects.

The second scenario is different from the first one in that people frequently seem to remember the next object upon drawing the previous one resulting in a high score of *looped*, *S-shaped* and *straight-curved* path strategy sketches. The relatively low number of random sketches (only one out of 23) might, accordingly, indicate that our subject had a hard time to draw the sketch directly out of their memory and that the spatial scene came into life not until the subject started to draw objects.

Unfortunately our analysis considering the spatial sequence of objects seems to describe sketched scenes only insufficiently. On one hand this may be due to the simple and not very accurate method that was used to determine the location of sketched objects, but it is also feasible that some information concerning the temporal sequence of sketched objects was incorrectly supplied by the sketching subjects. However, we think it would be revealing to investigate this issue further, perhaps with a more developed methodology. An other related question concerns the process of the creation of individual sketch objects. Are objects drawn in a single approach or do people commonly compose sketch objects in multiple, chronologically not connected attempts? An ideal method to investigate such a question would involve an automated recording of all sketched objects and include video taping of the subjects as an additional source of information.

4.6.2 Thematical Object Sequence

The thematical object sequence gives an indication about what objects classes are used at what time during the sketching process. We have temporally divided the sketching process into three phases, reflecting three particularly interesting phases. The first phase is called *start*-phase and involves up to three sketching objects drawn at the very beginning of a sketch. The number of objects in this phase can not exceed one third of the total of number of sketched objects–this measure is necessary for sketches with very few objects. The third phase is called *end*-phase and it can, accordingly, contain up to three objects drawn at the end of a sketch. The *end*-phase is subject to the same restriction as the start-phase: the number of objects in the end-phase may not exceed one third of all objects drawn in a particular sketch. The *body*-phase, finally, contains all objects that fall neither into the *start* nor into the *end*-phase. To be able to compare the three phases we compare the average frequency with that objects occur throughout the entire sketch with the frequency that is specific to each of the three phases. The following three sub-sections analyze each phase separately and Figures 75 and 76 in the Appendix compare the three phases graphically.

Start Phase

Figure 32 shows the distribution of different object classes within the *start*-phase. Obviously there is a difference between the average distribution and the distribution in this first phase: Objects classes with line characteristics, such as the *road system*, *body of water*, *railway system*, or *boundary* object class have significant higher occurrence frequencies than other object classes that represent objects with areal characteristics.

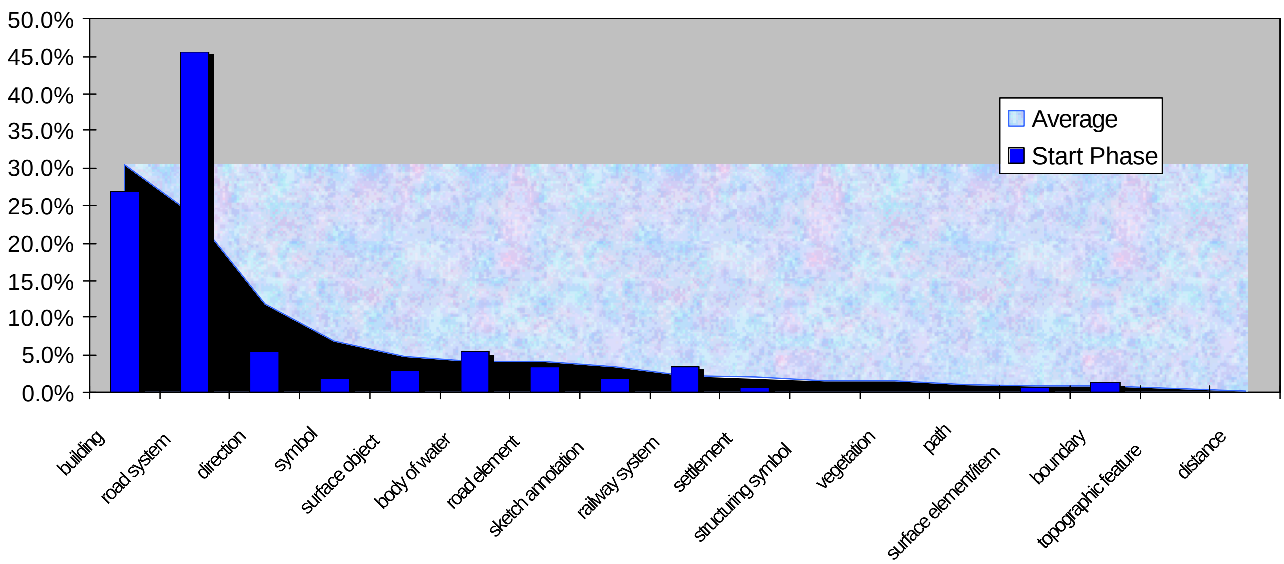


Figure 32 Graph with the normalized relationship between the average frequency of objects from different classes and the frequency that objects of a specific object class fall into the start phase of a sketch. (Scenario 1 & 2).

This observation suggests that line objects, especially those that extend over a large portion of a sketch are particularly well suited to structure and partition the drawing space in this initial phase of a sketch. Line objects seem to be responsible for the creation of a framework layer that can be considered as an internal referencing system during *and after* the process of sketching. This system of line objects appears to be the network or the scaffolding that glues objects that are subsequently drawn together. Beside this, we believe that this framework of objects with line characteristics is also responsible for the definition of the local orientation and scale. The reason why we assume that objects with line characteristics are the preferred tool to define orientation and scale in a sketch is that these objects stretch in general over a large portion of a sketch and that they, therefore, provide a better rule or local referencing system than objects with surface characteristics that are typically much smaller.

Surface objects with a particular large or otherwise extended shape might as well qualify for the same purpose. An examples of such as reference object with surface characteristics is a long lake. The third possibility is that prominent landmarks are used to spread a virtual base line that can then be used for referencing purposes as well. Such, it is also feasible for other objects to be drawn in the *start*-phase. But still, objects with line characteristics seem to be the most frequent.

Body Phase

Since most sketched objects are drawn during the *body*-phase it is not astonishing that–looking at Figure 33–there is a big correlation between the average distribution of object classes and the one for objects used in the *body*-phase. However, there are two exceptions, concerning the *direction* and the *sketch annotation* object class. The number of objects is for both classes considerably less than average in this middle phase. If we take the previous Figure about the *start*-phase into account as well, we can infer that objects of these two classes are preferably drawn at the end of a sketch. Beside this there seem to be no other relevant trend in this figure.

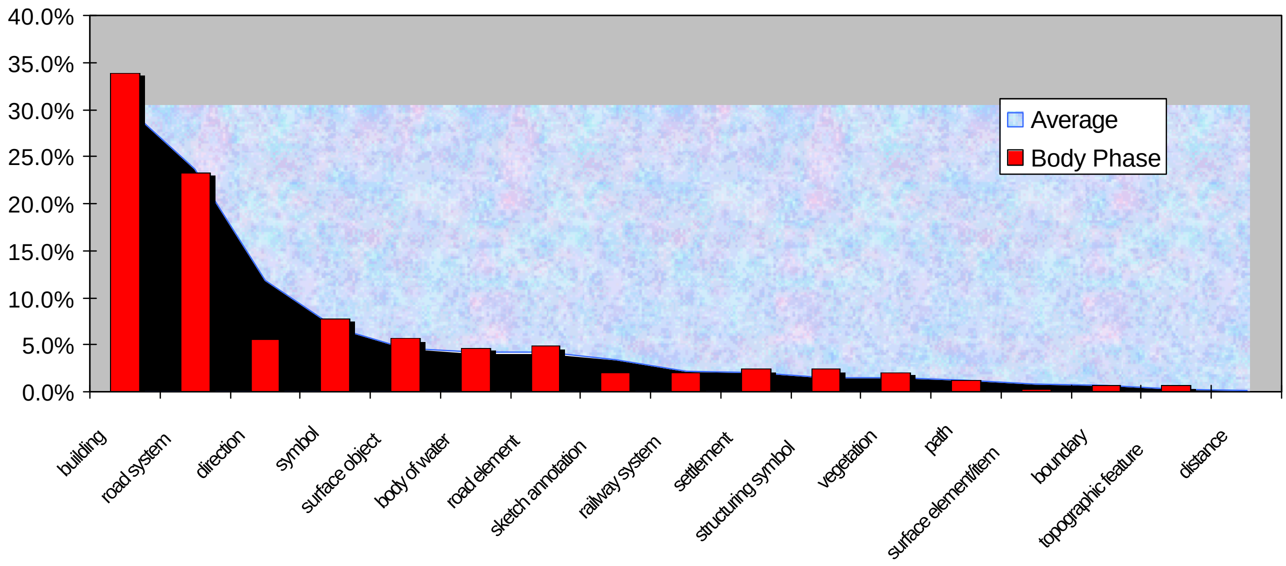


Figure 33 Graph with the normalized relationship between the average frequency of objects from different classes and the frequency that objects fall neither into the *start*- nor in the *end*-phase of a sketch. (Scenario 1 & 2).

End Phase

As expected based on our observations in the two previous sections (Figure 32$ and 33$), we can observe a significantly increased number of objects in the *direction* and *sketch annotation* object class in this final stage of a sketch. Likewise people seem to add objects of the *path*, *surface element*, and *item* class preferably at the end of a sketch. On the other hand there are fewer structural objects capable of defining the framework of a sketch; the *road systems*, *body of water*, and *structuring symbol* object classes are the most prominent examples of classes that are represented far below average. Accordingly, we can assume that people are concerned about the details and the finer points of a sketch in this phase of drawing (*surface elements*, *items*, *symbols*, and partially also *buildings*). This is a logical consequence of the nature of the sketching process, in which every new drawn object inherits the constraints created by all previously drawn objects, which leads in general to an increased refinement of objects at the end of a sketch.

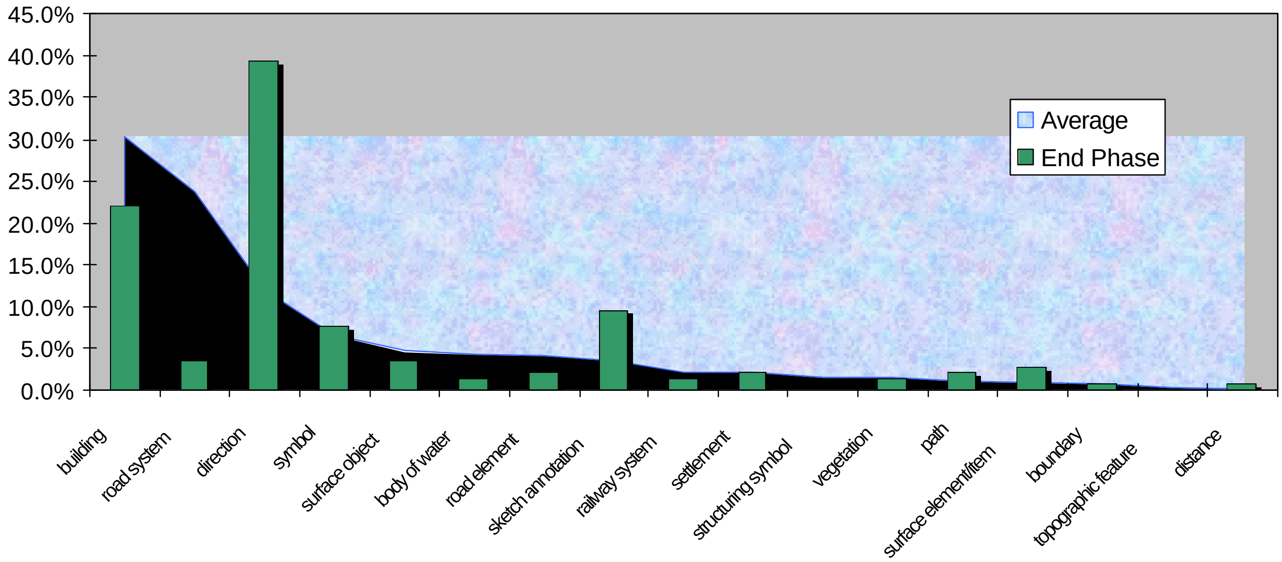


Figure 34 Graph with the normalized relationship between the average frequency of objects from different classes and the frequency objects fall into the *end* phase of a sketch. (Scenario 1 & 2).

4.6.3 Sequence considering Object Purpose

The distribution of objects concerning their purpose is closely related to the distribution concerning their affiliation to an object class. The difference between the two approaches lies primarily in the way that objects have been classified. To determine the class of an object, it is detached from its neighborhood and judged without context. Taking an object's neighborhood into account is only in rare occasions necessary. The definition of an object's purpose, on the other hand, needs an extended interpretation that is based on the context of an object. This is also why the purpose of an object is less obvious and more dependent on a subject's individual interpretation than an object's affiliation to a specific class. A further difference is that it is possible for an object to have more than one purpose but in the same time it can only belong to one object class. Figure 35$ below shows the distribution of object purposes during the three sketching phases.

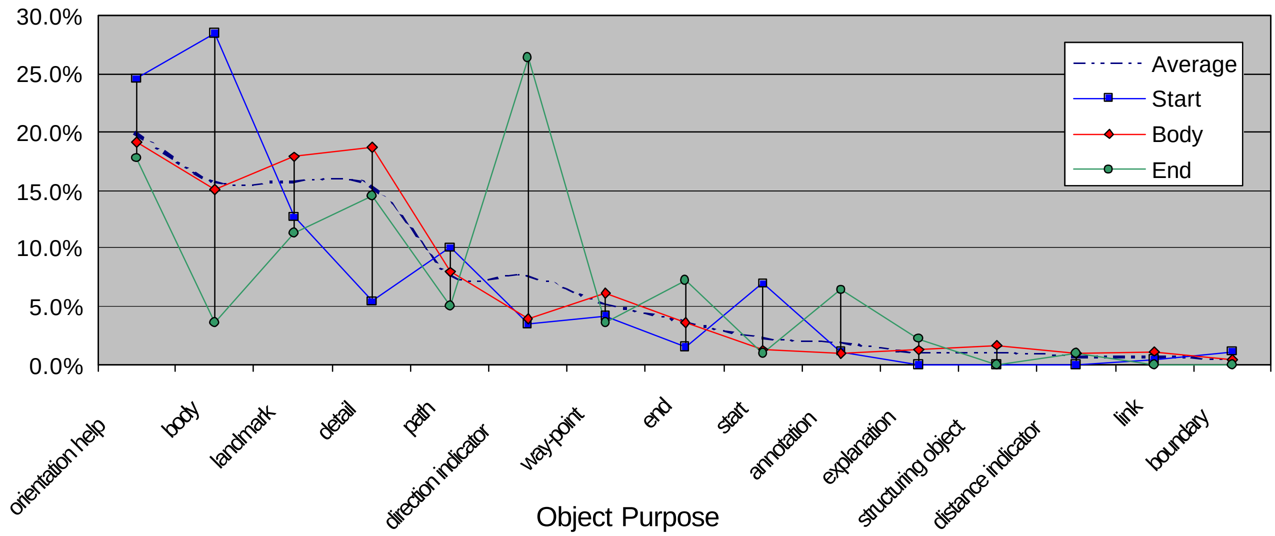


Figure 35 Graph with the distribution of object purposes during the three sketching phases. The black line represents the average distribution, the colored lines those of the three phases: start (blue), body (red), and end (green). The sum of every phase is 100%, so that object quantity is taken into account as well. (Scenario 1 & 2).

Start Phase

The first phase is dominated by objects with *orientation help* and *body* characteristics. The term *body* in this context may not be confused with the second sketching phase with the same name. The purpose type *body* is attributed to structural objects that belong to the basic framework of a sketch, but that are not as prominent as landmarks or other points of orientation. Objects of type *orientation help* fall into the same category, because they are used to fix the sketch in space. As could be expected most objects with a *start* purpose tag are also drawn in this first phase.

The only observations that surprises is the relatively high number of objects that have been classified as *path*. This seems at first glance to contradict our findings from the previous section, where we have stated that path objects are drawn in general during the *body* and *end* phases of a sketch. The cause of this divergent observations is the way objects have been classified. To qualify for the *path* object class, an object has to be explicitly declared as a path, e.g. as a sequence of arrows from A to B. In order to get the *path* purpose tag it was enough if an object was implicitly declared as a path, e.g. a road from A to B could be of type *road system* and qualify for purposes, such as *body* and *path* if it is obvious that the subject meant the road to be a path.

Most other object purposes, such as d*etail*, *direction indicator*, *explanation,* or *end* are little represented in this first phase.

Body Phase

People seem to concentrate on extending and completing their sketches in the intermediate body phase. Hence, we can observe a slightly over average number of objects with *landmark*, *detail*, *way-point*, and *structuring object* purpose tags. Most other purpose types score close to the average, an exception are objects with *direction indication*, *start*, *end*, and *annotation* purposes, which show significantly lower numbers.

End Phase

This last phase is dominated by objects that explain and round up a sketch. At this point the framework is fixed and most of the primary objects are already drawn, the task that remains is to explain and refine certain objects and relations and to check the sketch for its comprehensibility–at least this seems to be a common sketching strategy in our survey. This sketching tactic reflects also in the purpose of objects chosen in this phase. Objects with a purpose, such as *direction indicator*, *end*, *annotation*, and *explanation* score noticeably over the average value. Objects with a *detail* purpose tag show average and others, such as *body*, *path* and *start* purposes indicate a below average use. With the exception of *path* purpose objects that we explained in the *start* phase, these observations seem to support previous findings made during the examination of the temporal sequence of objects in a sketch.

4.6.4 Summary

During this sub-chapter we have investigated the chronological sequence in which objects are drawn within the process of sketching. We analyzed this chronology in regard of the position, the object class, and the purpose of objects. Concerning the location of objects have found five distinct sketching strategies that describe how people place objects in sequence on a sketch. We observed that 88% of all objects where placed in the close vicinity of the previously drawn objects and those objects with a random distribution were very likely to have a thematical relationship with objects previously sketched. Unfortunately our methodology for this spatial evaluation proved to be not sufficiently accurate and, therefore, we were not able to extract more information from our analysis.

In respect to the temporal distribution of objects and considering both, an object's class and purpose, we have found that there are differences between objects drawn in the beginning, in the middle, and at the end of a sketch. Objects sketched in the first phase concentrate on defining the rough framework, the structure, and the local orientation of a sketch, this is done mostly by using objects with line characteristics, such as road systems or rivers. The composition of the intermediate phase is very similar to the average distribution of objects in a sketch. In the last phase, finally, we have experienced an increase of objects that refine or annotate a sketch or that provide a global orientation. In all these cases we had to rely on the sequence of objects provided by the subjects and a relatively rough classification scheme for the spatial location of sketched objects. Based on our results we would suggest that for a subsequent analysis of the chronological sequence of objects in a sketch this methodology would have to be improved as stated earlier in this sub-chapter.

4.7 Parallelity and Rectangularity

Parallelity and rectangularity play an important role in our artificial environment and, therefore, also in our lives. Although barely found in a pure form in nature these simple geometric concepts prevail in most any domain of modern human activity. Because of this omnipresence and the simplicity of the principle of parallel or rectangular structures we expect that it is possible to show that these concepts have an impact on the way people sketch as well. To quantify parallelity and rectangularity we have determined for each sketched object the number of adjacent objects that lie parallel or rectangular to this particular object. In order to qualify as an adjacent object, the object has to be in direct "sight" to the referring object and its distance can not exceed the maximal extent of the candidate object (the adjacent object). An object is defined parallel or rectangular to another if the main axis of the two objects are visually parallel or respectively rectangular to each other. This condition has to be true only on a local base, so it is possible, for instance, that a road has a different main direction than a building and that they are still parallel to each other, such as in the sketch in Figure 36$.

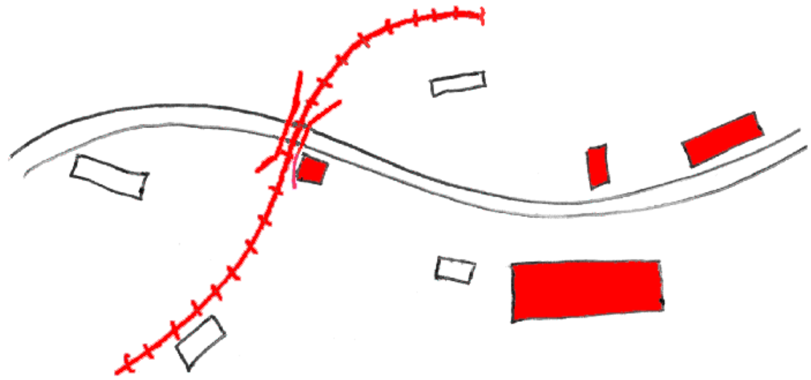


Figure 36 All objects that have been found parallel or rectangular in reference to the road are marked with red color.

In the scope of our analysis we are not concerned about a distinction between objects that are parallel or rectangular to an object and we leave this differentiation open for future, automated examinations. The number of objects parallel or rectangular to an object is identified simply by counting all neighboring objects that qualify and recording this number. Therefore, there is no explicit linkage between objects and each parallel or rectangular relationship is counted twice. Figure 37$ shows a histogram with the frequency of objects, considering scenarios one and two only that have parallel or rectangular objects in their vicinity. The first bar on the left is a reference and indicates those objects that have no parallel or rectangular objects in their neighborhood, while the bars to its right depict those objects with one or more such object relations.

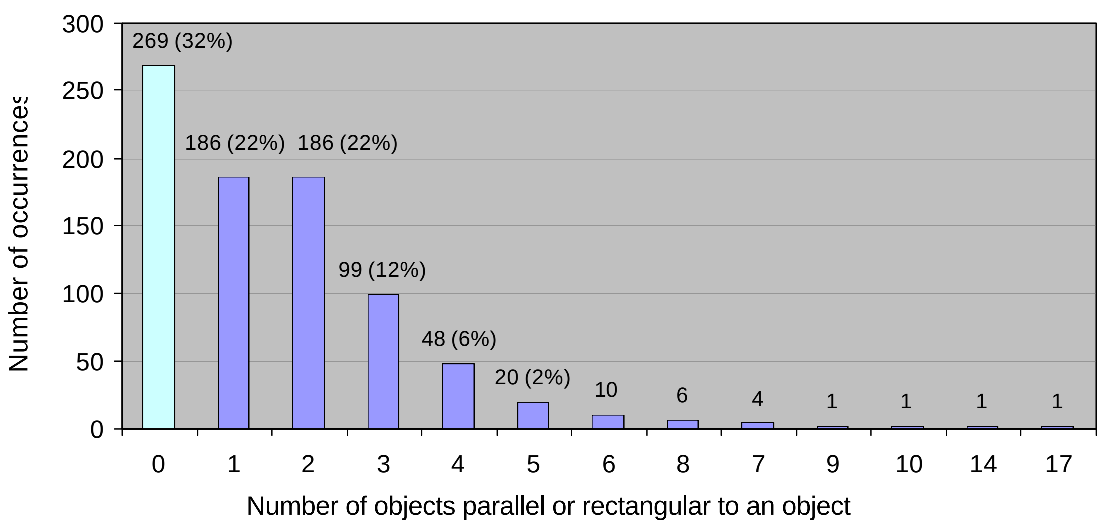


Figure 37 This histogram shows the frequency of objects (in scenarios 1 and 2) with parallel or rectangular objects in their vicinity, according to the number of such conditions. E.g. 6% of all objects in scenario one and two had four parallel or rectangular objects in their neighborhood.

The environment most often described in the scope of the first and second scenario is of an urban type, containing roads, buildings, and many other artificial monuments of human origin. Looking at Figure 37 this seems to reflect exceptionally well: Two thirds of all objects have at least one neighboring object that is parallel or rectangular. This is a significant number of objects with such a condition and it weights even more if we compare this result with the same analysis made for the third scenario (Appendix Figure 77). In this third scenario that involved primarily rural and non-artificial geographical structures, only a mere third of all objects has one or more neighboring, parallel or rectangular objects. Hence, people seem to make a difference between natural and artificial structures in that they preserve such characteristics in a sketch as well. As a spin-off, parallelity and rectangularity may, therefore, be used as an indication of the urbanity of a sketch.

Concerning the number of objects in the vicinity of an object that are either parallel or rectangular to an object, we have experienced that in does not depend on the type of environment and that most objects have between one and four objects with such conditions in their immediate neighborhood (scenario one and two 95%; scenario three 99%). The average number of parallel or rectangular relations per object is 1.6 for the first two scenarios and 1.3 for the third scenario. This calculation includes also objects with no such relations.

Figure 38 below examines the number of objects that have one or more parallel or rectangular objects in their vicinity with the number objects that do not have such a relationship for each object class. The red bar indicates the number of objects with no parallel or rectangular objects. Hence, objects in classes with a relatively small red bar experience parallel or rectangular relations to neighboring objects more often than those that have a large bar. As could be expected, object classes with a predominance of objects with line characteristics, such as *road system*, *body of water*, *railway system*, or *path* score stronger in this scope than classes with surface characteristics, such as the *direction*, *sketch annotation*, or *settlement* class. Making the same analysis for scenario three we come to the same results, although the tendency to avoid artificial object configurations in this rural environment is predominant what reflects in an increased number of objects per class that have almost no parallel or rectangular objects in their vicinity.

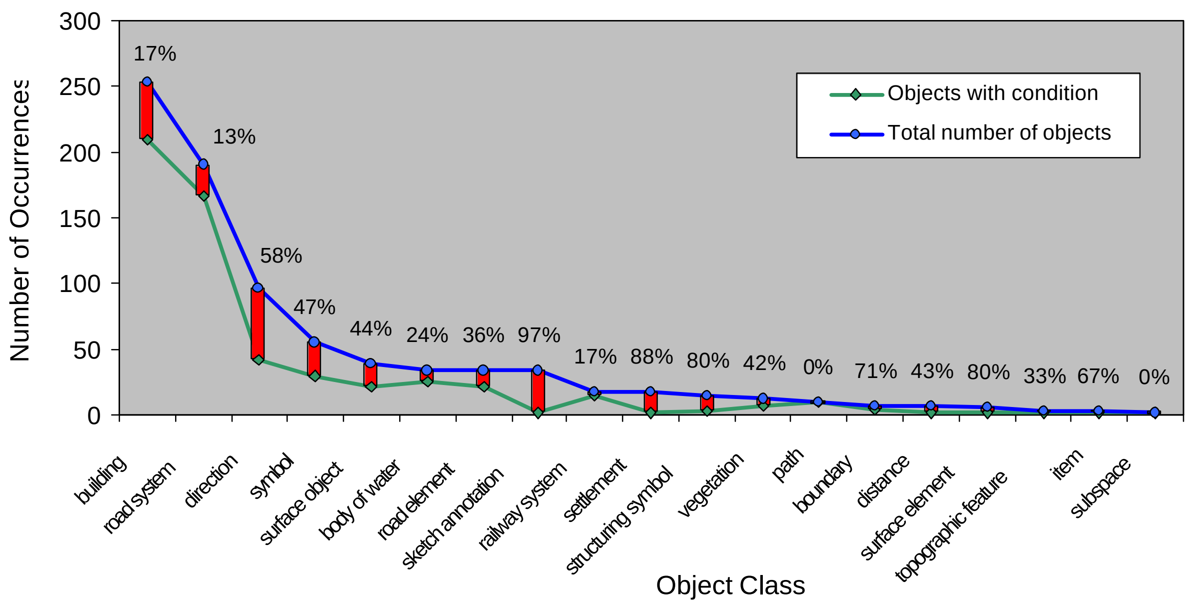


Figure 38 This graph lists the number of objects per class that have one or more parallel or rectangular object in the vicinity (green), the total of all objects per class (blue) and the difference (red bars). All object of the first two, mostly urban scenarios are included.

During this sub-chapter we have investigated *parallelity* and *rectangularity*, two special object relations that can involve two or more objects. We have observed that there is a significant difference between sketched representations depicting rural or urban environments, in that parallel and rectangular object configurations were much more frequent in the urban environment, where $^2/_3$ of all objects where part of such an object relation, compared with the rural environment of scenario three where only $^{1}/_{3}$ of all objects has parallel or rectangular neighbors. Artificial objects, such as buildings and objects with line characteristics, such as roads or rivers were most frequently involved in a parallel or rectangular relation with objects in their immediate vicinity.

Beside *parallelity* and *rectangularity* there are other object relations that are frequently used in our human environment and that have an influence on peoples sketches as well? *in line* and *along* are two examples. Unfortunately this is out of the scope of this report. However, based on our observations in this sub-chapter, we can assume that other artificial structures and peculiarities of our environment are depict in sketches as well, which is most likely, because such structures appear to be easy to remember and also easy to represent in a sketch. The knowing of this fact is very valuable, because it may eventually help to match sketches with artificial structures in a database.

In general we can even observe a trend to simplify reality by emphasizing or over-emphasizing certain simple object relations. The use of 90° degree angles, the scaling of objects, the straightening of a curved road, or the reduction of a building with a complex shape to a square are some examples where people reduce the complexity of a spatial scene without losing the actual message. What is true for objects can also be considered valid for relations, in that they are often simplified and conceptualized and this sub-chapter is a good example for this observation. With these general considerations about the abstraction mechanisms used for drawing geo-spatial sketches we conclude this chapter about object relations and move on to investigate how people use written annotation in sketches.

5. Annotations

Sketching is a very descriptive way of communication and there is a multitude of situations where it is by far easier to explain a specific situation by sketching than it is by describing the same situation in a verbal manner. Hence, this form of graphical representation of objects and situations provides an excellent method for the communication of spatial, hierarchical, or conceptual structures (Blaser 1997). On the other hand, there are also “things” that cannot be described visually, because it would either be too complex and, therefore, inadequate or simply because there is no common understanding of a visual representation of this object or of this relation. Imagine, for instance, how a local government building, a street address, or an oak tree could be sketched. It appears that as soon as the required level of detail in of a sketch exceeds a certain limit it is unavoidable to incorporate additional forms of information beside the visual representation of objects and relations in a sketch. These extra information must not necessarily involve all sketched objects equally but can be locally focused on some relevant objects. It is as well feasible to provide global specifications that are not bound to any drawn object or relation. The most natural approach for providing such additional information is to use gestures and to talk. Beside spoken verbal annotations, it seems also very common to annotate objects by writing. Whichever method is chosen, sketching and verbal annotation are rather complimentary than mutually exclusive.

During this chapter we will take a look at annotations made in the scope of our survey. Due to the setup of the survey, we are able to analyze written annotations only. It can be assumed that written annotations are a subset of all annotations that would have been made if spoken verbal annotations had been allowed as well. We can further assume that written annotations are more concise that verbal statements. These assumptions are based on the fact that it takes a greater effort to write than to talk. Furthermore it is common for people to use complete sentences when communicating verbally, while most people tend to use headwords or ellipsis when they just make short notes. There are a couple of interesting question that arise in this context. For instance, what kind of objects get annotated or in which cases do people annotate objects or relations in a sketch? Other questions concern content, form, spatial location, and symbols used for annotations. The following sub-chapters will focus on some of these peculiarities of annotations.

5.1 Use of Annotation

In this sub-chapter we will investigate in which cases people prefer to annotate sketched objects and in which cases they think that the sketched representation provides enough information. We focus especially on two issues, the first is concerned about object classes and the second about the purpose of objects. But first some general observations. We found that most people make frequent use of annotations, in general over all three scenarios we found that 61% of all objects had at least one linked annotation. This number was astonishingly constant over all three scenarios (Scenario one, two, and three: 59%, 66%, and 60%) and produced a maximum in the second scenario, most likely because this scenario involved the representation of a few but important objects. The second scenario was also the scenario with the highest uncertainty. There was only one sketch with no annotations and there was only one single sketch in which all objects had an annotation, both in the scope of the third scenario. The standard deviation over all sketches is 21% of the average, which shows that our results are relatively constant. Based on our findings we can assume that making annotations is a significant part of the sketching process, although it is left open if people would rather prefer writing or talking for this task.

The setup of our survey allowed objects to have more than one annotation. Table 13$ shows the according distribution of the number of annotations per objects over all three scenarios. The vast majority of object had only one annotation and few had more–13% in total. The slight increase of objects with four annotations in comparison with those objects with three objects can be explained with some directional symbols that had four attached annotations.

Frequency	Annotations per object	%
677	1	87%
81	2	10%
7	3	1%
12	4	2%

Table 13 Number of annotations per object, including objects from all three scenarios.

Figure 39$ shows the percentage for each object class of those objects that have at least one annotation. The graph is sorted they frequency with that objects in an object class are annotated.

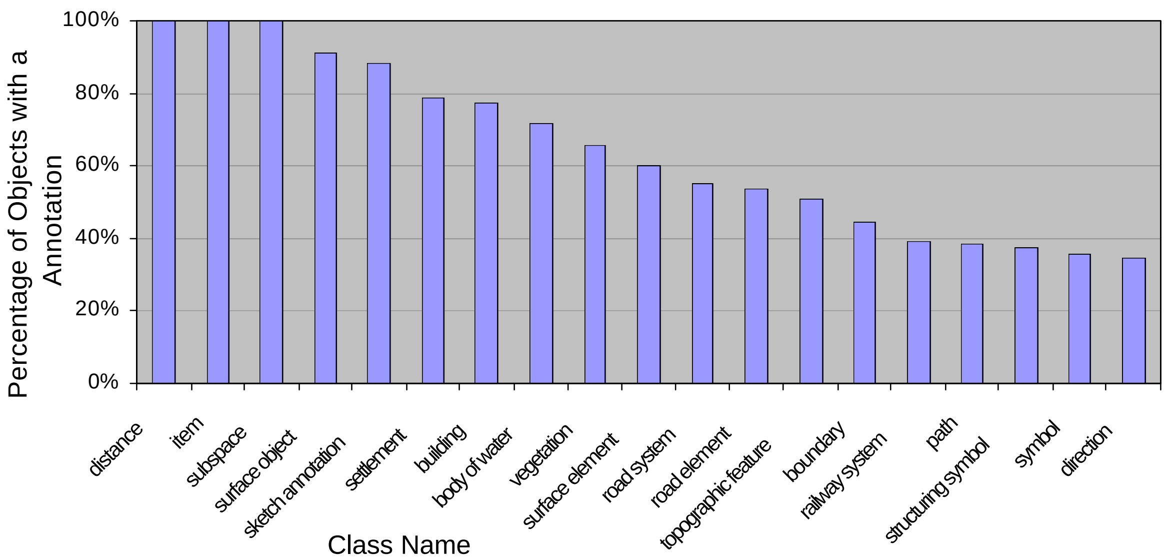


Figure 39 This graph shows the distribution of object classes depending on the frequency with that annotations are being used. (Scenarios 1, 2 & 3).

It is apparent that certain object classes seem to imply an annotation. This observation is obviously true for objects of the *distance* object class that cannot be circumscribed graphically, but it seems also valid for other classes, such as the *item* and the *subspace* object classes, although we have to consider that both classes are relatively small. The explanation for this high percentage of objects with annotations is that both object classes frequently contain objects with an incomplete meaning that are difficult to represent visually and, therefore, lack essential information without a further, verbal specification. For instance it appears insufficient if a subject divides the sketch into several subspaces without any verbal description in regard to this visual partitioning of space. In general we can observe that those object classes with more complex meanings are more frequently enhanced with annotations than those that are simple. Complex, in this scope, is to understand conceptually not graphically. A direction or a symbol, for instance, needs in most cases no further explanation, because it is self-explanatory. Classes that fall into this conceptually simple category are *railway system*, *path*, *structuring symbol*, *symbol*, and *direction*. Objects of more complex object classes, on the other hand, are more frequently annotated with prominent object characteristics, such as names or attributes. Examples are rivers (name), buildings (address, name of store, color, etc.), or vegetation (type). The result concerning the *sketch annotation* object class seems to be illogical at first glance, because one would expect a value of 100% in Figure 39. The reason why this class scores less than the maximum is because we have included purely graphical sketch annotations (12%) as well.

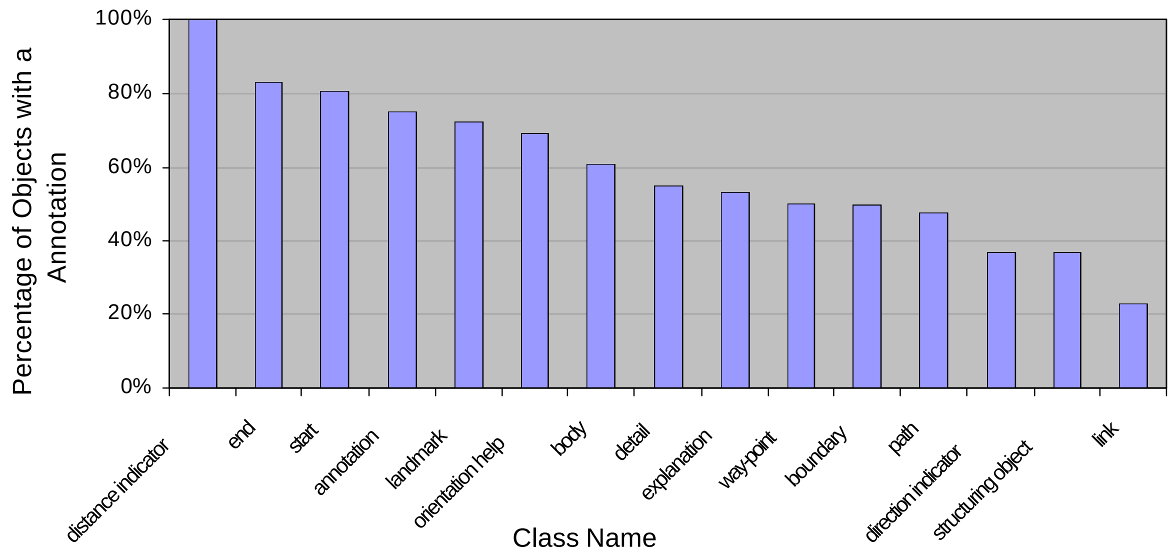


Figure 40 This graph shows the percentage of those objects that have an annotation distinguished by purpose. (Scenarios 1, 2 & 3).

Figure 40 shows a similar comparison as the previous Figure, but this time we take a look at the purpose of sketched objects. The scale on the Y-axis indicated the percentage of objects that have an annotation in respect to the total number of objects in all three scenarios. Objects with a *distance indicator* purpose tag imply an object annotation, this is consistent with the previous interpretation. Apart from this, we can observe that object with a significant role in the sketch are more likely to have an annotation than objects that belong to the body or structure of a sketch. Hence objects with *end*, *start*, *landmark,* or *orientation help* character score higher in this comparison. Those objects with guiding (*way-point, path*, and *direction indicator*), *bounding*, *structuring*, or *linking* purposes have fewer annotations, most likely because their visual representation seems to be less complicated and, therefore, less ambiguous.

Based on our results we can assume that there are multiple, interacting reasons why people annotate objects.

- Complexity of an object (objects not sufficiently describable with a sketch alone)
- Significance of an object (e.g. start, end, or goal)
- Reasons of ambiguity (similar objects that are depict the same, e.g. a row of buildings)
- Simplicity (if an object is better circumscribed by an annotation than by a drawing)

Looking at the amount and relevance of information conveyed by verbal annotations we believe that this form of communication definitively plays an important role in sketches and that we cannot afford to ignore this aspect of sketch-based user interaction.

5.2 Form of Annotation

In this sub-chapter we analyze the form or style of verbal sketch annotations. To get insight into how people annotate sketched objets in this respect, we have recorded the following general characteristics of annotations:

- Global form of an annotation (grammatical form of annotation)
- Type of writing (writing style of annotation)
- Type of annotation (thematic type of annotation)

The *global form of an annotation* considers the grammatical and general composition of an annotation. In the scope of our survey we distinguish between three categories. The *simple object specification* is an annotation that provides only a single information. This can be a name, an attribute, or an other simple specification. Examples are: “house”, “office building”, or “straight”. The next category is more complex and involves additional information, such as adjectives or multiple attributes but it is not yet a complete sentence. Examples are: “my house”, “tall office building on the left side”, or “straight and narrow road”. Finally, there are the complete sentences, such as “this is my house” or “take the first intersection to the left”. The results of this analysis are depict on Figure 41.

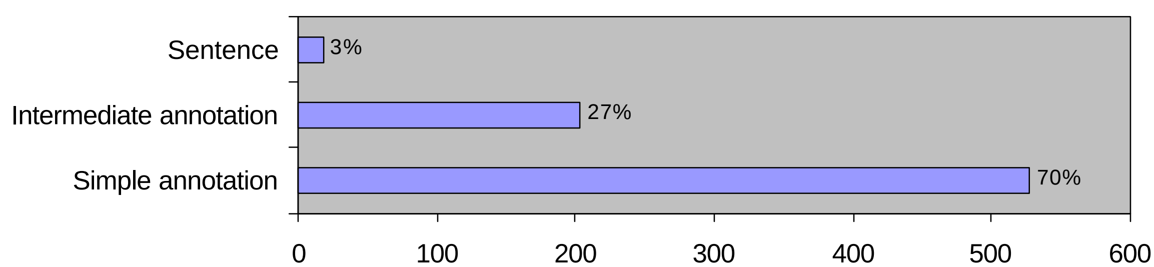


Figure 41 Chart comparing the frequency of the three complexity levels for verbal sketch annotations–Global form of annotation. (Scenarios 1, 2 & 3).

Obviously people keep written annotations very simple, as one can infer from Figure 41. The subjects of our survey used only in three percent of all cases full grammatical sentences to add information to their sketches and they preferred short forms of annotations for most situations instead. Again, this might be different if people are allowed to talk to a system or if they would explain their sketch to a human counterpart.

The *type of writing* is concerned about the writing style of an annotation. The only forms of writing styles we distinguish in our survey are words made up of single characters (block letters, print), connected letters (script), and a combination of both (mixed). This investigation is most likely not the first one of its kind, but it is still interesting to see how people write when they annotate objects in a sketch.

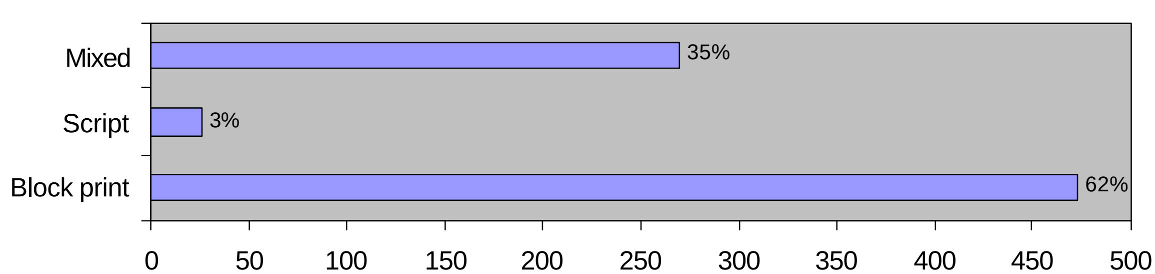


Figure 42 Graph comparing the distribution between different types of writing. (Scenarios 1, 2 & 3).

Contrary to our initial expectations, we can observe that $^2/_3$ of all annotations are of type block print and only about 3% are pure script. This distribution can be interpreted as an indication that people take greater care of how they write in the context of a sketch than if they put down a sketchy note. But it is also possible that this distribution simply reflects our subjects' common writing style. However, these results suggest that the chances of recognizing a major portion of all written statements in a sketch are relatively good, even when applying today's handwriting recognition techniques that are still in an early stage. Moreover, one could argue that those subjects that are already using the mixed annotation style could easily be motivated to print their text entirely, because they are already partially writing this way. Under this consideration the remaining 3% of all annotations that are of pure type script become insignificant.

From reflections about grammatical and technical aspects of object annotations we move to thematical considerations regarding the use of annotations. Our analysis is limited to the first two scenarios, because there the selection of objects is less influenced by the problem description than it is in the third scenario. According to our definition, the *type of annotation* states which characteristics of an object are expressed by an annotation. Conversely to other investigated issues in this survey we did not a priori make a list of fixed classes (annotation types) and we added categories as necessary during the process of surveying. The 10 most frequently used categories are listed in Table 14. The remaining 9% contain mostly combined types, such as for instance *type and description*.

Count	Category	%
196	name	36%
181	type	33%
28	name and type	5%
22	description	4%
19	direction	3%
15	distance	3%
10	name of direction	2%
9	address	2%
9	annotation	2%
5	explanation	1%

Table 14 Distribution of the type of annotations used in the first and second scenario.

Table 14 indicates that a significant majority (70%) of all annotations were confined to describe *name*, or *type* of objects only. This observation supports claims made earlier in this sub-chapter that annotations on sketches are short and simple. It fits also very well with the results shown on Figure 41$ where also 70% off all annotations were classified as *simple annotation*. More complex annotations that required more than just a simple specification are relatively rare, but nonetheless important, because they can contain a sketch's most crucial information, such as the address of a person or a detailed description of a sketched object.

This sub-chapter has shown that people prefer the use of short and simple annotations within the context of their sketches. This observation is true for the way people write–two third of all annotations were written in block print–and it is also true in respect to the type of expressions people use: The majority of all annotations consisted only of single words, sometimes extended by adjectives or attributes, but very seldom extended to grammatically correct sentences. And finally, we have seen that most annotations (70%) specify either the name or the type of an object.

5.3 Spatial Component of Annotation

If an annotation is referred to a sketched object then it has necessarily a spatial relation to this object, otherwise the annotation could not be associated to the appropriate object. This spatial link must not necessarily consist of a drawn symbol, such as an arrow connecting annotation and object, it is as well feasible that the link is made solely by writing the annotation close to the object so that the affiliation can be made virtually. The goal of this sub-chapter is to investigate these relational properties of object annotations and to see if there are any particularities how people are applying them. To structure the topic, we will look into the following four issues that concern spatial components of annotations:

- *Orientation* of the annotation in respect to the annotated object
- Actual *writing direction* of the annotation in relation to the drawing device
- *Topological relation* between annotation and object
- *Relative location* of the annotation in respect to the object

For the first analysis about an annotation's *orientation* in respect to the annotated object we distinguish only between three general cases. Based upon our classification the writing direction of an annotation can either be parallel to one of the object's main directions, it can be aligned with the X- or Y-axis of the drawing device, or it can have a random direction. An object's main direction, in this context, needs not to be equal to the principal orientation of this object, for it is also feasible for an annotation to be locally parallel, such as for instance when an annotation is parallel to a segment of curvy road.

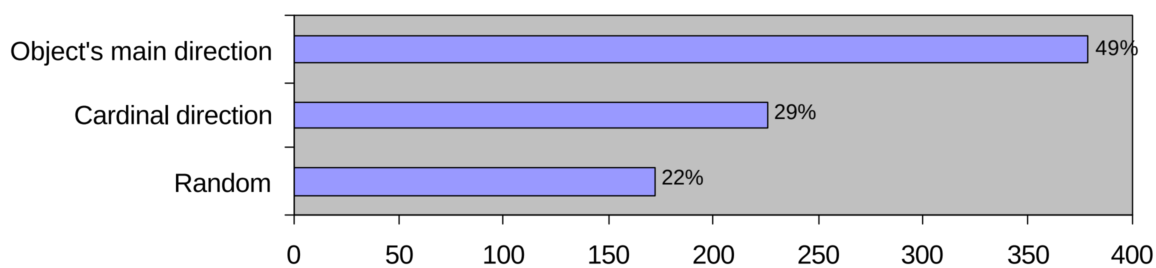


Figure 43 This graph shows the relation between the three possible categories of annotation orientations. (Scenarios 1, 2 & 3).

As we can infer from Figure 43, almost 50% of all annotations in our survey are aligned to sketched objects. About one third is aligned to a main direction of the drawing device and the rest, only about one fifth, has a random direction in respect to the referring object or in respect to the drawing device. The number of annotations with a random direction seems to be high at first, but because some people seem to have a general tendency to write slightly tilted, this deviation is relatively easy to explain. Such observations are helpful, because they indicate that there are a geometrical relationships between objects and annotations in addition to the thematical links. This may be welcome information when objects must be associated with annotations during an automated interpretation process of a sketch.

The *writing direction*–with the drawing device as the system of reference–is closely related to the relative orientation between annotation and object and between annotation and drawing device. The results are depict on the Figure 78 in the Appendix. The outcome is compatible with our findings about the orientation of sketched objects (Sub-chapter 4.4) and our observations about the relative orientation of annotations in respect to sketched objects from the section above, in that the majority of object annotations are parallel to the X-axis of the drawing device. Beside this preference for the horizontal axis and similarly to previous observations about the direction and orientation of sketched objects we can again observe a tendency that annotations are slightly upwards deflected

The third point is concerned about *topological relationships* between annotations and objects. Our simplified approach considers only three possible topological configurations: *inside*, *overlap,* and *outside*. To reduce the number of possible spatial relations from eight to three is adequate and justified, because our manual method of examination does not provide enough evidence to distinguish further nuances and because some relations are only possible in theory. Figure 44$ shows that the majority of annotations are outside of the sketched objects and that they lie inside in about one third of all cases. People seem to have little inclinations to overlap objects and annotations. One possible explanation for this observation is that people like to keep their representations clear and their drawing objects separated.

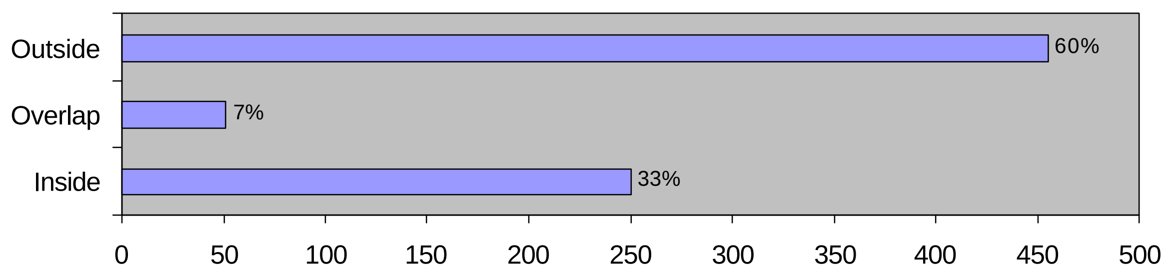


Figure 44 Distribution of the three distinguished categories of topological relations between annotations and referring objects. (Scenarios 1, 2, & 3).

The final step in assessing spatial components of object annotations in our survey consisted in recording the relative location of the annotation in respect to the center of the annotated object. We have used a compass like classification schema that distinguishes eight principal directions as shown on Figure 45. The referencing system was again the drawing device. The deciding factor for our classification was the relative location of the two geometrical centers of annotation and object, hence when the center of an annotation lies north-east of the center of the object, then it falls into the *NE* class. For those annotations that are inside an object and that have their geometrical center at about the same location as this object we have specified a special class called *Center*. It is important to state, at this point that not all annotations that are inside an object qualify for this class, as we did not take topological aspect into account for this evaluation, but only the relative location of the two geometrical centers of object and annotation. Finally, there are those annotations that could not be classified, because they were ambiguous and, therefore, could fall into more than one class. Those relationships are classified under the *Various* class.

Count	%	Class
89	11%	N
92	12%	NE
89	11%	E
54	7%	SE
92	12%	S
43	6%	SW
62	8%	W
51	7%	NW
174	*22%*	*Center*
31	*4%*	*Various*

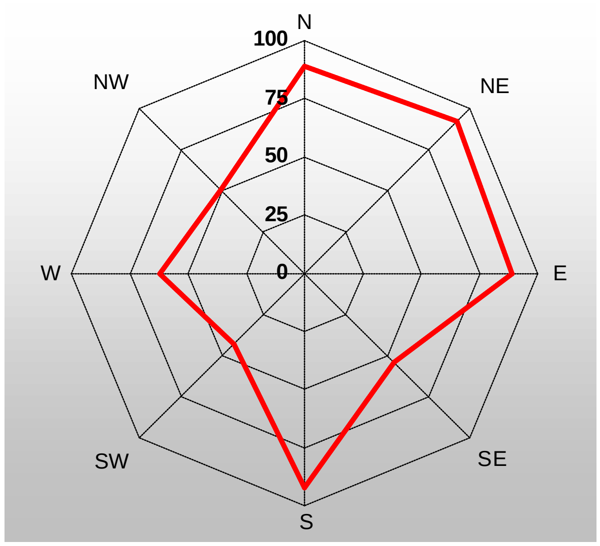


Figure 45 Distribution of object annotations in respect to the referring object. The graph is non-logarithmic. The table on the left of the graph depicts the same data, but in addition to the chart it shows also the number of annotations that were classified as being in the center and those that could not be classified. (Scenarios 1, 2 & 3).

Although the distribution on Figure 45 is not as pronounced as on other graphs comparing similar data with a concern for direction or orientation, it is noticeable that a considerable number of annotations is placed in the second quadrant (N, NE, or E) of the referred object. While there is another significant accumulation of annotations located on the southern side of objects, all other direction play a less important role. This observation may be once again explained by the common habit of placing annotations on graphical presentations or on maps either to the north, south, east, or north-east of objects. The second interesting assumption that can be made if we refer to Figure 45 and Figure 44$ is that annotations that are inside an objects are very often centered to this objects–70% of all annotations inside an object are centered.

This sub-chapter shows once again the importance of the concept to align objects or text to each other or to one of the two principal axis of the drawing device. We have also found evidence that people tend to keep their sketches clear by keeping objects and annotations spatially separate from each other. The influence of graphical presentations in our daily life appears to play an important role as well. It appears that the placement of an annotation often has a predictable relative location in respect to the annotated object.

5.4 Symbol of Annotation

Annotations are often accompanied by a special, mostly directional symbol starting at the annotation and pointing to the referring object. These symbols are meaningless if considered out of context, which is why we treat them as a part of an annotation. The set of used symbols for the purpose of annotation in our survey is quite small and can be reduced to only three categories: Simple *lines*, single *arrows*, and *double arrows* (Figure 46$).

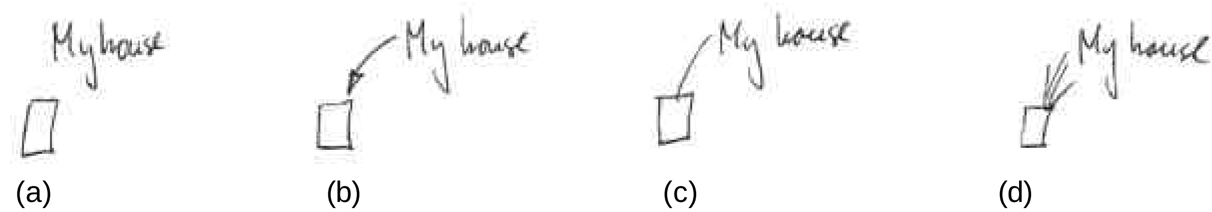


Figure 46   Four different ways to annotate a box as “my house”

How these symbols were used in our survey can be taken from Figure 47$. It appears that the majority (83.5%) of all annotations manages to be comprehensible without any symbol that links an object with an annotation. The arrow notification is beside the no-symbol approach the most popular method to refer to an annotated object graphically, but it is with only 12% of no particular significance in this context. The same can be stated for the line and double arrow annotation. Despite these preliminary results, it is also reasonable to argue that such symbolic forms may have a significance for a certain group of people. Accordingly, if we only include those subjects into our examination that have used linking symbols for their annotations more than occasionally (more than twice in a complete survey), then we get an average of 24% of annotations accompanied with a linking symbol. This is still not a majority, but indicates that it depends on a subject’s liking which style of annotation is chosen.

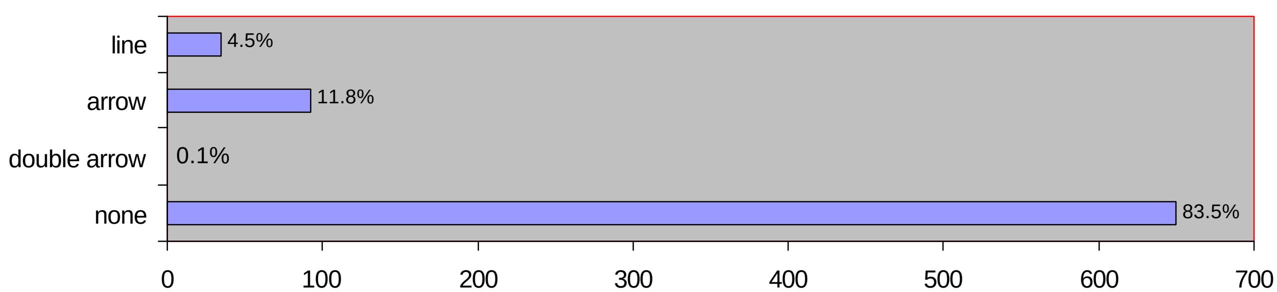


Figure 47   This figure depicts the use of linking symbols for annotated objects. (Scenarios 1, 2 & 3).

Another graphical method that can emphasize a written annotation is the underlining or encircling of an annotation. Table 15$ suggests that there are only few occasions where written annotation are emphasized this way. However, and considering the fact that almost two third of all objects with an encircled annotation have been classified as *end* or *start* object (in respect to their purpose), we can assume that this kind of additional graphical notification is of great importance when people interpret a sketch, presumably, because it tells them where to focus. This observation is important for automated interpretation processes of sketches, since this form of additional graphical notification is relatively easy to detect and because it may simplify the process of logical reasoning about the meaning of a sketch considerably.

Count	%	Type of Annotation
15	1.9%	underlined
13	1.7%	encircled
2	13%	underlined *and* end
8	62%	encircled *and* start (2) or end (6)

Table 15 The first two rows indicate the number and percentage of annotations that were underlined, respectively encircled. The two rows below depict those annotations that additionally belong to a *start* respectively to *end* purpose object. (Scenarios 1, 2 & 3).

This sub-chapter was concerned about the use of graphical gestures in connection with written object annotations. The first type of gestures includes symbols that link an annotation with the referred object, such as lines or arrows. Depending on individual subjects we could only observe a moderate use of graphical links between annotation and object (16%-24%). The second part of this sub-chapter focused on gestures, such as encircling or underlining an annotation. We found that, although not applied very often, this type of stressing an object can be very relevant, because objects that are annotated this way are frequently *start* or *end* points or they are otherwise of special importance.

5.5 Time of Annotation

In respect to the time of an annotation there are basically two different tactics in use and they can be called *immediate annotation* and *post annotation*. Applying the first method, the annotation is made immediately after the object is sketched or in some cases even during the process of sketching the object. The *post annotation* tactic is in so far different that there is no immediate connection between the time the object is drawn and the time the annotation is made. Hence, the annotation is quasi out of sequence, because the object is not immediately annotated after the process of sketching. Mixed forms are possible as well, but not very common. An example would be when the subject draws an object, writes the referring annotation, then continues to sketch and after a while returns to the initial object to make a further, more extended annotation. Another, relatively unlikely case is that the annotation is made before the object is actually drawn. Throughout our survey this case occurred only with four annotations.

Unfortunately and as stated before the data regarding the temporal component of annotations proved to be very unreliable. This is on one hand, because it seems that many subjects forgot when they made an annotation by the time they had finished the sketch. On the other hand it appeared that our instructions in respect to the recording of the sequence of events was not clear enough. The result was that more than half of all annotations came without a time bound record.

Count	%	Time
4	1%	before
192	26%	immediately after
156	21%	after
382	52%	indefinite

Table 16 Frequencies of different times when objects are annotated. (Scenarios 1, 2 & 3).

Table 16 shows a relatively equal distribution between the immediate and the post annotation method. We confirmed this observation by analyzing each survey individually, on a subject by subject basis, and determined a subject’s inclination to one or the other method. To qualify for this secondary examination the two scenarios from a single subject must include at least a total of five annotations that belonged to either of the two described annotation methods. Of the 21 surveys that complied with this requirement 11 preferred the *immediate* and 10 the *post* annotation method. Those subjects preferring the *post annotation* approach are slightly less consistent in using one method over the other (73%) than those using the *immediate annotation* approach (83%). But still, both groups show a significant inclination to on or the other annotation tactic.

Based on these observations we can conclude that both annotation approaches have to be considered in an automated analysis of a sketch. It appears also that the time when an annotation is made is no clear indication to infer from an annotation to a drawn object, although in some cases–e.g. for a certain type of user–this may work quite well. The spatial relationship between object and annotation appears, therefore, to be a more reliable source of information to link an annotation to an object.

With these temporal considerations about object annotations we finish our “low level” investigations concerning objects, their relations, and annotations. The following chapter focuses on the bigger picture of a sketch, in that we look at a sketch more as if it were an object. In the same time we will include and refer to our observations made during the three previous chapters.

6. Sketch in General

During the previous chapters of this technical report we have primarily focused our attention on the three elementary components of a sketch, which are sketched objects, their relations, and annotations. Although, we have referred occasionally to the sketch as a whole, we did not really leave the elementary level of a sketch. The following investigations will close this gap, in that we take a step back and look at sketches from a more global point of view. This change of granularity or resolution will allow us to consider issues, such as global orientation, scale, or the structure of a sketch. In terms of the more general setup of this analysis and to obtain the best results possible, each sketch was once again examined and a secondary interpretation was made. Since there was no need for an object by object analysis, more sketches than in the previous, more detailed examination could be considered. The total number of sketches that we have included is 91–in comparison to 81 sketches that have been used for the first part of this report. The distribution for the three scenarios is 31, 29, and 31, which equals the entire set of all sketches but those two sketches that have been left blank.

6.1 Orientation of a Sketch

We have been looking at orientation before, but when we did so we focused our attention primarily on objects and object groups. This time and in the context of this chapter we want to explore if and how a sketch as a whole is oriented. For this purpose we will focus at three issues that have an impact on a sketch's orientation. The first point of interest concerns the north direction indicator, which was preliminary addressed in Chapter 4.5$. At this point we will not only review the direction in which the north direction indicator points but also the time when it is drawn. In the section thereafter we consider the entire set of sketch objects as one unit and discuss the orientation of this global "sketch object". In the last part, finally, we will investigate eventual flow directions in sketches. For all our examinations we will use the drawing device as our frame of reference--this is the same approach that was made for the two Sub-chapters about *Orientation* and *Direction* (Chapter 4.4$ and 4.5$).

6.1.1 North Direction Indicator

After completing each sketch and noting the sequence of the sketched objects the subjects were asked a couple of simple questions, as was stated before. The last of these questions was if they could specify the north direction in their scenario and if the answer was *yes*, we asked them further to indicate North on their sketches. The advantage of this approach is that people had to think about the global orientation of their sketches and that in many cases they actually came up with a direction that they thought represents North. An indication of the North direction is important, because it can serve as an secondary referencing system in addition to the drawing device. It is also interesting to compare the alignment of the drawing device to the North direction. On the other side there were also some disadvantages in explicitly asking the subjects to indicate the North direction on their sketches. The primary disadvantage is that people were explicitly reminded to specify the North direction. The high percentage (84%) of sketches with a North direction indicator is most likely too optimistic and probably due to our reminder. We have to interpret this percentage, therefore, as a maximum and assume that in reality the ratio would be lower. However, Figure 48$ shows clearly that the majority of subjects adopted the concept of standard maps in that most North direction indicators point towards twelve o'clock of the drawing device. A total of 42% of all subjects that were able to specify North in their sketches choose this approach. If we include all North direction indicators that point between 350Az and 10Az (North +/- 10Az) then this percentage increases even at 51%. Only 7% of all sketches have the North pointing at three o'clock and 9% pointing to 9 o'clock, all other directions are only marginally represented.

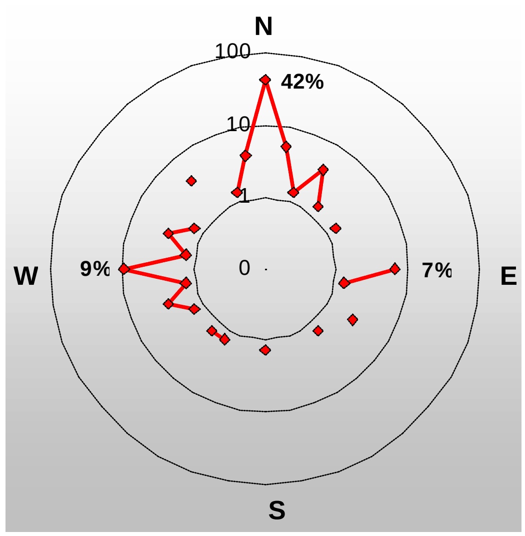


Figure 48 Distribution of North direction indicators for all sketches in our survey that have a North direction indicator (84%).

The time when a North direction indicator is drawn is an other detail that might be worth to investigate, because it may give us some idea when the subject is thinking about the global orientation of his or her sketch. Table 17$ below shows our results of this examination. As we have found earlier, it seems difficult for the subjects to remember the time of drawing for all objects when it comes to writing down the object sequence of the sketch–that 22% of all North direction indicators had no time stamp can be considered further evidence.

Count	%	Code
17	22%	not known
3	4%	beginning
10	13%	middle
46	61%	end

Table 17 Table that indicates the time when the North direction indicator is drawn. (Scenarios 1, 2 & 3).

The complication with Table 17 is that the table is highly influenced by the fact that we *asked* the subjects explicitly to indicate the North direction on their sketches. Those North indicators that have been made rather at the beginning or in the middle can be considered relatively authentic. Those North indicators with no time-stamp and those that were drawn at the end are more critical. One possible argumentation is that those North indicators with no time-stamp are those that would have been forgotten if people were not reminded by our question. The same is true for those North directions with an end time-stamp. The only difference is that for these North indicators there is an entry in the object sequence table. But because the entry is at the end of the list, we can not say if the North direction would have been forgotten without our reminder or if it had been specified anyway.

Hence, it is not possible to make a quantitative statement about the time when the North directions are typically drawn. Despite this and although not consolidated by our examination, we believe that people indicate global symbols of orientation, such as the North direction, rather at the end of the sketch than during the sketching process. However, for future surveys it would probably be best to avoid reminding the subjects to specify the North direction on their sketches. A promising approach could, for instance, include a sketching scenario with a fixed spatial location, where the orientation is a priori known so that the indicated North direction and the orientation of the sketch could be reliably verified. Unfortunately, this was not possible in the scope of our survey, because we were often not familiar with the sketched environment of the subjects.

6.1.2 Main Orientation of Sketches

The main orientation of a sketch is given through the general orientation of the sketch in reference to the drawing device. One method to obtain this general orientation is to superimpose a minimum bounding rectangle (MBR) over all sketched objects and derive the orientation from this rectangle. For more complex sketches more than once MBR is adequate, which is why a sketch can have more than one orientation. In general we found that the orientation of a sketch frequently correlates with prominent objects that line characteristics and that spread over a large part of the sketch. A highway or a river are two examples. Like with the orientation of sketched objects (Sub-chapter 4.4$) we chose a symmetric representation in Figure 28. If we compare both Figures (28$ and 49$) we can observe a very similar distribution with an emphasis for the two cardinal axis. The alignment in respect to the East-West axis is even more pronounced (44%), but we believe that this is due to chosen format and orientation of the drawing device, which was of type landscape.

Object Orientation	Count	%
0°	**29**	**27%**
10°	2	2%
20°	1	1%
30°	4	4%
40°	0	0%
50°	0	0%
60°	**11**	**10%**
70°	1	1%
80°	2	2%
90°	**48**	**44%**
100°	3	3%
110°	1	1%
120°	3	3%
130°	0	0%
140°	2	2%
150°	0	0%
160°	0	0%
170°	1	1%

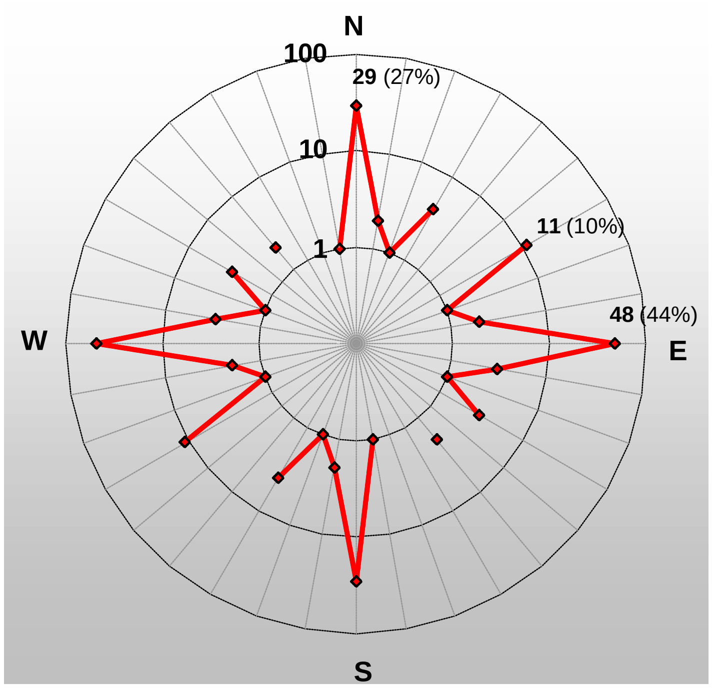


Figure 49 This graph shows the distribution of the orientation of all sketches in our survey in a logarithmic fashion. Because orientation has no direction the graph is symmetric.

Beside the predominant North-South and East-West orientation there is only the 60Az orientation that scores significantly above average–with the average being 5.6% for every 10Az. We assume that this exception is another indication that people, in general, have a slight upwards tendency, although we have no explanation why Although we believe that this exception is another indication that people, in general, have a slight upwards tendency when they draw or sketch, we do not know why the deviation is as high for this specific orientation. However, what this analysis seems to prove is that people like to orient their sketches in reference of the two cardinal axis. At least on a non-rotational drawing device.

6.1.3 Main Flow Direction in Sketches

The main flow direction is similar to the main sketch orientation in that the global picture of a sketch is considered and in that the referencing system is again the drawing device. The difference is that the flow is directional and that not every sketch has a flow direction. To qualify for a main flow direction, a sketch has to have one or more (directional) objects that indicate explicitly or implicitly some sort of flow. Directional objects, such as paths, roads, or rivers are, therefore, often present. A total of 63% of all sketches in our survey had a main flow direction. As could be expected, these numbers are highly influenced by the scenario description: A main flow direction could be detected in 84% of all sketches of scenario one and three (These two scenarios explicitly involved a path description), while there were only 17% of all sketches in scenario two that had such a property. Like with the main orientation of a sketch, it is possible for a sketch to have more than one main flow direction. The average number of flow directions per sketch of those sketches that have at least one flow direction is 1.4, which means that having multiple flow directions is relatively common. Figure 50$ shows the distribution of the main flow directions in our survey.

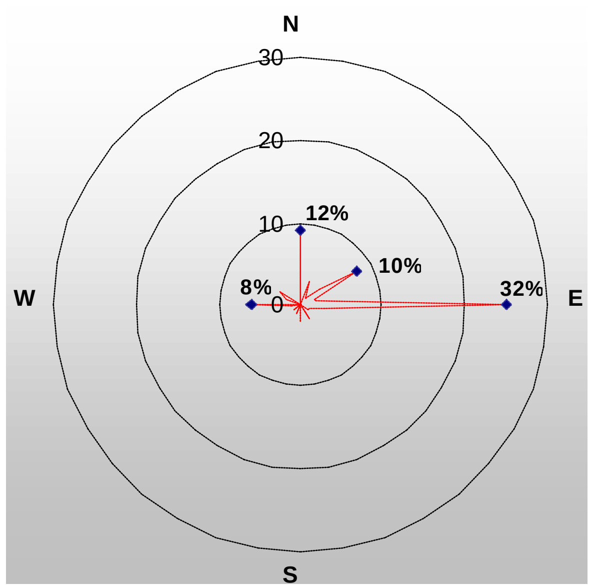


Figure 50 Graph showing the distribution of the main flow directions in our survey. (Scenarios 1, 2 & 3).

Figure 50 holds no surprises, but the graph seems to confirm previous findings concerning people's preferences regarding direction and orientation. There is again this predominant left-right tendency (32%) that we have attributed to the western habit of tackling things from left to right. The bottom-up tendency, although weaker (12%) might go back to people's cognitive experience with a host of real world objects that grow also from ground upwards. The down-left to up-right tendency (10%), finally, can be seen as combination of both approaches.

Summarizing the three above sections, we have seen that the predominant direction for the North direction indicator is twelve o'clock of the drawing device. Due to our methodology that asked people explicitly to indicate the North direction, we can not make a well-founded statement about the direction and drawing time of North direction indicators in general, but we assume that this is done rather at the end. Similar with the orientation of single objects, people seem to orient their sketches according to the two cardinal axis of the drawing device. Likewise most flow directions that are aligned with these axis. The previously observed left-right and bottom-up tendencies could again be noticed with the main flow direction of a sketch.

6.2 Scale

The assessment of scale within a sketch is extremely complex and involves at least a detailed analysis of various metric properties of objects and their relations among each other. The complexity start already at a very basic level: A house, for instance, is often represented as a box. But what if this box is out of proportion with the original?–a very likely case. Which side has to be taken to establish the scale? We can also assume that the house is drawn with a different scale than the road that goes nearby to the neighboring town. If the town is represented only by a surrounding circle, what is it the scale? Beside these divergent scales on the local level there are other difficulties that arise from a lack of metric knowledge in a sketch. As we have seen during our survey, metric information is very rarely provided in geo-spatial sketches and, therefore, we are often missing clues that help to determine scale, simply because there is no explicit information about the dimension of objects.

This introduction shows obviously that there is no simple and easy way to calculate the scale of a sketch. Nonetheless, we think that scale is an important issue of a sketch and, therefore, should not be uninvestigated. A qualitative look at this topic seemed to be adequate, because automated recording and analyzing tools were necessary to assess such information quantitatively. To gather information concerning the scale of objects we examined each sketch upon two issues concerning scale that are relatively easy perceivable. First each sketch was examined on local variations of scale. To qualify for a *Yes* (scale varies locally), a sketch had to have a large discrepancy between the scale of different objects or groups of objects. Small to medium variations in scale were still considered as *no variation*. An example of a sketch with a variation in scale is presented in Figure 51$. Here, several objects and object relations are out of scale.

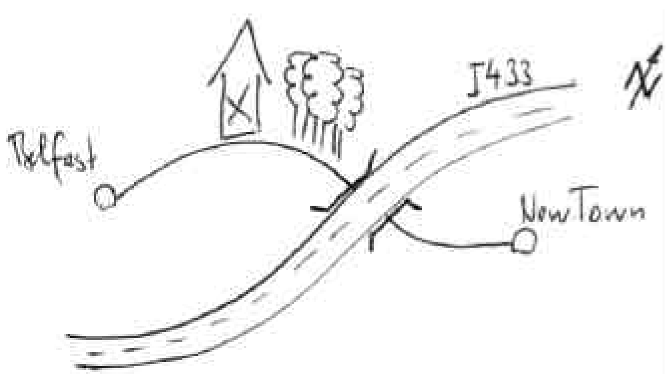


Figure 51 Sketch with several significant local variations in scale.

The second question that was answered for every sketch asked if there were variations in scale between different local scenarios on a single sketch. Table 18$ list the two questions regarding scale and the summarized outcome. We found that in about half of all sketches scale was inconsistently used. This suggests that many people are insensitive against changes in scale and that metrical issues are considered inferior to topological correctness. How much this is true for the interpreting person as well has yet to be determined. In regard on the second question we found that the tendency to vary in scale increases if the sketch is visually divided into multiple autonomous but interconnected sub-sketches or scenes. Table 18$ shows that only 14% of all subject considered it necessary to keep the scale consistent throughout the entire sketch

Does the scale varies locally?

Count	Code	%
48	Yes	53%
43	No	47%

Does the scale varies between local scenes?

Count	Code	%
18	Yes	86%
3	No	14%

Table 18 The two questions concerning the constancy of scale within a sketch and the results from our survey. (Scenarios 1, 2 & 3).

There are other considerations that seem to be important as well. For instance, we expect that objects that are more important are either more reliable concerning their scale–and also their dimensions–or they are larger than neighboring objects (scale is larger), but we believe such objects are never smaller than the average. The reason for this unproved statement is that it is illogical that emphasized objects are smaller. Despite this complexity in respect to different scales in one single sketch, we assume that it is still possible to determine some kind of a general scale in a sketch. The most promising approach would probably induce the global scale of a sketch based on objects with large extensions, such as straight roads, lakes, or distances between more prominent objects, such as towns, while disregarding the scale of smaller objects in a sketch. In theory this is relatively obvious, the practical translation is not. However, it is a first assessment of the scale in a sketch.

Summarizing our results about scale, we can assume that people are used to apply variable scales in sketches and that this tendency is increased if a sketch contains multiple local scenarios. It appears also that people are relatively unsusceptible against changes in scale within a sketch, as long as the sketch itself and its topology are clear. Otherwise it would be illogical why changes in scale are used so frequently.

6.3 Structure

This sub-chapter deals with the structure of a sketch from a visual and graphical point of view. There are two questions related to this topic. The first one focuses on the visual subdivision of a sketch into multiple sub-scenarios, such as addressed in the previous sub-chapter. The second question is concerned about techniques that are used to indicate topographic structures, such as slopes or mountains.

6.3.1 Multiple local Sub-Sketches

We found a total of 21 (23%) out of 91 sketches, where the sketch was actually based on multiple, more or less interconnected sub-sketch (Table 19$). Similar to the previous investigation about scale, this assessment concerning a subdivision of sketches is based on a manual and visual interpretation of our survey. In order to qualify, a sketch has to have multiple, visually distinguishable spatial structures–written annotations, such as a legend or a note are not considered to be such spatial structures. Separate sub-structures may be connected through objects, such as streets, arrows, or connecting lines, but it is also feasible that sub-sketches are connected virtually by the context.

In the scope of our examination of local sub-structures we found that there is, in general, a clear visual division between local scenarios within a sketch that makes it simple to visually distinguish between different sub-structures (Table 19$).

Is there a clear division between the local scenes?

Count	Code	%
14	Yes	67%
7	No	33%

Table 19 Two third of all multi-scenes sketches allowed a clear distinction between the various local scenarios. (Scenarios 1, 2 & 3).

If we take the number of objects and the complexity of a sketch in to account, e.g. when comparing the three sketching scenarios of our survey, then we can observe that the tendency to divide a sketch into multiple sub-structures increases when the sketches become more complex. For instance, for scenario one the percentage of sketches with more than one sub-structure was 41%, while for the less complex scenario two there were only a mere 4% with this characteristic. The third scenario scored somewhere in between (32%) and is in this case not so representative, because the spatial concept was predefined by the scenario description. However, variations in the third scenario shows that the same situation can be interpreted and represented in different ways. As the complexity of a sketch increases so does, in general, the number of sketched objects. Therefore, it is an almost logical consequence that we can observe a higher average of objects per sketch for those sketches with multiple sub-structures. The increase of the average is 29% (from 14.9 to 19.3 objects per sketch) if we only consider sketches with multiple sub-structures.

The number of actual sub-structures in a sketch is an other characteristic. Figure 52$ shows the distribution of sketches with more than one sub-structure in function of the number of sub-structures. The labeled percentages are in respect to the entire number of sketches in the survey.

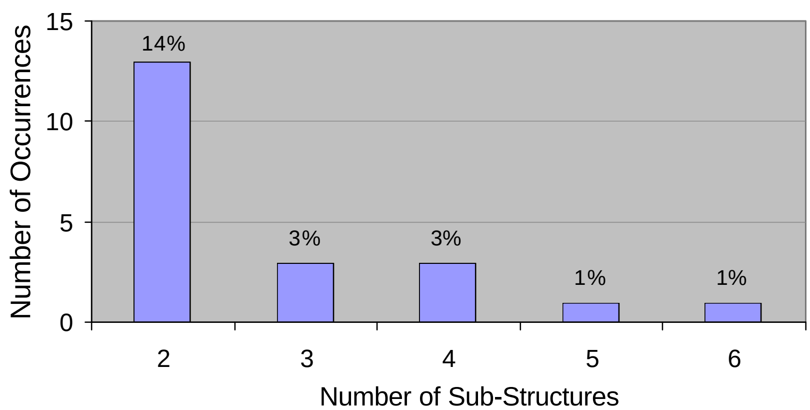


Figure 52 Distribution of sketches with more than one sub-structure. The indicated percentage is in relation to all sketches. (Scenarios 1, 2 & 3).

Obviously there is a tendency not to divide a sketch into too many pieces, most likely in order to keep the sketched representation simple. Hence, we can conclude that people use the subdivision of sketches to structure the content, when the sketch gets to complex or if there are too many objects involved. We believe also that people would structure their sketches more frequently if the sketching procedure was more dynamical in the sense that objects and groups of objects could be moved around the drawing surface.

6.3.2 Structures indicating topographic Features

In our discussion about object classes and object types, we have already seen some forms of graphical representations for topographical features in sketches. This previous analysis was primarily focused on the frequency of topographical structures, while this section is more concerned about the *how* topographical features are represented. There was only one question in respect to this specific issue. The question was: *What kind of techniques are used to represent topographical features in a sketch*. We have seen earlier that people seem to avoid topographical features in simple sketches. Accordingly, we found only one topographical object within the first two scenarios. Therefore, most topographical structures originated in the third sketching scenario, where we asked people explicitly to specify some topographical structures. However, there was still one subject that managed to totally avoid topographical objects within last scenario.

Count	%	Type
18	58%	Perspective
6	20%	Mixed
4	13%	Contour lines
1	3%	Hatch
1	3%	Symbols
1	3%	No topographic feature

Table 20 Frequency of the different used methods to represent topographic features within a sketch in the scope of scenario three.

Our question concerning the structure of topographical features looked at sketches in a rather global manner. Only one classification per sketch is permissible and the schema of classification is based on the five categories that are listed and raked by their occurrence frequency in Table 20. Most types are self-explanatory. The *symbols* class stands for sketches that include topographical symbols, such as known from cartographic maps. The *hatch* class is represented by objects involving hachures that indicate a topographic structure and sketches that fell in to the *mixed* class could have different forms of perspective structures. Of the five categories, the *perspective* class seems to be the most preferred method that was used to give a sketch a topographical touch. We attribute the popularity of perspectives to the fact that perspectives are rather direct representations of what people perceive when they look at three dimensional objects in their environment. It seems, therefore, more difficult for people to produce map-like sketches than to translate the mental image directly into a image or picture-like representation, such as a perspective. Another reason why people seem to like perspective views of topographical objects could be because people are not used to draw such kind of objects.

However, this simple analysis shows that it seems challenging to cope with topographical features in sketches. This is true for people that draw sketches as well as for those that have to interpret sketches, because the initial insecurity about how to represent topographical structures is often directly translated into a manifold of subjective and rather unusual interpretations of three-dimensional structures. Such undefined and not yet explored situations provide, on the other hand, also room for innovative methods, and devices that go beyond the simple pencil-paper metaphor and that use alternative approaches to let people describe and perceive topography or space in general in a more consistent way.

With these considerations about sketches in general we have reached the end of chapter six, which was also the last part focusing on an analysis of the surveyed sketches. Before we come to our conclusions concerning the present survey, we will make an interpretation of the compiled answers of our subjects concerning the general questions of the survey. This is done in the next chapter.

7. Sketch Questionnaire Responses

Beside asking our subjects to draw sketches based on written descriptions, we have asked them also to answer some questions in respect to the sketching process and concerning specific sketching task. There were questions for each sketch and they were answered subsequently to noting the sequence of objects. At the end of the survey, finally, the subjects had to answer a page of questions about their person, the survey and sketching in general. The first part of this chapter is relatively short and focuses primarily on temporal issues of sketching. In the second part we have compiled the results of the remaining questions depending on their thematic. The two sets of questions are listed in the Appendix (11.7.1 and 11.7.2)

7.1 Sketch related Questions

The two first questions that had to be answered immediately after each sketch were primarily aimed to distract the sketching subject from the primary reason of the survey in that they seemed to suggest that the amount of time spent to make the sketch is an important issue, which was not the case. Instead we wanted the subjects to sketch rather rapidly and not starting to make pictures or images. Our idea was that most subjects would first read the entire description of a sketch and then also the description of the task that they had to perform (the answering of questions) *before* they would actually start sketching. We believe that the subjects are very likely to associate *fast* equals *good* and *slow* equals *bad*, when reading that they had to note the time. The third and fourth question had a similar distracting purpose. We asked the subjects how many times they had to start over until they could finish the definitive version of the sketch. Because this “starting over” bears also for many people a negative component in mind, we believe that the subjects were urged to finish the sketch in only one approach and reflecting, therefore, the subjects’ sketching behavior in a more accurate and realistic manner.

The answers of the two first sketch related questions are primarily analyzed for reasons of completion and to give a rough idea about how much time was used to complete the different tasks as well as getting a first impression of how efficient and direct people are able to translate a description into a sketch.

	Scenario 1		Scenario 2		Scenario 3	
	Reading & Understanding	Sketching	Reading & Understanding	Sketching	Reading & Understanding	Sketching
Time per Sketch	**2:44**	**9:34**	**3:06**	**6:48**	**4:19**	**9:29**
Standard Deviation	**3:15**	**6:42**	**1:40**	**3:57**	**3:07**	**4:59**
Minimum	**1:00**	**2:00**	**1:00**	**3:00**	**1:00**	**1:00**
Maximum	**15:00**	**30:00**	**7:00**	**18:00**	**11:00**	**22:00**
Time per Object		**0:29**		**0:30**		**0:42**
Standard Deviation		**0:17**		**0:15**		**0:23**
Minimum		**0:09**		**0:11**		**0:06**
Maximum		**1:23**		**1:12**		**2:00**

Table 21 Statistical values for different tasks during the process of sketching. The first four rows reflect the entire sketching process, while row four to eight show averaged times in respect to objects. All times are indicated in minutes.

Table 21 indicates the results of various statistical analysis concerning the time that our subjects spent for reading and understanding the description of the scenario and concerning the time they spent for actually drawing the sketch. The time spent for reading and understanding is proportional to the number of words in each description. However, we assume that the description of scenario three was also consulted during the process of sketching, because we do not believe that the subjects were able to learn the entire scenario by heart. The differences of other global sketching values reflect individual preferences, such as time to comprehend a problem and time to translate a virtual situation into a sketched representation. Astonishingly the time used to draw individual objects is remarkably constant. Our subjects spent in average around 30 seconds for an object in scenario one and two and about 45% more in scenario three (42 sec.). Of course this time includes the drawing as well as the pause between drawing two object. We believe that more time for scenario three was used, because the subjects occasionally re-read the description and because they encountered unusual sketching objects, such as the suspension bridge or the monolithic rock.

The analysis of question three to five (Drafts and verbal explanation of sketches) follows in the next sub-chapter together with considerations about the general survey questions, because of thematical reasons.

The sixth and final question in the scope of each sketch was intended to remind the subjects to indicate the North direction in their sketch if it was remembered. Consequently we were unable to determine if the North direction would have been indicated or left out without our reminder, which would have been an interesting question either. However, the decision to remind the subjects was made, because we estimated the potential of insight about the orientation of a sketch relative to the North higher than knowledge about the frequency with that this direction was indicated.

7.2 General Questions of the Questionnaire

In this sub-chapter we analyze the subjects' answers regarding the general questions at the end of our survey. For this purpose we have divided the answers into categories, concerning the following four issues: the survey in general, a hypothetical sketching user-interface, the subjects' sketching techniques, and some personal information.

7.2.1 Questions concerning the Survey

There were only two questions concerning the survey in general. Both questions were kept relatively open so that multiple answers were possible. The subjects had to specify the easiest and most difficult part or task of the survey and the results are summarized in the following two tables (Table 22 and 23)

Easiest task in survey	Count
Scenario 1	8
Sketching and drawing in general	4
Scenario 3	3
Coming up with ways how to express objects	3
Scenario 2	2
Answer questions	2
Remember distances	1
Putting a sense of scale or depth in the scenario	1
Note sequence of sketched objects	1
Easy to understand instructions - more difficult to sketch	1
Sketch orientation in reference to NS-WE axis	1
Conversion of text into a sketch	1

Table 22 Sorted answers concerning the easiest task in the survey.

Most difficult task in survey	Count
Scenario 2	6
Scenario 3	5
Division of space on device	4
Read and understand the descriptions	3
Sketching	3
Remember names and locations of objects in sketches	2
Scenario 1	2
Drawing for an unknown person	1

Table 23 Sorted answers concerning the most difficult task in the survey.

An interpretation of the different answers is difficult, because people seem to have converging ideas about which tasks they consider difficult and which they esteem rather simple, which results in a variety of contradicting judgments. For instance there was no unambiguous consent about the level of difficulty of the three scenario and although scenario one was considered by many subjects as the easiest part of the survey, there were others that found it was the most difficult task. However, it is still possible to perceive some general tendencies of how people judge the challenges of a sketching task. So for instance, people seem to have no problem with sketching the scenarios, but on the other hand they considered it to be difficult to partition their drawing space for their sketch. From this observation we can infer that most people would welcome some sort of "endless" paper for sketching–in our case a panable and zoom-able electronic device–, instead of the limited area that they had in the survey.

Based on these answers, we can conclude that there is no single preference that all subjects would agree on. We can, therefore, also assume that individual profiles are an essential part of every higher level user-computer interaction. This observation extends also to the choice of interaction modality that is also dependent on a subject's liking (Blaser 1997).

7.2.2 Question concerning the User Interface

A total of four questions concerned the sketching device and the sketch-based user interface. One question was aimed to learn how far people are ready for an interaction with a sketch-based system as described in the survey. Hence, we have asked our subjects if they could imagine to work with a sketching device similar to the one proposed in the survey in addition to their typical office environment. Only about half of the subjects (49%) thought a sketch-based system would actually be useful for their everyday business life. The reason for this disappointing result is most likely due to the fact that we did not include any application examples with the survey description. Conversely we found that people appeared optimistic and interested in using an automated sketching device, during other occasions when we proposed our idea and included some examples that showed how such a device could actually be used. We can further assume that the three sketching scenarios were in so far misleading in that they suggest rather limited and non-essential applications for such a sketch-based system. The dormant potential that lies in this technique was, therefore, most likely not easily perceivable.

The subjects were much more in consent about the dimension of the sketching device. The average dimension of the device comes very close to the standard American letter size (letter legal 8.5 x 11") in that it was only missed by half an inch in length. This is astonishing for two reasons: first because there were about 60% non-American subjects that have a different standard format (A4) and secondarily because, as can be inferred from Table 24, there were big differences between the proposed dimension for such a device. The high percentage of intellectual people that took part in the survey seems to reflect in the proposed depth of the device, which is relatively big but also very realistic in respect to the contemporary technologies. The average device has the same width like US letter legal paper, the same length like an A4 sheet, and a depth of a modern laptop computer.

	Length	**Width**	**Depth**
Average	*11.5*	*8.5*	*1.0*
Maximum	23.6	23.6	2.0
Minimum	5.0	3.9	0.0

Table 24 Result of the question concerning the dimension of a sketching device. The dimensions are in inch.

The next two questions were focused on tools and operations that the subjects would have liked to use during a sketch-based interaction. The first question asked what kind of operations editing tools of a sketching device should provide. The summarized results are presented on Table 25 (a). The second questions asked for additional tools that would be appreciated during the sketching process (Table 25 (b)).

Useful Editing Operations	Count
Delete	16
Move	13
Modify Shape	9
Resize	5
Windows generic functions (copy, cut, past)	5
Functions of a drawing program	4
Annotation	4
Rotate	3
Change color	2
Library with sketch objects	2
Zoom	1
Mirror	1

(a)

Useful Sketching Tools	Count
zoom tools	8
allround tool	4
pan tool	3
object library	2
rotate tool	2
annotate	1
layer management tool	1
group tool	1
no tools	1
scrollable window	1
tool to annotate distances	1

(b)

Table 25 List of useful editing operations (a) and tools (b) that would have been appreciated by our subjects during the sketching process.

Unfortunately the reviewing process of our survey did not reveal the fact that the given examples accompanying these two questions could influence the subjects answers. We had included *delete*, *move* and *re-shape* as examples for editing operations and *zoom* and *pan* as examples for sketching tools. Looking at the two tables above we suspect that many subjects simply copied our examples. However, we assume that despite these unfortunate circumstances the list of basic operations for a sketch-based user interface is relatively complete. From our experience and from observations of how people sketch, we think that deleting, moving, and eventually reshaping of objects are widely desired functions that a system should provide. Other generic operations, such as copy, cut, or past that were popularized by modern user interfaces and graphical applications might be a part of a user's expectations as well. This is despite the fact that we think that these operations are not as natural as move and delete (change of location and destruct), which stand for metaphors that work in our daily life as well. Copy, cut, and past on the other hand are not 1:1 translatable into real live. On the other hand we have to assume (and accept) that the world is changing constantly and that, maybe, a behavior or preference that was natural ten years ago is unnatural for future generations. In so far we have to admit that operations, such as copy, rotate, mirror, or zoom can become natural functions as well.

7.2.3 Question concerning the Subjects' Sketching Techniques

This section investigates sketching techniques considering eventual drafting phases during the initial stage of a sketch and people's preferences for deletion, annotation, and generation of sketched objects.

Draft and Start-Over

After every sketch our subjects had to answer how many, if any, drafts were made and how many times the subjects did start over. Table 26 indicates that, depending on the sketching task, between 14% and 32% of our subjects chose to make a draft before actually drawing the sketch. As mentioned before, it is likely that these numbers are too conservative, because we suspect that some people did not want to admit how many times they really had to start over or how many approaches they had to take until they were satisfied with the resulting sketch. However, this puts us on the safe side if we claim and anticipate that people would welcome editing functions that would allow a refinement of a draft or corrections during the sketching phase.

Question	Answer	Scenario 1	Scenario 2	Scenario 3
Drafts made?	**No**	74%	86%	68%
	Yes	26%	14%	32%
How many start-overs?	**0**	81%	86%	71%
	1	13%	14%	29%
	2	3%	-	-
	3	3%	-	-

Table 26 Summary of answers concerning drafts made during the sketching process and the frequency people had to start-over while sketching the scenarios.

According to Table 26, more people chose to make a test-run if the sketching task was based primarily a the translation of a written description into a sketch (scenario three) than in the two other scenarios. We believe that this is, because it is easier to generate a mental picture of a situation if one has a visual support, which is in contrary to the human memory non-volatile and also able to capture more than just a few objects, as well as their spatial relations and other characteristics. Although this seems not further relevant at the first glance, it is another indication of the potential of sketch-based representations for applications that include multiple objects with specific constraints. The comparably low numbers of drafts and start overs made in scenario two, on the other hand, can be interpreted as an indication that people are capable to reproduce their mental images quite well and relative directly into a sketch if the scene is simple and not many objects are involved. The opposite may be the case for more complex scenes, such as involved in scenario one. Here people seem to have higher standards and, therefore, more approaches are made.

Preferred Methods for Deletion and Correction

The next questions was concerned about how people deal with apparent errors that they had detected during the sketching process. We asked the subject about their preferred method for deletion. Subsequently they had the choice between erasing (like with a rubber gum), scribbling, and crossing out. The subjects could chose more than one method for deletion and they could also indicate if they would prefer another, not listed method. The results of this question are listed in Table 27 (a).

Count	Best Deletion Method
18	by erasing rubber gum
5	something else
4	by scribbling
3	by crossing out

(a)

Count	Best Method to Correct
18	depends on situation
6	correct with a tool
5	erase and redraw

(b)

Table 27 Answers concerning the preferred method for deletion and correction.

We think it is remarkable that 18 subjects (60%) preferred deleting an object with a rubber gum like tool, because it takes more time and “effort” to delete an object this way than with all other methods. The reason for this preference is most likely due to the great popularity and deep-rooted acceptance of the paper-pen metaphor that offers no real alternative than using a gum–we do not consider cutting or white painting over an object as valid approaches–. Other methods, such as scribbling and crossing an object, are associated to negative marking In this context. Those subjects that chose to delete with *something else* were probably alluding to the traditional computer oriented method of deleting objects, which involves a selection and a subsequent deletion.

The second question that focused on errors occurring during the sketching process asked if incorrectly sketched objects should rather be erased and then redrawn, corrected, or if this depends on the situation. The vast majority of our subjects (18 or 62% in Table 27) thought that this is situation dependent. This suggests that people consider editing and partial-destructive methods, such as reshaping or moving to be appropriate approaches for correcting an object as well.

Verbal Explanations of Sketches

Two different questions addressed the subjects' preferences concerning an additional verbal explanation of their sketch. After each sketch the subjects had to answer if they would have liked to express their sketch verbally. Three answers were possible and the result is displayed in Table 28. It seems that people prefer an additional verbal explanations if they are insecure about the correctness of their sketches (high score of *Yes* and *Partially* in scenario 2) and that they would like to give further verbal explanations to consolidate their sketches. Verbal explanations appear to be useful for detailed sketches (scenario 1) as well, while less than half of all subjects found it necessary to explain their sketch verbally if a written description had to be translated into a sketch (scenario 3).

Question	Answer	Scenario 1	Scenario 2	Scenario 3
Explain Sketch verbally?	Yes	40%	54%	43%
	Partially	23%	25%	10%
	No	37%	21%	47%

Table 28 Analysis concerning people's preference to explain a sketch verbally.

At the end of the survey we asked the subjects the same question again to reassure the previously obtained results. Here the subjects were even more convinced that verbal explanations are a useful way to enhance the message in a sketch, as 57% of all subjects stated that they would have liked to explain their sketches verbally. In addition to this question, we asked the subjects about the preferred time of explanation

%	Time of Explanation
61%	after
26%	during
13%	depends

Table 29 Answers concerning the preferred time for verbal explanation.

According to Table 29 it seems that most subjects have a preferred time when to explain their sketches, because only 13% of all subjects thought that this is situation dependent. Although our results suggest that more people would rather explain their sketches after the sketch was finished, we believe–based on our experience and various observations–that most people choose a mixture between individually explaining and annotating objects during the sketching phase and providing additional explanations after the sketch is finished. However, we can interpret these results also in so far that explanations during the sketching process are kept rather short, for instance in form of annotations, and that explanations that are made after a sketch has been finished are more comprehensive.

These results seem to prove that people are comfortable with using systems that offer a multi-modal interaction and it demonstrates further that verbal and visual interaction easily can go hand in hand.

Sketching Tools

For every sketch made we noted the tool that was used. Table 30 shows how frequently which drawing tool was chosen. Without going into too much detail, it seems again that drawing methods that provide a simple way of correction are most popular among many people. There may be, of course, many other reasons that influenced our subjects when choosing their tool. For instance they simply could have used the first tool available or their usual drawing-writing tool. It is, therefore, hard to say, which was the true reason of their choice. What we could observe was that all subjects but those that used color stuck only one drawing single tool.

%	Sketching Tool
70%	Pencil
16%	Felt pen
13%	Ballpoint

Table 30 The subjects' preferences concerning the drawing tool used for the survey.

7.2.4 Question concerning the subjects personal profile

In this section we look at some personal characteristics of the subjects that were involved in our sketching survey. The information results primarily from the questionnaire on the survey. The covered issues are: Sketching skill, use and frequency of sketches in business and private life, the professional and cultural background, and finally the distribution of subjects depending on age and gender.

Sketching Skills

The subjects were asked to estimate their own sketching skills on a scale between 1 and 10. The resulting graph is shown in Figure 53. Although not fundamentally relevant in this context it is still interesting that the selected group of people appears to have either a rather bad or a relatively good opinion about the own sketching abilities, while people that considered themselves to sketch average were relatively rare. The reason for this unusual distribution is probably the composition of the surveyed subjects as well as the relative small number of samples and the fact that every individual has his or her own scale of judgment.

Figure 53 Self-estimated sketching skills of the surveyed subjects.

Use of Sketches and Frequency

Another pair of questions aimed at estimating the use and frequency with that our subjects used sketches in their everyday life. We provided three possible categories: *pleasure*, *business*, and *other* activities. The results are listed in Table 31. For the selected group of subjects, it appears that most individuals sketch primarily for their pleasure, but still more than one third stated that they use sketches also for business purposes. Five subjects selected both pleasure and business (14%).

%	Use of Sketches
43%	pleasure
36%	business
14%	pleasure & business
7%	other

Table 31 Table indicating the use of sketches of the surveyed subjects.

The second question in this context addressed the frequency with that sketches are made. For each of the three available categories (private, business, and other) the subject could choose a frequency on a scale between *once a year* and *more than once a day*. The results are depict in Figure 54.

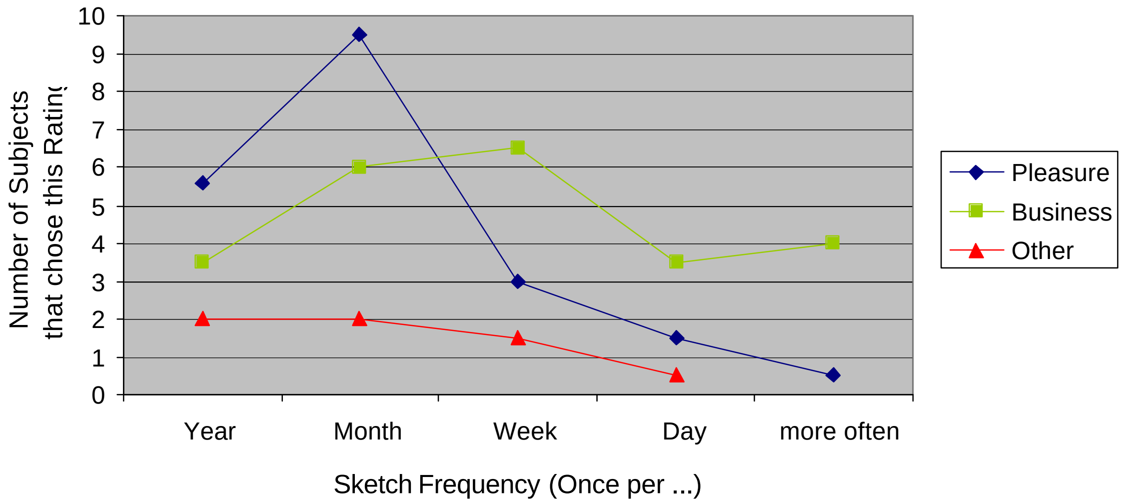


Figure 54 Graph showing how frequently sketches are used for different purposes.

Figure 54 confirms that more subjects tend to sketch for their pleasure than for business reasons, but those who use sketches for business purposes use them more often. That is the average frequency of sketches used for pleasure reasons is around once a month, while sketches for business purposes are in average generated every other week. Again, this distribution is strongly dependent on the professional and educational background of the subjects and, therefore, we cannot generalize this observation. However, it may be still considered a first rough estimate.

Gender Distribution

Table 32 shows that one third of our subjects are females and consequently two thirds are males. This distribution is a relative common for many of today's technical fields of applications and provides, therefore, a good basis for a survey.

Count	%	Gender
21	66%	Male
11	34%	Female

Table 32 Gender distribution of the subjects

Age Distribution of Subjects

Most subjects that took part in our survey were in their thirties. The youngest subject was 25 and the oldest subjects were 57. The average age was 36 years with an increased concentration of subjects with around 30 years.

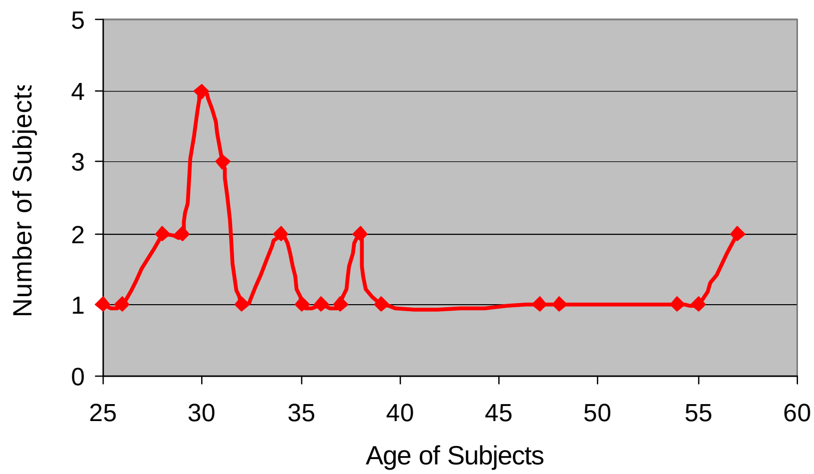


Figure 55 Age distribution of the surveyed subjects.

Professional Origin of Subjects

The professional background of the surveyed subjects is depict in Table 33. In order to keep the composition as heterogeneous as possible, we chose our subjects from different professional fields, but still with an emphasis on profession in engineering domains. Hence, subjects with an occupation in an engineering environment make up 58% of all involved people. Other scientific or academic professions are represented with 16%, while non-engineering and non-science professions make up the remaining 26%. Although it is difficult to make the right selection of people, we think that this selection is more appropriate for our purpose, than if all subjects would originate from the same domain, such as for instance if all subjects where undergraduate students of a psychology department. We believe that age, the maturity of the spirit, social and professional background, as well as many other personal and cultural parameters play an essential role how we perceive and describe our environment and that, therefore, it is advantageous to have a heterogeneous composition of subjects in every respect possible. This composition should, of course, be tailored to the targeted public.

(58%)	***Engineering***
4	Computer Engineer
4	Engineering (no specification)
4	Spatial Information Engineer
2	Civil Engineer
2	Electrical Engineer
1	Agronomy Engineer
1	Network Engineer

(16%)	***Other Sciences***
2	Architect
1	Biologist
1	Chemist
1	Geographer

(26%)	***Non Engineering / Non Sciences***
2	Office Employee
1	Mechanic
1	Music Teacher
1	Public Teacher
1	Site Manager
1	Technical Assistant / Railroads
1	Writer

Table 33 Composition of the surveyed group of subjects depending on their professional background.

Nationality

The cultural or social background of subjects plays also an important role. Almost two third our subjects originate from Europe (Switzerland. Germany, Austria, Greece, France) and one third from America (North and South America), one subject originates from India. Also in this respect, the composition of our subjects is relatively heterogeneous.

%	**Nationality**
61%	Europe
36%	America
3%	Asia

Table 34 Distribution of the subjects in respect to their nationality

Sketching Education

The last question in our survey was concerned about an eventual education in sketching that our subjects had received during their professional formation. We asked our subjects to specify if they had learned to sketch and if this education has put an emphasis on sketching. According to our survey, only one out of five subjects has learned to sketch and only 50% of those whose education involved some form of sketching stated that there was an emphasis on sketching (Table 35).

Question	Yes	No
Learned to sketch?	22%	78%
Emphasis on sketching?	11%	89%

Table 35 Questions and answers focusing on sketching education.

These results demonstrate that, unlike reading and writing that are taught and trained during many years in school, sketching is only seldom taught and, therefore, relatively non-standardized. Hence, we can consider sketching as a very natural and expressive form of communication that is not bound to a specific language or culture, but that is still capable to convey a lot of information. With these philosophical thought about the art of sketching we are at the end of this survey.

The next chapter presents a summary of our observations and tries to link the various findings to a meaningful bigger picture. We will also discuss and analyze our methodology and point out some weaknesses that we became aware during the process of analyzing the survey. The report closes with an outlook into the future and some suggestions for upcoming applications that involve freehand sketching.

8. Compendium

8.1.1 Initial Approach

This survey evolved from the need to know more about how people sketch in order to be able to develop methods and procedures to automatically interpret the content and the meaning of sketches in a geo-spatial environment. In this context we were primarily interested in discovering reoccurring sketching pattern and sketching techniques that people apply to generate sketched representations of geo-spatial scenes. Such knowledge is essential to be able to anticipate people's intentions and to comprehend sketched scenes. In the scope of this survey we have asked 32 people with different origin, sex, age, and profession to draw each three sketches based on a written description. The thematic of these three written scenarios was chosen, such that it is possible to cover a wide variety of aspects in geo-spatial sketches. Each sketch was analyzed on an object-by-object base and the results were feed into a database. The primary focus of this investigation was on sketched objects, their relations to other objects, and on their annotations, but we did also consider global structures and the sketch in general.

8.1.2 Findings

Because of the extent of our investigations there is no space to take every detail of our findings concerning peoples sketching habits and pattern into this summary of our findings. Instead we have compiled a reasonable set of observations that we think are essential in the first place when dealing with geo-spatial freehand sketches. For a more detailed discussion we have to refer to the technical report itself.

During our examinations, we have observed that people keep the number of objects that they use to describe a spatial situation relatively small. Depending on the complexity of a sketch we experienced in average between 12 and 17 objects per sketch. We have also experienced that most subjects seem to favor artificial object, such as roads, buildings, or other human built monuments over natural objects, such as vegetation or topography in their sketched representations. Those natural objects that are frequently used have almost always a clear boundary and are typically of a larger extent, examples are rivers, lakes, or the sea, while other natural objects that can be found everywhere but that have fuzzy boundaries are almost non existent in sketches. Examples here are forest, hills, or valleys. In this context we have observed the general tendency that people tend to represent geo-spatial situations in a pure two-dimensional, map-like manner without taking any topographic features into account. If the third dimension is considered then this is limited mostly to an object or to object groups, such as the front view of a house or the silhouette of a town.

People keep the shape and structure of most objects rather simple, in that they use only a few strokes to draw an object and in that they tend to use symbolic structures with no details to represent real world objects. Such it is no surprise that boxes and straight lines are the preferred forms for representing object in a sketch. We observed also that objects are in general relatively carefully drawn, so that for instance boxes are closed and lines representing streets tend to meet but not to cross. Because of their simplicity sketched objects taken out of context do frequently have no own meaning. We found two ways how people attached a meaning to these objects. The first uses the context of an object and the ability of people to infer a meaning, while focusing on a group of objects within a particular spatial configuration. The second possibility is to annotate sketched objects verbally or by writing. We could not record verbal annotations but we found that almost two third of all sketched objects of our survey had an attached annotation. Annotations in our survey were in general simple words or ellipses, while phrases were rarely used.

We were surprised about the use of metric information in sketches as we have observed that people rely primarily on the topologic configuration of object in a sketch to describe a geo-spatial scene. Explicit distance indications of any form–time or direct--were almost non-existent in our survey. However, some implicit forms of distance indications, such as the relative closeness of objects seem to be important as well. Direction and orientation of objects and object groups, conversely, seem to play an essential role in sketches. We found that 27% of all objects in our survey had an indicated or deduced direction associated and that many objects were linked to other objects through parallel or rectangular relationships– only one third of all objects had no such relationship–. The preferred orientation for objects and the sketch itself is along the North-South or West-East axis of the sketching device. But, despite our subjects' general preference to align their objects according to these two cardinal orientations, we noticed a slight upwards deflection to the upper right for many objects.

Context and spatial configuration of objects in a sketch are important. We have found that sketched objects are typically connected with each other via overlap and meet relations (if we exclude disjoint relations that can connect objects as well), while other topological relations indicating containment are only sparsely used. Objects that are topologically equal to other objects are, according to our analysis methods, quasi non-existent in sketches, because no two objects are drawn onto each other. Considering their location we have observed that objects drawn in temporal sequence are typically closer to each other than objects that are out of sequence. However, we have found also other sketching strategies, where people tend to sketch a sequence of objects based on their thematical relationship. Looking at object type and the temporal sequence with that objects are drawn, we can observe that objects with line characteristics are frequently drawn first, most likely because they can be used to define the drawing space and serve as local reference frame. Annotations and direction indications a normally drawn at the end of a sketch. In general we have found that a typical sketch has three distinct phases that can be described as follows: The initial phase is characterized by defining the rough framework of a sketch, the second phase is used to populate the sketch with additional substantial objects, and the last phase, finally, is responsible for concluding details and the message of a sketch. Although there is no iron rule for the composition of a sketch, we observed that many sketches fit into this scheme and if not temporally then at least thematically.

Based on our questionnaire we have learned that there is almost no consent about what our subjects considered to be difficult and what they think are easy sketching tasks. Conversely, the approval of an appropriate size for an electronic sketching device was much more evident. The averaged format comes close to the US letter format (11 x 8.5"), although 60% of our subjects were from Europe. According to our questionnaire, the preferred erasing tool is an electronic rubber gum. Finally, we found that people would prefer for the most part to interact also verbally with a computer system. Depending on the complexity of the sketching task between 53% and 79% of our subjects stated that they would partially or definitely like to provide verbal in addition to the graphical input. Which indicates the necessity of multi modal systems when dealing with spatial information.

8.1.3 Interpretation

In different places and on various occasions throughout this technical report we have been reasoning about and describing possible consequences of our observations and findings. At this point, however, we will present a concise summary of what we think is the true essence and the outcome of this survey. There are basically two issues in this context. The first point is concerned about the core of fundamental observations regarding geo-spatial sketches, while the second point of interest is more focused on questions, such as relevance and consequences of our findings.

Essence of this Survey

People's sketches are simple and abstract

People are able to represent their environment (geo-space) with simple and relative abstract sketched objects that have frequently no meaning if they are taken out of context. Hence, a typical sketch contains only a small number of relevant and prominent objects. These objects are in general highly abstract representations of their real life counterpart and often described with simple lines or boxes. Objects that have a more complex graphical representation have typically a verbal annotation or their meaning can be deduced from their visual appearance that is, they have a symbolic or pictorial character. Finally, we have found no evidence that people use negation in their sketches. All sketches in our survey were formulated in a positive way, this is true for objects and their properties

Topology matters and metric refines

People focus primarily on topology when drawing a sketch. The relative positioning between objects and object groups appears to be much more important than explicit metric conditions. In this context it seems also essential that the sequence of objects along objects with line characteristics is consistent, since these later objects are frequently responsible for the basic framework of a sketch. However, relative metric descriptions, such as far, close, or parallel play an important role in geo-spatial sketches, but as they are in general implicitly stated they can be interpreted differently from person to person. Orientation and direction, finally, seem to be relevant on the global and local level of a sketch, but rather less important on the object level, which supports that objects are highly abstract entities.

People use generic and domain specific symbologies in their sketches

There are symbols and sketching patterns that tend to reoccur frequently in sketches, while other symbologies seem to be used only for specific purposes. The generic type of symbol is characterized by a simple and constant visual appearance, but its semantic is changing significantly depending on the actual context. An sketched arrow, or a box are two examples. The secondary set of symbols is typically more specific and detailed, as well as dependent on the application domain. Although we focused primarily on geo-spatial sketches, we believe that this observation is true for other domains as well. We can, therefore, assume that people use essentially always the same limited set of generic symbols in conjunction with one or more domain specific sets to express themselves graphically within sketches. This common, sketch-based sign language is comprehensible by the majority of people, independent of their language or their origin. Of course this may be different for certain domain specific symbolic sets that may require some expertise in a particular field of application. However we can still claim that pure sketches are language independent.

People have a specific sketching signature in their sketches

Although we did not explicitly investigate individual sketching characteristics of our subjects, we could observe conspicuous similarities between the three sketches of each subject. This concerns the choice for the representation of sketched objects, the sketching style, and the use of a particular symbolic. These individual differences between subjects suggest the introduction of personal profiles or preferences in addition to the generic and domain specific sets of symbols.

Sketches are typically structured in three layers

Sketches are frequently based on three functionally distinct groups of objects that can be combined into three layers. The first layer defines the global orientation, the division of the drawing space, and the rough structure of a sketch. The second group of objects is concerned about finer sub-structures on the local level and for the body of the sketch. The third layer, finally, is responsible for the actual message in a sketch, but it incorporates also last minute details and corrections. These three functional layers can be found in almost any geo-spatial sketch and we have observed that people frequently use a similar chronological approach to draw a sketch. However, some subjects proceeded also in the opposite direction that is, they applied bottom-up strategies to build up a sketched scene.

Significance of this Survey

The primary objective of this survey was to foster the general understanding and knowledge concerning freehand sketches in a geo-spatial environment. In this context we can summarize the benefits of our investigation into the four points stated below. However, because this study has just been finished, we can only make assumptions about its future relevance and try to anticipate the potential of our findings.

The actual challenge in a sketch-based system is the interpretation of the sketch

Considering the fact that people tend to use a simple symbolic in their sketches, it appears relatively straightforward to detect objects in a sketch. A secondary reason that makes us believe that automatically perceiving sketched objects should be rather easy is that sketched objects are drawn in a inherited sequential manner. This temporal component of the sketching process can be used to detect objects and important relations as well. The real challenge when interpreting a sketch comes with the reasoning about the meaning of objects, the evaluation of priorities among spatial and virtual relations, and the perception of intent and message of a sketch. However, we think that is possible to implement an intelligible and domain specific system that is capable to understand the essence of sketch-based object configurations, because it seems that a host of sketching patterns are repetitively and frequently used in sketches.

This survey can serve as a reference for the development of sketch-based applications

The survey has shown that people's sketching strategies obey certain rules and that it appears feasible to implement a sketch-based application user interface. Beside this, we consider this survey also as a valuable source and reference for the development of such an implementation. Our observations cover all essential parts of a geo-spatial sketch and provide statistical information about their characteristics, such as distribution, preferred location, occurrence frequency, their typical representation in a sketch and many other qualities as well.

This survey is the base for the development of a semantic model for geo-spatial sketches

Before we can use an automated spatial reasoning mechanism we have to convert a sketch into an artificial representation that reflects all essential characteristics of a sketch. The base for such a translation and the generation of a semantic network of a sketch are consistent rules that are founded on comprehensive observations of the real world. This report provides such base knowledge, specifically about geo-spatial sketches and is, therefore, well suitable as a base for the definition of a formal model of sketches in this environment.

This survey can serve as a starting point for future investigations

We are aware that our examinations of geo-spatial sketches were limited in so far that our observations are based on a manual analysis of a rather small number of sketches. We have mentioned before that certain results have to be considered, therefore, rather as likely trends than as iron facts. However, our intention was to obtain a first general overview of people's sketches and not an in depth analysis of one particular characteristic of a sketch. Accordingly the survey is relatively broad, but it addresses many sketch related issues on the other hand. Topics that appear to be interesting or that need further attention are pointed out, such that the survey can also be used as a starting point for further investigations that pursue similar sketch-focused questions, but that take a deeper look at these issues. We have also noted where we had difficulties and proposed alternative approaches and methodologies, what should simplify subsequent surveys dealing with similar issues.

8.1.4 Discussion of the Survey

In the previous sections we have summarized our findings and reasoned about possible implications of our survey for geo-spatial applications. This final part of the report analyzes our methodology for this survey and describes some changes to our approach for subsequent surveys with a similar topic.

Setup of the survey

The involvement of a larger group of subjects would certainly be advantageous, not only for statistical reasons but also to cover as many sketching strategies as possible. We would stick to the principle to let people draw multiple sketches in a survey, because such, the subjects are not stressed by the constraint to "do it right" with only one single shot. The background and the purpose of the sketching scenarios should be well balanced, focused, and the scenarios should not be too influential, such as was the third scenario in our survey. At least one scenario should address a spatial configuration that is known to all subjects as well as to the interpreting scientists. This allows the perception of certain sketching characteristics, such as correctness or completeness that require a comparison with the actual situation in the real world. Obviously this limits the scope of eligible subjects to people that are acquainted with a specific environment.

Another important point concerns the degree of automation, which should be as high as possible so that the subjective component during the sketch analysis can be reduced. In this context it seems favorable to employ automated electronic sketching devices that record the subjects' sketches as detailed as practicable. Such a procedure requires the subjects to be physically present, but allows on the other hand a much more precise assessment of quantitative object characteristics (e.g. number of strokes, orientation, alignment, chronological sequence, metrical parameters, etc.) and it relieves people from making additional statements, such as the list concerning the sequence of sketch objects. A supplementary benefit is that the data is already available in a digital format and has, therefore, not be processed manually. However, because it appears not yet feasible to make a fully automated assessment of a sketch, we suggest that the manual part of the analysis is carried out by at least two, better three people and that additional techniques, such as audio and video taping are being used to better cover other human input channels (Ericsson and Simon 1993). Such an approach allows the subjects to focus on the sketching task, without being distracting by making lists and answering sketch related questions between the sketches. Furthermore it provides more accurate information concerning the verbal input during the sketching process than our approach did. In regard to the set of individual sketching tasks, we think that their thematic should be more focused on the field of intended applications than this was the case in our survey.

Analysis of the survey

The analysis of our survey was based on a relative broad examination of sketch characteristics and object features. This approach was appropriate for an initial attempt to perceive the bigger picture of sketches in geo-space. However, for subsequent surveys it seems favorable to limit the number of investigated and examined features to the really necessary, which is obviously depending on the scope and focus of the survey. In this context a partial redefinition of some classification and interpretation schemes seems to be appropriate, insofar that redundant or less important issues are being dropped and other questions that have not yet received enough attention are analyzed on a more detailed level. Unfortunately it is not possible, at this point, to be more specific, because as mentioned before the individual setup of the survey is primarily dependent on the actual purpose of a survey.

Results of the survey

We have basically covered the significance of our observations during the previous interpretation of our findings. However, the results of our investigations can be further condensed in so far that we have found that people tend to sketch geo-spatial scenarios much simpler than we had initially expected. Despite this simplicity most sketches remain sufficiently expressive so that an intended message can be easily conveyed. Therefore, and because of other research concerning the potential of sketching in GIS (Blaser 1997) we have strong evidence to believe that sketching can be considered as a valuable and very promising method for interaction with computers, especially when spatial object configurations and complex spatial constraints have to be explained or queried. These results lead us also to the next point on our research agenda that focuses on modeling geo-spatial sketches and that will ultimately provide the base for a prototype implementation of a sketch-based query user interface, called Spatial-Query-by-Sketch (Egenhofer 1996).

9. Acknowledgements

My thanks go to Max Egenhofer, my thesis advisor, who left me a lot of free room to investigate this issue, to Kate Beard and Doug Flewelling, who made valuable input, and of course to all participants of the sketching survey for that they had taken the time to translate the written scenario descriptions into sketches and answer all the questions.

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11. Appendix

11.1 General Statistics about the Survey

Surveys sent out to:

External subjects:	32	63%	(in respect of total no surveys sent out)
Internal subjects:	14	27%	
Initial test subjects:	5	10%	
Total:	51		

Surveys received:

External subjects:	19	59%	(in respect of surveys sent out)
Internal subjects:	13	93%	
Initial test subjects:	5	100%	
Rejected surveys	-1	2%	
Total:	36	71%	(inclusive test subjects)
Effective Total:	*31*	*61%*	(exclusive test subjects)

Gender distribution:

Female subjects:	22	43%	(of surveys sent out)
Male subjects:	29	57%	

Final gender distribution:

Female subjects:	11	35%	(of surveys received)
Male subjects:	20	65%	

11.2 The Survey

11.2.1 General Instructions

I - Introduction

This survey is structured into four parts: After the introduction, we have put together some general instructions (II) for completing the survey, there after follows the "fun part" (III) where we would like to have you sketch some imaginary scenarios and finally —when you are a sketching expert— there is a section with some general questions about sketching (IV). The instructions are simple, but it is important to *read them first*, in order to complete the survey in a straightforward manner.

Thanks again for your cooperation and support!

II - Instructions:

- ✍ The pages are **stapled** together in a special way to facilitate the completion of the survey. - You can always have the sketch on your left and the scenario on your top right.
- ✍ Please **note the time** (for each sketch), when you start reading the scenario description, when you start sketching and again, when you are done with a sketch.

  T1: Evaluate the time you have used for building up your sketch idea (= reading the description, making up your mind).

  T2: Estimate the time used for the sketching (from the first to the last stroke).
- ✍ Try to **sketch naturally**, do not hesitate too long on how to sketch - This is most important as we want to know how you sketch intuitively - No art skills are required!
- ✍ If a sketch drifts into a wrong direction, you may **start over** again, if necessary several times, or just correct your sketch as necessary – but please *do not discard* your drafts, as they contain much valuable information for this survey and we would very much appreciate if you could send these drafts along, together with the rest of the survey.
- ✍ You may use **any style and any tools** you like to express yourselves in a sketch: drawings, references, text, symbols, colors, etc. - But again, please do not think too long, the sketch should be as simple and natural as possible to bring the necessary message through.
- ✍ Please draw your sketch on a **soft surface**, because the sketch will develop better, in addition it will be easier to interpret the sketch afterwards.
- ✍ Once you are done with sketching, please **note the sequence** in which you have sketched the elements of your sketch.
  For example: `1. house, 2. river, 3. road, 4. Name of the road ...`
  If you have drawn more than 22 elements please attach an additional sheet of paper.
- ✍ **Comments** are welcome! - If you have any comments about the sketching scenarios (like "I had a hard time sketching the ...", etc.) or the project itself, please write them down.
- ✍ After completing the survey, please **send it to the address below**.

Andreas Blaser
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Department of Spatial Information and Engineering
Boardman Hall 321
Orono, Maine 04469-5711
USA

11.2.2 The three Sketching Problems

Sketching Problem 1

"Make a sketch of the route from your home to your working place so that your great uncle from Russia, who is visiting you, could find you there - He is absolutely not familiar with the environment you live in, as he has just arrived with Aero?lot from far Krasnoleninskiy."

Sketching Problem 2

"Recall your last vacation and imagine you have lost your leather case with your airplane tickets while shopping in a store in one of the towns you visited on this trip (Please recall a real location where you have been recently in vacation). Unfortunately you do not realize your loss until you are at the airport. At the airport security office, you make a sketch for the officer in charge, explaining all the details that are important to relocate the specific store in the foreign town, (e.g. streets, intersections, monuments, other shops, houses, and so on) because you cannot recall the original name of the store“

Sketching Problem 3

Imagine you are a historian and you have just recently discovered a part of an old document, that describes the location of the Golden City. But unfortunately nobody knows where this city lies and the only reference you have is the textual description on the fragmented papyrus. To find possible locations, you read the text carefully and make a detailed sketch which you then give to a historical librarian who is willing to help you find the place. Here is the translation of the ancient text:

"... after having traveled for several days through the jungle along a big stream, which the natives call "Ugiduggi“ we cross the canyon of a small brook on a small suspension bridge. To my surprise the brook has built quite a delta where it drains into the stream. A huge, monolithic rock in the middle of the stream is just above the confluence with the brook. Just after the bridge, a small steep trail begins, which guides us upwards. After ten long hours from the bottom, we finally reach the top of the mountain. We are delighted by the magnificent, open view in all directions - but most of all, we can finally spot the glittering of the Golden City, which lays in the middle of a big plain, several thousand feet below and eastwards about three day-trips away..."

11.2.3 Sketching Surface

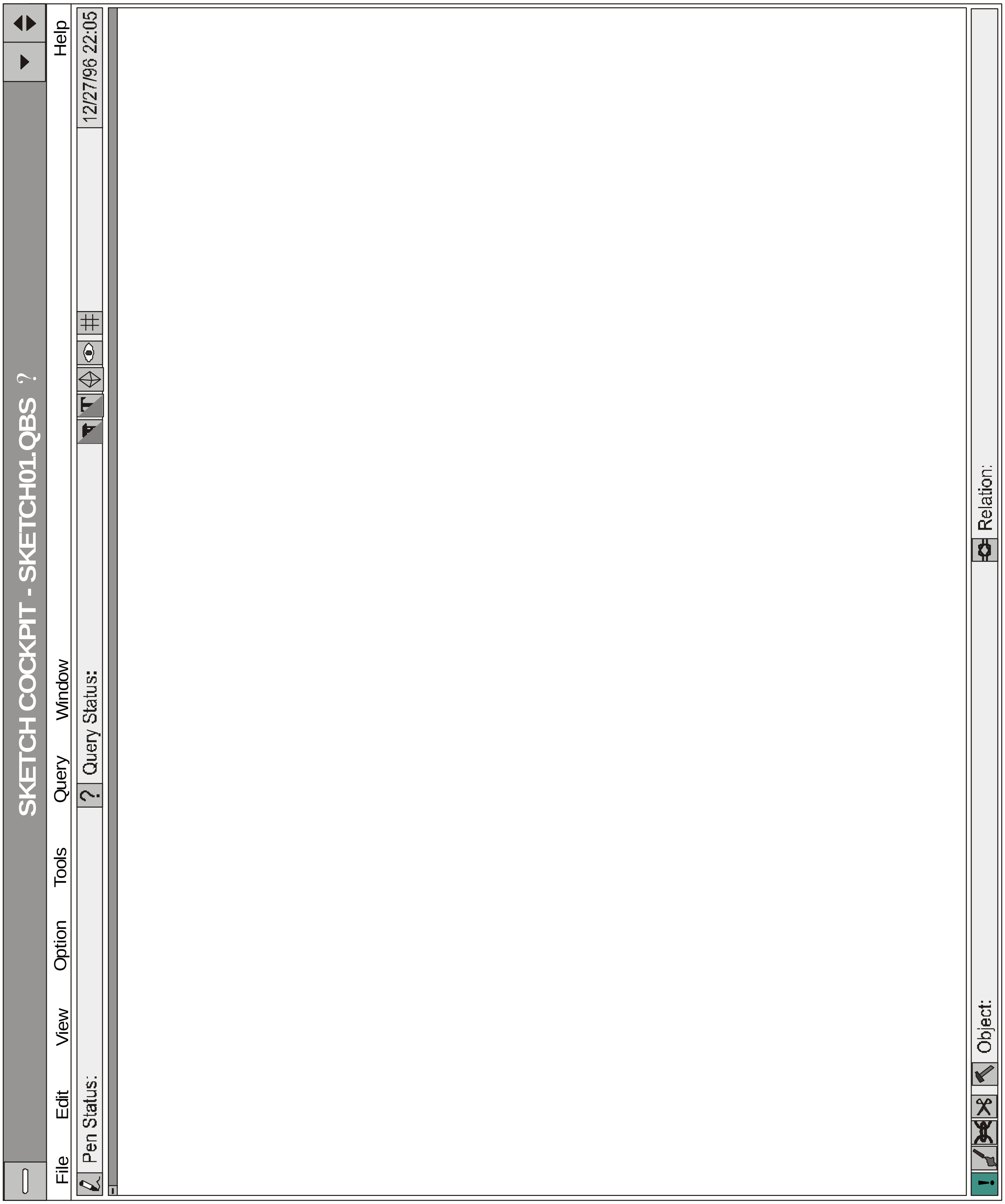


Figure 56 Mockup of a sketch-based user interface as it was provided in the survey for each sketching scenario.

11.3 Sketch Database

11.3.1 Schema of the MS Access Database

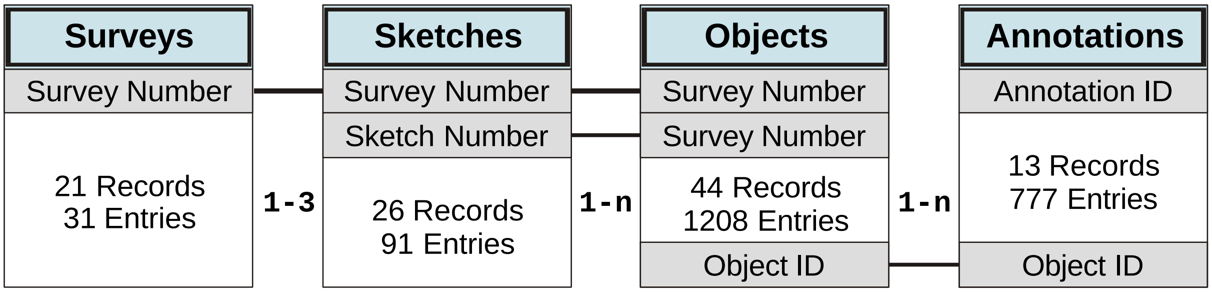


Figure 57 Database schema of the MS Access database that was used to store and query the information obtained by the analysis of all sketches.

11.3.2 Description of the Content of the four Database Tables

The following four sub-sections provide a description of the content of the individual database records and they state what values these can take. The database was designed based on five preliminarily analyzed surveys. For a second survey we would probably use a slightly modified database schema with some additional entries. In turn we would eliminate some ambiguous and not so relevant specifications that have been included in the original survey. The following Tables have also been used to classify our sketch objects.

Object Table

A Specification:

1 ✍ **type of object**: 0D object (0) / 1D-object (1) / 2D-object (2)
[for complex objects: they can include objects of lower order see C3-C5)]
[if the object is an annotation, then it is considered a 0D-object]
2 ✍ **class** of object (e.g. building, body of water, vegetation, etc.): (string)
3 ✍ **name** of object, river, street, highway, etc.: (string)
4 ✍ **location**: (1-16)

B Purpose / Role:

1 ✍ **purpose**/role: (body (1) / start (2) / end (3) / way-point (4) / orientation help (5) / landmark (6) / detail (7) / direction-indicator (8) / distance-indicator (9) / link (10) / path (11) / explanation (12) / boundary (13) / annotation (14) / structuring object (15)):
[*end* is also the main point of interest]
2 ✍ **sequence** / when was the object drawn? (1-n / -)

C Representation:

1 ✍ object is **composed** from other object (e.g. forest composed of trees) (1-n)
2 ✍ global object has an own independent boundary: (y/n)
if more than one object and primary object has no independent boundary ✍ structure of sub-objects
3 ✍ **Shape**: symbolic (1) / half symbolic (2) / realistic (3)
4 ✍ 1D-type of shape: (straight (1) / curved (2) / complex (3))
5 ✍ 2D-type of shape: (square (1) / box (2) / circle (3) / oval (4) / complex (5) / cross (6))
6 ✍ **type of outline**: (none (0) / doted line (1) / line (2) / 2D-line (3) / multi-stroke line (4) / mixed (5) / dashed (6))
7 ✍ object drawn with how many **strokes**: (n)
[contains substructure strokes but not hatch]
[if dotted line, count only mayor strokes, not dots or dashes]
8 ✍ **completeness** of object: (complete (1) /partially complete (2) /incomplete (3))
9 ✍ kind of **texture** (none (0) hatch (1) / cross-hatch (2) / filled (3) / complex (4) / doted (5) / hachures (6) / color (7) / color filled (8))
10 ✍ **perspective** other than *map-view* (y/n)
11 ✍ what kind of perspective? (elevation (1) / 3D (2) /mixed (3))
12 ✍ contains **sub-structure**(s): (y/n)

13 ✍ name of sub-structure? (string)
14 ✍ signs of **uncertainty**: (y/n)
15 ✍ how do uncertainties manifest themselves? (string)
16 ✍ type of **distance indicator**: (none (0) / time (1) / distance (2) / mixed (3))
17 ✍ type of **direction indicator**: (none (0) / arrow (1) / double arrow (2) / multiple arrows (n))
18 ✍ object **encircled**: (y/n)
19 ✍ Comments (string)

D Topology:

1 ✍ does the object **overlap** with other object: (0-n)
2 ✍ does the object **meets** an other object: (0-n)
3 ✍ does the object **contains** an other object: (0-n)
4 ✍ is the object **contained** by other objects: (0-n)
5 ✍ is the object **equal to** an other objects: (0-n)
6 ✍ is the object **in line** with other objects: (0-n)
7 ✍ object **along or bordering** with other objects: (0-n)
[no necessarily meet condition]
8 ✍ does the object **belongs** to a group of similar objects? (y/n)
9 ✍ how many similar objects are present in the sketch: (n)

E Orientation

1 ✍ what is the **orientation** of the object: (3,6,9,... Az) (99 := no orientation)
2 ✍ what is the object's **indicated direction**?: (3,6,9,... Az) (99 := no indicated direction)
3 ✍ object is **parallel** of in **a right angle** to neighboring objects (how many)? (0-n)
[also if parts of the object are parallel or in a right angle to other objects]

F Annotation:

1 ✍ object has **annotation** (y/n)
2 ✍ Number of annotations (n)
2b ✍ Time of annotation: (before (1) / right after (2) / after (3) / indefinite (0))
2c ✍ Sequence number of annotation: (n)

Annotation Table

F Annotation: *(continued)*

3 ✍ **type of annotation**, name, attribute, time, distance, etc.: (string)
4 ✍ only annotation **no object** (y/n)
5 ✍ annotation describes **only a part** of the object (y/n)
6 ✍ **place of annotation (**inside (1) / outside (2) / overlap (3) / mixed (4))
6b ✍ **direction of annotation** (Middle (0) / N (1) / NE (2) / E (3) / SE (4) / S (5) / SW (6) / W (7) / NW (8) / various (9))
7 ✍ **form of annotation**: (object spec (1) / object spec with attr. adj. prep. (2) / sentence (3) / ad-on info (4) / other (5))
8 ✍ **characters**: (single (1) / connected (2) / mixed (3))
9 ✍ **orientation** of annotation: (cardinal direction (1) / object main direction (2) / random (0))
10 ✍ **writing direction**: (3,6,9,... Az) (99 := no indicated direction)
11 ✍ **symbol** of annotation: (arrow (1) / double arrow (2) / line (3) / none (0))
12 ✍ annotation was **added immediately** after object (y/n)
13 ✍ annotation **encircled** (y/n)
14 ✍ annotation **underlined** (y/n)

Sketch Table

G Type of sketch

1 ✍ type of sketch: (single path (1) / multiple path (2) / situation (3) / path(s) & situation (4))
2 ✍ purpose of sketch: (description (1) / question (2))

H Orientation / Direction

1 ✍ is there a **sketch orientation indicator**: (3,6,9,... Az) (99 := no orientation)
2 ✍ when are orientation objects drawn? (not known (0) / beginning (1) / middle (2) / end (3))
3 ✍ is there a **main direction** in the sketch? (3,6,9,... Az) (99 := no main direction)
4 ✍ is there a **main flow direction** of the sketch? (y/n)
5 ✍ what is the **main flow direction**? (3,6,9,... Az) (99 := complex)
6 ✍ is the sketch **twisted**? (yes (1) / no (0) / partially (2))

I Structures

1 ✍ is there an indication of **topographic structures**? (none (0) / contour lines (1) / symbols (2) / hatch (3) / perspective (4) / mixed (5))

2 ✍ is the sketch composed of **multiple local sub-sketches**?: (0-n)
3 ✍ with **how many objects** is the sketch composed: (n)

J Scale

1 ✍ does the **scale varies locally**? (y/n)
2 ✍ does the **scale varies between different local scenarios** in one sketch? (y/n)
3 ✍ can a **clear dividing** line be drawn between these variations in scale? (y/n)

K Diverse observations

1 ✍ sketch is drawn in a **perspective** other than map-view (y/n)
2 ✍ have **symbols** been used? (y/n)
3 ✍ was there a sign of **editing** on the sketch? (y/n)
4 ✍ What **tool** was used? (ballpoint (1) / pencil (2) / felt pen (3))

L Questions concerning the individual sketches

1 ✍ **time before** sketch was started: (x:xx)
2 ✍ **time to draw** the sketch: (x:xx)
3 ✍ was a **draft** made prior to the sketch (y/n)
4 ✍ if yes how many drafts? (n)
5 ✍ was there a desire to **explain the sketch verbally** (yes (1) / no (0) / partially (2))
6 ✍ **north direction** could be indicated? (y/n)
7 ✍ **Comments of subject**: (string)
8 ✍ **Comments of examiner**: (string)

Survey Table

M Questionnaire

1 ✍ **dimension** of drawing device: (x,y,z)
2 ✍ would sketching **device be useful** at present: (y/n)
3 ✍ most **difficult** part of survey: (string)
4 ✍ **easiest** part of survey: (string)
5 ✍ what **operations** would have been practical for sketching: (string)
6 ✍ what **editing tool** would have been practical: (string)
7 ✍ **best method** for deletion: (crossing out (1) / scribble out (2) / eraser (3) / else (4))
8 ✍ **in case of error** prefer erase and redraw (1) or tool (2) or depend on situation (3)?
9 ✍ **explain sketches** verbally (y/n)
10 ✍ explanation during (1) or after (2) or depends (3).
11 ✍ sketching **skills** (n)
12 ✍ sketching **environment**: pleasure (1), business (2) or other (3) or both (4)
13 ✍ **frequency** of sketching: year (1), month (2), week (3), day (4) or more (5)
14 ✍ **age**: (n)
15 ✍ **profession**: (string)
16 ✍ **learned** how to sketch: (y/n)
17 ✍ emphasis on sketching (y/n)

11.4 Sketched Objects

11.4.1 Description of the Object Classes in the Sketch

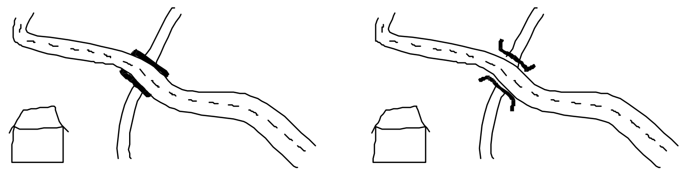
In the following part we describe the set of objects that is contained by the 20 classes found in our survey as far this is not apparent from the class name.

building: This class contains all artificial, human made structures that do not significantly raise above the surface and that do not have line character. Examples are: house, church, stadium, or station.

road system: This class includes all artificial, human made structures that can be used as a path for man made traffic excluding railroad systems. The objects in this class must have a line character. Examples are: streets, highways, or trails.

direction: This class contains objects that have in general a symbolic character and that point into one or more directions. Examples are: north arrow, arrows used to specify a path, or arrows to connect multiple scenes.

symbol: This class contains all symbolic representation of objects used in a sketch. Because a sketch is per see of a symbolic nature it is sometimes hard where to set the limit between a symbol and an object from a more specific class. To show how we defined this distinction for the interpretation of the survey sketches please refer to Figure 58$ below. Both (a) and (b) depict a bridge, but only (b) was classified as symbol, because (a) pertained certain characteristics of the original bridge, while the drawing in (b) is uses a rather symbolic approach.



(a) (b)

Figure 58 A symbolic (b) and a non-symbolic representation of a bridge (a).

sketch annotation: A sketch annotation can be everything between the title of the sketch and a legend. This class includes al written statements that are not explicitly bound to an object or a relation but bear some additional information for the understanding of the sketch.

surface object: This class contains all objects that have aerial characteristics, such as a parking area, a park, or an airport and that are not included in one of the other classes (e.g. vegetation, body of waters).

body of water: This class contains all natural and artificial bodies of water on the earth surface covered or not covered by other objects. Examples are: river, ocean, channel, or canalization.

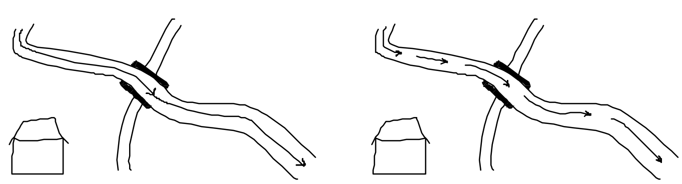
road element: A road element is in general a part of a road system but opposite to this one it has no line character. Hence, bridge, an highway exit or stairs can classify as road elements.

settlement: A settlement is a special area where there is human activity. Such this class can represent a town, a village or a district.

railway system: Similar as to the road system class, this class includes all artificial, human made structures that use rails for human made traffic. The objects in this class must have a line character.

vegetation: This class includes all natural or artificial forms of plantations, where vegetation is predominant. In this scope a meadow, forest, or a field are considered vegetation, but not a park. (Which is an arbitrary definition)

path: This class includes all symbolic representations that denominate an entire or partial path, not including multiple arrows, as this definition of a path involves some kind of connected-ness. The sketch (a) in Figure 59$ depicts a directional path while the representation in (b) would be considered as a sequence of directional arrows (direction indicators).



(a) (b)

Figure 59 A path (a) and a sequence of direction indicators (b).

distance: This class implies always an annotation of a distance that can be directly of type distance (e.g. distance in meter or feet) or of type time (e.g. 10 minutes along this road) that is mostly attached to an object with line characteristics, such as a road system object or a railway system object. Objects of this class can also be used to specify the dimension of an object (Refer also to Figure 60$ below).

boundary: Objects belonging to this class have mostly line characteristic and they do not qualify as areas. They can bound or delimit different objects and are frequently very vague.

structuring symbol: This class of object has as its name says a structuring function, in so far as an object of this class is used to graphically divide a sketch into more than one parts. An example of an object of this class is shown on Figure 60$.

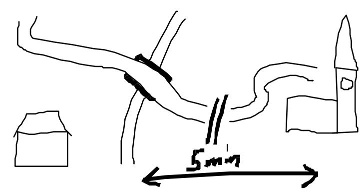


Figure 60 This sketch shows a structuring symbol and a driving distance in form of a time indication.

topographic feature: Objects that qualify for this class must be have a natural topographic character. That is, they must be of a structure that can be found in our environment. Hence, all truly natural features of our environment such as mountains, valleys, or an island can qualify. Human made topographic structures are considered belonging to this class if they have a natural character, such as it is the case with a hill resulting of a former waste deposal site planted with grass.

item: An item is small mobile thing that can not be classified by any of the other classes but that plays yet an role of a certain importance in the sketch. Example: suitcase

subspace: A subspace is an object within an other object that plays an important role. This is similar to the item class but conversely to that class the subspace class is immobile.

surface element: In contrary to the class of surface objects this class is concerned about objects that are neither buildings nor surface objects and that are smaller than buildings and that do not necessarily have a large aerial extension. Examples are: a monument or a fountain. Objects in this class may also be mobile, such as an airplane. Similar to the relation between road system and road element the class of surface elements depicts some sort of a sub-class of the surface object and buildings class.

11.4.2 Retrieved Object Types

Table 34 a and b list the object types that were found in the individual object classes.

Class Name	Count	Object Name
body of water	52	river
	26	brook
	5	sea
	4	channel
	1	boat landing
	1	lake
boundary	3	forest boundary
	2	costline
	1	beech
	1	city boundary
	1	riverbank
	1	scene boundary
building	68	house
	29	public building
	20	structure
	19	commercial building
	15	railway station
	15	shop
	14	office building
	14	store
	10	restaurant
	7	church
	6	fastfood restaurant
	4	bus stop
	4	hotel
	3	shopping mall
	2	bank
	2	booth
	2	cathedral
	2	gas station
	2	stadium
	2	subway station
	1	airport
	1	bar
	1	castle
	1	city hall
	1	hall
	1	kiosk
	1	market
	1	plant
	1	police
	1	theater
	1	train station
	1	tram station
	1	university

Class Name	Count	Object Name
direction	67	direction indication
	65	north direction
	5	directional route
	4	walking direction
	1	driving direction
	1	path direction
	1	point indication
	1	view direction
distance	23	distance indication
	2	hight indication
item	2	suitcase
	1	sign
path	13	path
railway system	14	railway track
	2	tram track
	1	railway item
	1	railway terminal
road element	37	bridge
	5	highway exit
	4	rotary
	4	underpass
	2	stairs
	1	intersection
	1	traffic island
road system	182	street
	34	trail
	5	highway
	3	interstate
settlement	27	city
	8	town
	8	village
sketch annotation	8	legend
	5	city name
	5	direction indication
	5	sketch description
	3	scale
	3	sketch comment
	3	town name
	2	detail
	2	place name
	1	building complex
	1	building name
	1	map specification
	1	orientation annotation
	1	settlement
	1	view point
	1	village name

Table 36a Retrieved object types sorted and grouped by their affiliation to the object classes (part a).

Class Name	Count	Object Name
structuring symbol	16	scene connector
subspace	1	office
	1	store
surface element	2	fountain
	2	monument
	1	tour buses
surface object	14	parking area
	7	park
	7	plain
	7	square
	2	city district
	2	commercial district
	1	air force base
	1	airport
	1	island
	1	perron
	1	pier
	1	shopping mall
	1	university district
symbol (part a)	21	traffic light
	13	bridge
	6	rock
	6	stairs
	4	cross
	4	hotel
	4	train
	3	airport
	3	view
	3	view point
	3	walking man
	2	city
	1	campus

Class Name	Count	Object Name
symbol (part b)	21	traffic light
	1	cathedral
	1	coffee shop
	1	compass rose
	1	fastfood restaurant
	1	item
	1	metro station
	1	mountain summit
	1	ship, fish
	1	start
	1	street sign
	1	sun
	1	swimming pool
	1	tower
	1	tram
topographic feature	27	mountain
	22	rock
	19	delta
	9	canyon
	7	plain
	4	hill
	3	mountain side
	2	mountain top
	2	slope
vegetation	23	jungle
	4	tree
	3	forest
	2	field
	2	lawn
	2	park
	1	alley
	1	mall

Table 36b Retrieved object types sorted and grouped by their affiliation to the object classes (part b).

11.4.3 Object Dimensionality

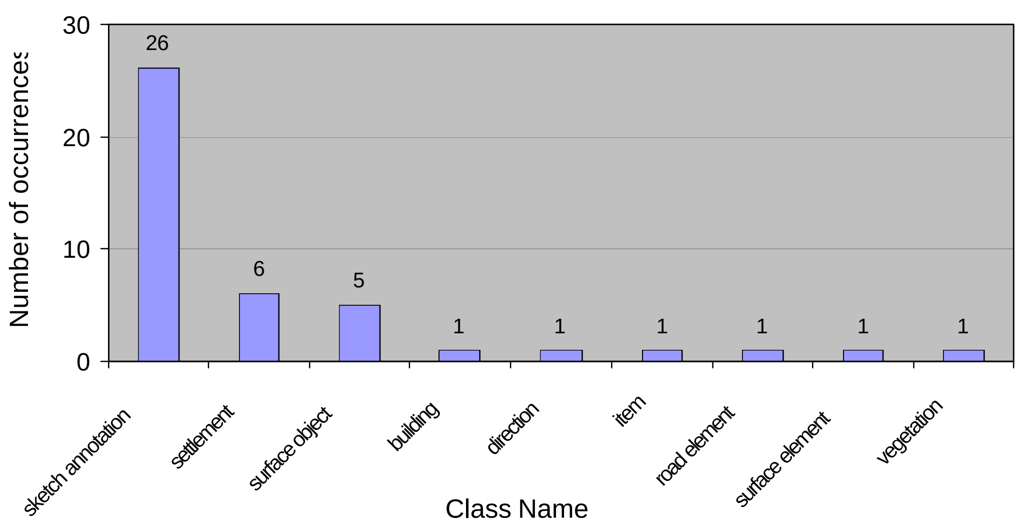


Figure 61 Distribution of zero-dimensional objects sorted by class frequency (Scenarios 1 & 2).

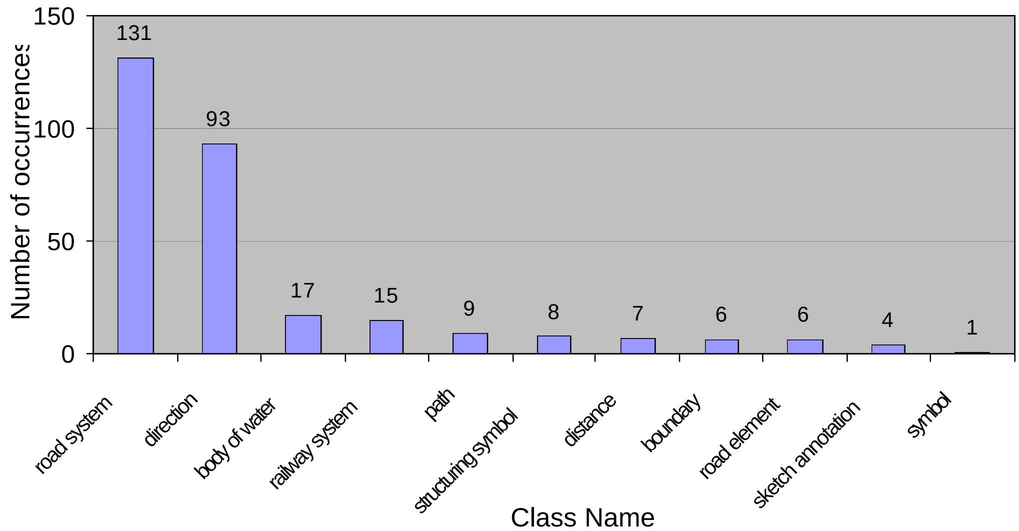


Figure 62 Graph with the distribution of one-dimensional objects in the surveyed sketches by classes (Scenarios 1 & 2).

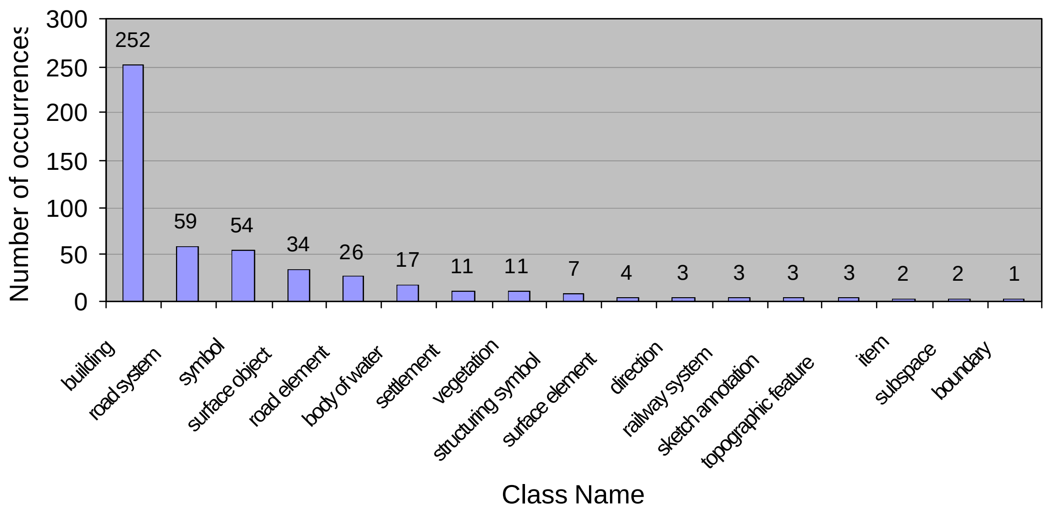


Figure 63 Graph with the distribution of two-dimensional objects in the surveyed sketches by classes (Scenarios 1 & 2).

11.4.4 Object Shapes

Symbolic Shapes		
Num	**%**	**Class Name**
138	28%	direction
88	18%	symbol
47	10%	building
34	7%	topographic feature
25	5%	distance
25	5%	road system
24	5%	settlement
19	4%	road element
16	3%	body of water
16	3%	structuring symbol
15	3%	vegetation
11	2%	sketch annotation
10	2%	surface object
9	2%	path
5	1%	boundary
5	1%	railway system
2	0%	item
1	0%	surface element
490	?	**(42%)**

Semi-symbolic Shapes		
Num	**%**	**Class Name**
199	31%	building
193	30%	road system
69	11%	body of water
58	9%	topographic feature
33	5%	road element
30	5%	surface object
21	3%	vegetation
13	2%	railway system
12	2%	settlement
5	1%	direction
4	1%	path
4	1%	boundary
2	0%	surface element
643	?	**(56%)**

Realistic Shapes		
Num	**%**	**Class Name**
6	29%	building
6	29%	road system
3	14%	body of water
2	10%	subspace
1	5%	road element
1	5%	surface element
1	5%	surface object
1	5%	topographic feature
21	?	**(2%)**

Table 37 Distribution of classes depending on object shape (Scenarios 1, 2 & 3).

Symbolic		***Semi-Symbolic***		***Realistic***		**Class Name**
Num	**1:X**	**Num**	**1:X**	**Num**	**1:X**	
138	***28***	5	***1***	0	-	direction
88	***X***	0	-	0	-	symbol
47	***8***	199	***33***	6	***1***	building
34	***34***	58	***58***	1	***1***	topographic feature
25	***X***	0	-	0	-	distance
25	***4***	193	***32***	6	***1***	road system
24	***2***	12	***1***	0	-	settlement
19	***19***	33	***33***	1	***1***	road element
16	***5***	69	***23***	3	***1***	body of water
16	***X***	0	-	0	-	structuring symbol
15	***1***	21	***1***	0	-	vegetation
11	***X***	0	-	0	-	sketch annotation
10	***10***	30	***30***	1	***1***	surface object
9	***2***	4	***1***	0	-	path
5	***1***	4	***1***	0	-	boundary
5	***1***	13	***3***	0	-	railway system
2	***X***	0	-	0	-	item
0	-	0	-	2	***X***	subspace
1	***1***	2	***2***	1	***1***	surface element

Table 38 Comparison of frequency/ratio of occurrence of objects in different shape categories (Scenarios 1, 2 & 3). A capital X indicates that this objects occurred only in one category.

1D-type shapes only		
Num	%	Class Name
213	67%	straight
64	20%	curved
41	13%	complex
318	?	**(40%)**

2D-type shapes only		
Num	%	Class Name
228	58%	box
106	27%	complex
31	8%	square
22	6%	circle
7	2%	oval
387	?	**(49%)**

1D-type and 2D-type shapes		
Num	%	Class Name
47	62%	straight - complex
16	21%	curved - complex
9	12%	straight - box
3	4%	complex - complex
1	1%	straight - circle
1	1%	complex - circle
76	?	**(10%)**

Table 39 Distribution of objects concerning their affiliation to the different shape types. (Scenarios 1 & 2).

1D-type shapes only		
Num	%	Class Name
288	59%	straight
128	26%	curved
70	14%	complex
486	?	**(43%)**

2D-type shapes only		
Num	%	Class Name
234	46%	box
210	41%	complex
32	6%	circle
32	6%	square
14	3%	oval
508	?	**(45%)**

1D-type and 2D-type shapes		
Num	%	Class Name
70	49%	straight - complex
31	22%	curved - complex
30	21%	complex - complex
10	7%	straight - box
2	1%	straight - circle
2	1%	complex - circle
143	?	**(12%)**

Table 40 Distribution of objects concerning their affiliation to the different shape types. (Scenarios 1, 2 & 3).

Objects with a complex 2D-type shape		
Num	%	Class Name
44	21%	topographic feature
33	16%	symbol
30	14%	building
22	10%	settlement
20	10%	road element
20	10%	road system
15	7%	vegetation
12	6%	surface object
8	4%	body of water
4	2%	sketch annotation
2	1%	surface element
210	?	

Table 41 Distribution of objects with a complex 2D-type shape (Scenarios 1 & 2 & 3).

11.4.5 Composite Object

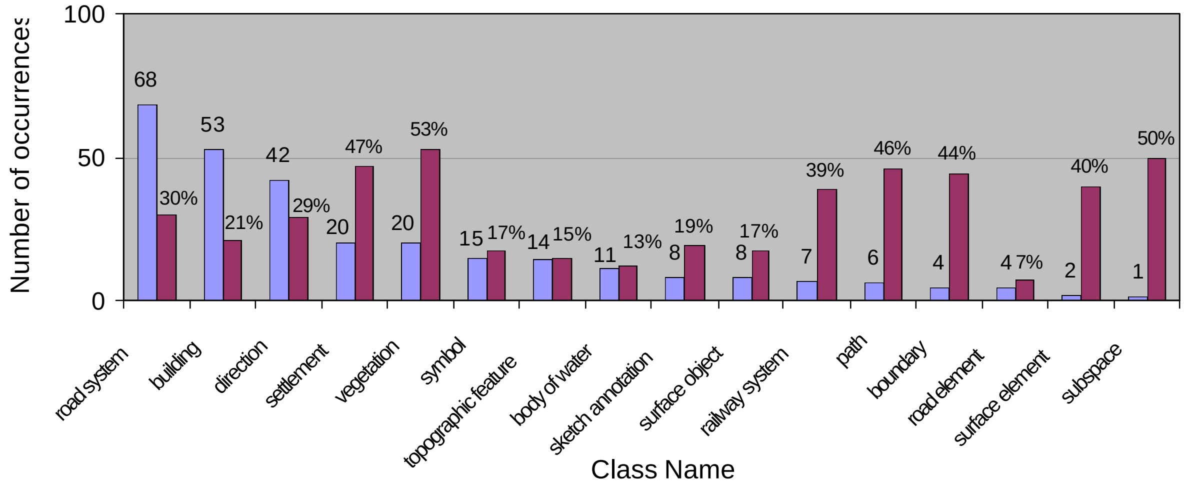


Figure 64 This graph shows the number of composite objects in each class (left column) and the ratio between composite and non-composite objects of each class (right column) e.g. there were 20 composite vegetation objects that represent 53% of all vegetation objects (Scenarios 1, 2 & 3).

11.4.6 Object Texture

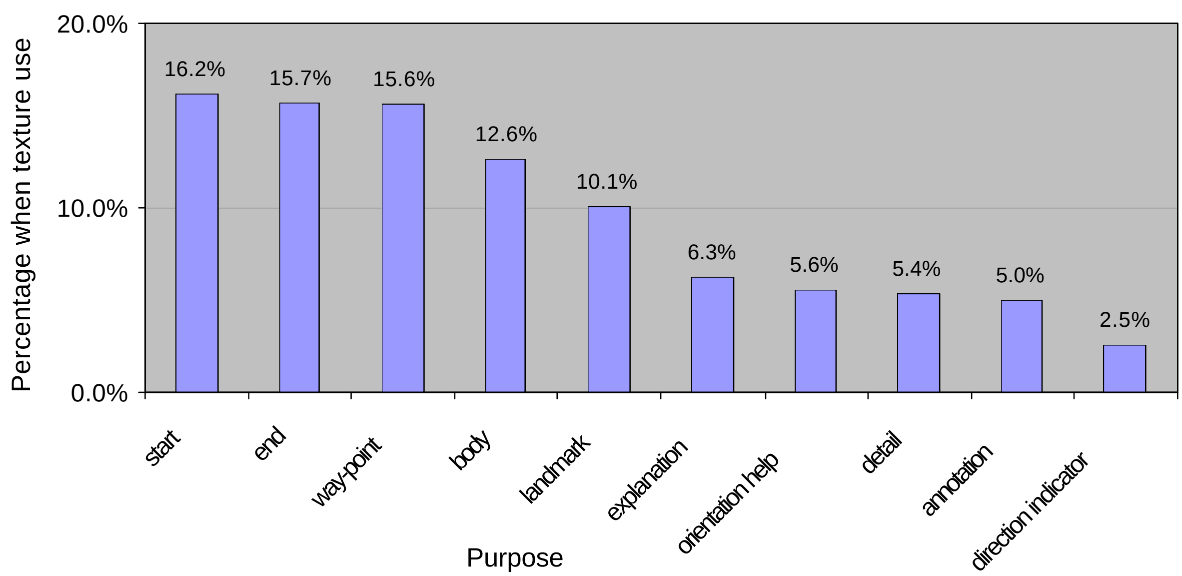


Figure 65 This graph shows the portion of objects divided in to categories by their purpose that used texture. For example 16.2% of all objects that were classified being a starting point have also a attribute for texture, and consequently 83.8% do not.
(Scenarios 1, 2 & 3).

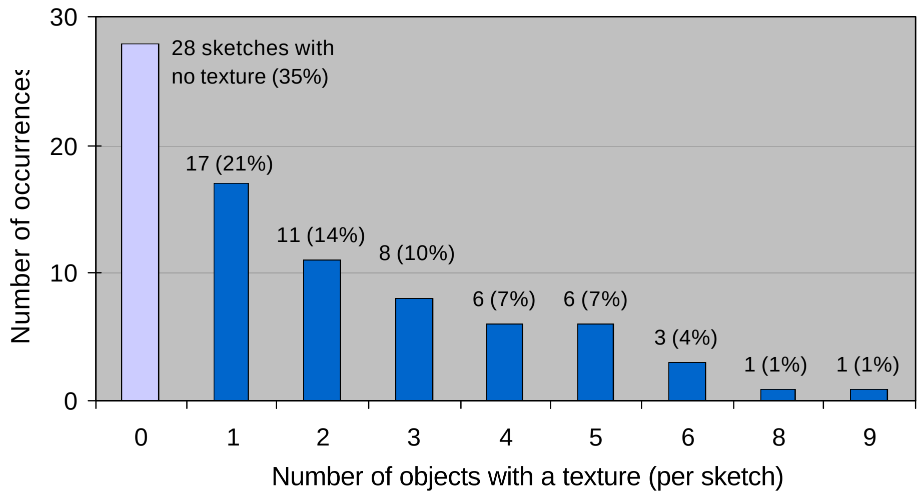


Figure 66 Number of sketches that have one or more objects with a texture compared with sketches that contain no textured objects. (Scenarios 1, 2 & 3).

11.4.7 Object Completeness

	%		
Stat. Value	***Complete***	***Partial Complete***	***Incomplete***
Average	49%	46%	7%
Variance	104%	102%	28%
Min	30%	25%	2%
Max	72%	70%	18%

Table 42 This table compares the standardized (every survey has equal weight) frequencies in which objects are drawn at different levels of completeness–so the average in the above table is actually the average of the ratio of all individual sketches–. This is in contrary to Table 3$ in the Report, where the analysis is made over the entire set of objects based on our classification for completeness. The variance is declared as percentage of the average value of the specific category. (Scenarios 1, 2 & 3).

11.4.8 Number of Object per Sketch

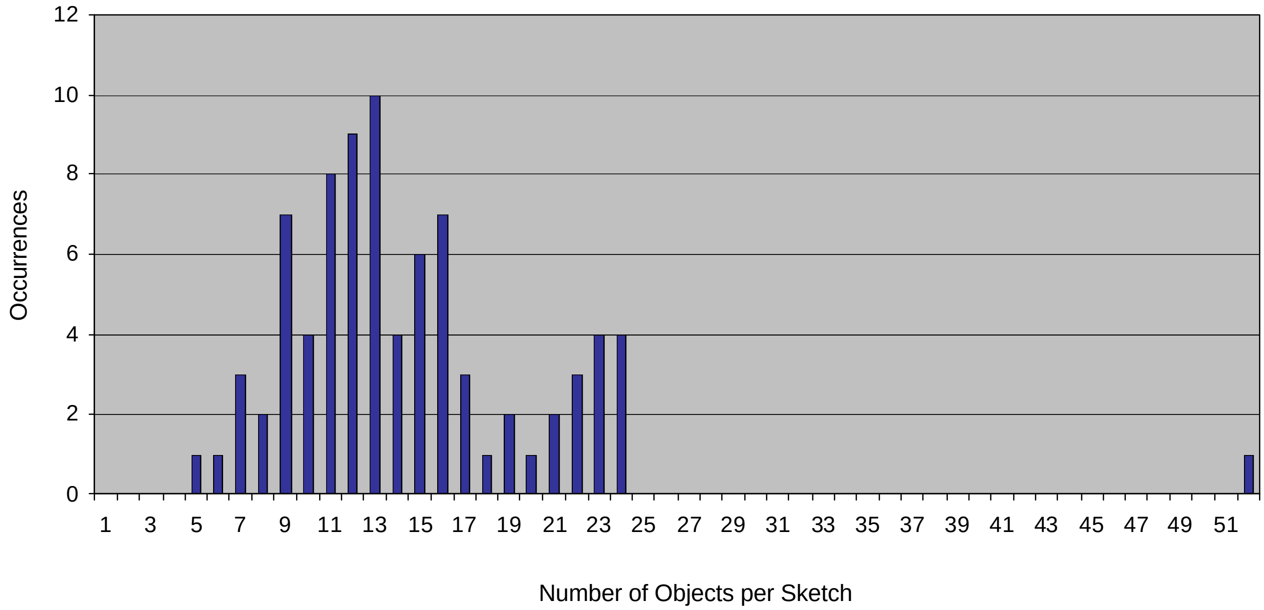


Figure 67 This histogram shows that most sketches contain only a relatively small number of sketched objects. The irregularity around 23 objects per sketch is due to scenario two and caused by the fact that people have different scene recalling capacities. This is also shown on the next Figure 68$. (Scenarios 1, 2 & 3).

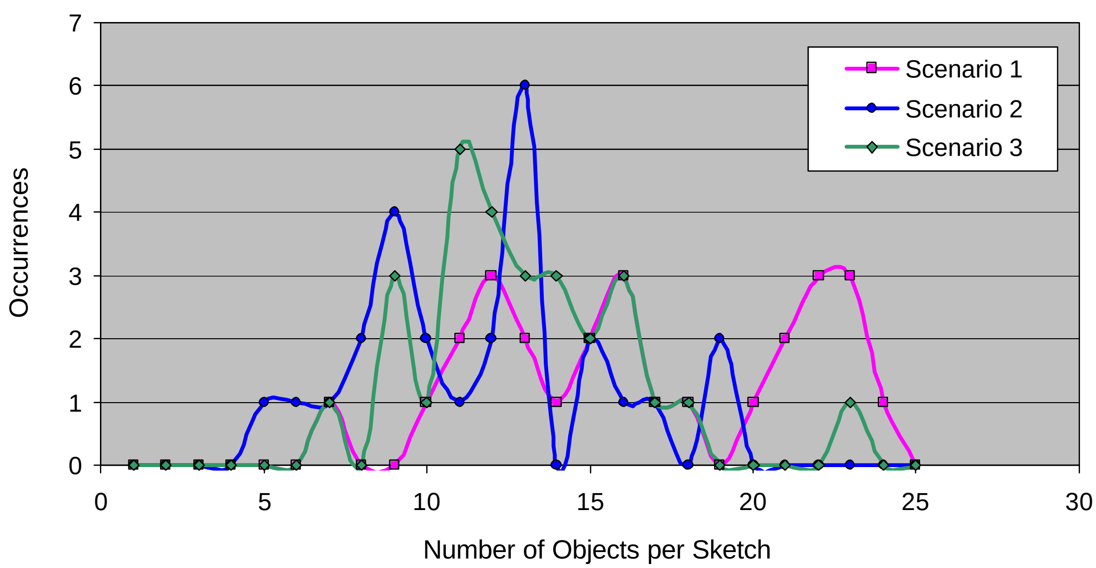
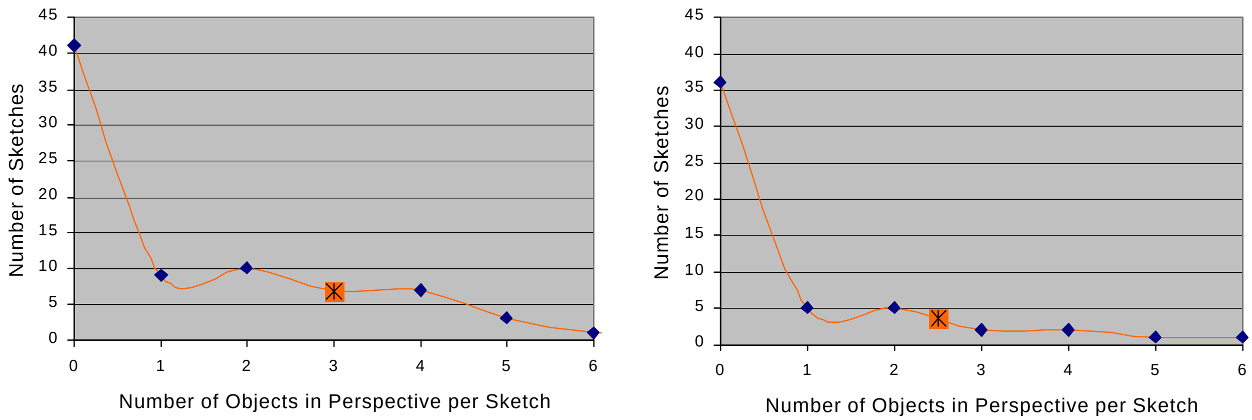


Figure 68 This graph shows a histogram for all three sketching problems, indicating the number of objects per sketch. One sketch with 52 sketch-objects has been excluded for this particular representation.



(a) (b)

Figure 69 These two histograms show how many objects per sketch are drawn with a perspective. The left graph (a) takes all sketches of the survey into account, while the one on the right (b) focuses on the first two scenarios. The average of perspective objects per sketch is depict with a cross symbol. This average is based on sketches that have at least one perspective object.

11.4.9 Metric Descriptors of Objects

	Count	Direction Type
	910	no direction
25%	214	single arrow
	15	double arrow
	69	multiple arrows
	1208 ?	

Count	Object Class
105	direction
66	road system
23	body of water
12	distance
6	path
5	road element
5	sketch annotation
3	railway system
2	structuring symbol
2	symbol
229 ?	

Count	Object Class
32	direction
26	road system
6	path
2	symbol
1	building
1	road element
1	sketch annotation
69 ?	

Table 43 These tables show the distribution of objects that have a directional component as well as their affiliation concerning the type of directional component and the different object classes. The percentage in the last column indicates the ratio in respect to the total number of objects in this class, while the percentage in parentheses refers to the ratio in respect to the directional group. (Scenarios 1, 2 & 3).

Scenarios 1 & 2 & 3		
Count	**Class**	**Name**
23	distance	distance indication
15	road system	trail
9	direction	direction indication
6	structuring symbol	scene connector
3	path	path
3	sketch annotation	scale
2	distance	hight indication
2	road system	street
1	direction	view direction
1	sketch annotation	legend
65	?	(5.4% of all sketched objects)

Scenarios 1 & 2			
Count	**Class**	**Name**	**%**
7	distance	distance indication	30%
1	direction	direction indication	11%
6	structuring symbol	scene connector	100%
2	sketch annotation	scale	67%
2	road system	street	100%
18	?	(1.5% of all sketched objects)	

Table 44 Listing of objects that have an attached distance indication.

11.4.10 Virtual Object

Area Objects		
Count	**Class**	**Name**
3	settlement	city
3		town
1		village
5	sketch annotation	city name
3		town name
2		place name
1		building complex
1		settlement
1		village name
2	surface object	square
1		air force base
1		city district
1		island
1		plain
1	topographic feature	delta
1		plain
1	vegetation	field
1		jungle
30	?	

Sketch Annotations		
Count	**Class**	**Name**
5	sketch annotation	legend
5		sketch description
3		sketch comment
1		map specification
14	?	

Sketch Details		
Count	**Class**	**Name**
1	building	office building
1	item	suitcase
1	road element	intersection
2	sketch annotation	detail
1		building name
1	surface element	monument
7	?	

Orientation & Direction		
Count	**Class**	**Name**
2	direction	north direction
1	sketch annotation	orientation annotation
3	?	

Table 45 Detailed distribution of virtual objects that consist only of an annotation, without any associated sketched object. (Scenarios 1, 2 & 3).

11.4.11 Object Purpose

Description of the Purpose Categories

In the following part we describe the set of purpose categories that was used to classify sketched objects in our survey. Objects can have more than one purpose classification. The ordering of the listing is taken from the interpretation sheet of the survey:

body:	This category is very broad and can comprehend drawn objects from all classes. To qualify, an object must not be too prominent within the sketched context (otherwise it may qualify as an orientation help or a landmark). Objects of this category help understanding the context they are the “meat” of a sketch. Examples are houses along a street or a network of streets in a city.
start:	Objects with this classification are part of a path classification of which they denominate the beginning. Often such objects are marked with a cross. A sketch can have more than one start, such as when multiple partial scenes are drawn with a different scale but with the same objects. ✍ close-up look at a scene.
end/focus:	Similar to the start categorization, but denominating the end of a path. Additionally this tag can be used to mark the focus of a sketch, without the need to involve any path schema. Example: A user sketches the plan of a town and marks the place of interest with a red circle.
way-point:	This is the third important categorization for a path. A way-point is used for an object that is on the path and that has a special meaning that is somewhat connected to the path. Examples are an explicitly drawn bridge on a path or a prominent intersection of two roads.
orientation-help:	Objects that are classified as *orientation-help* provide the sketch interpreter with information that he or she needs to cope with the sketch. This information goes beyond that of objects classified as body, because body objects are not specific enough. Example of objects classified as *orientation-help* are north-arrows or a explicitly drawn park on one side of a road.
landmark:	This is the strongest of all orientation categories (*body* < *orientation-help* < *landmark*). Landmarks denote prominent features in a sketch that can easily by identify by a user, such as a cathedral or a main railway station. However, the transition from all three orientation categories is fluent and dependent on the interpretation of a sketch.
detail:	Objects can be classified as *details* when they add a more specific notion to a sketch. Such details are often overlooked when a sketch is examined at first glance, but they can become in handy for a more detailed analysis. Examples are a specially shaped house, an island in a lake, or named bus station. Therefore, the detail purpose is often used in conjunction with other purpose classifications. E.g. body and detail.
direction-indicator:	This type of object is used to indicate a direction. Although most objects that belong to this class are directional arrows, it is feasible that other symbols, such as signpost are used to give the user directional information as well.
distance-indicator:	Similar to the definition of the direction-indicator above, the distance-indicator purpose category depicts an object that contains an indication of distance, whether in a direct (distance) or indirect form (time indication).

link: This rarely used purpose type is attributed to objects that link two or more different sketched scenes together. A link-object can for instance be a simple arrow, a line, or street with an interruption and a dotted part.

path: This purpose category needs not much explanation, it is given to objects that show or guide through a specific route through the sketch. Sketches with path objects do frequently have start and end purpose object as well.

explanation: An explanation in this context is a graphical of written annotation to a sketch that defines, explains, or describes the sketch or a part of a sketch that would be ambiguous without such an explanation. An explanation purpose object gives an answer to the question: “What is this?”

boundary: A boundary in the context of a sketch is defined as a line that clearly delimits two or more regions from each other. A coast-line or a forest boundary can qualify, therefore, for this purpose category.

annotation: This type of category is primarily used for objects that are defined without drawing, such as for objects of the *sketch annotation* object class. Opposite to the explanation category the *annotation* is primarily used to provide additional information for the sketch in general, such as a legend or a scale.

structuring object: These objects have been sparingly used in our survey. They have typically a symbolic character and are used to differentiate multiple parts of a sketch. Objects of the *structuring symbol* object class are an example (refer to the definition of object classes under 11.4.1).

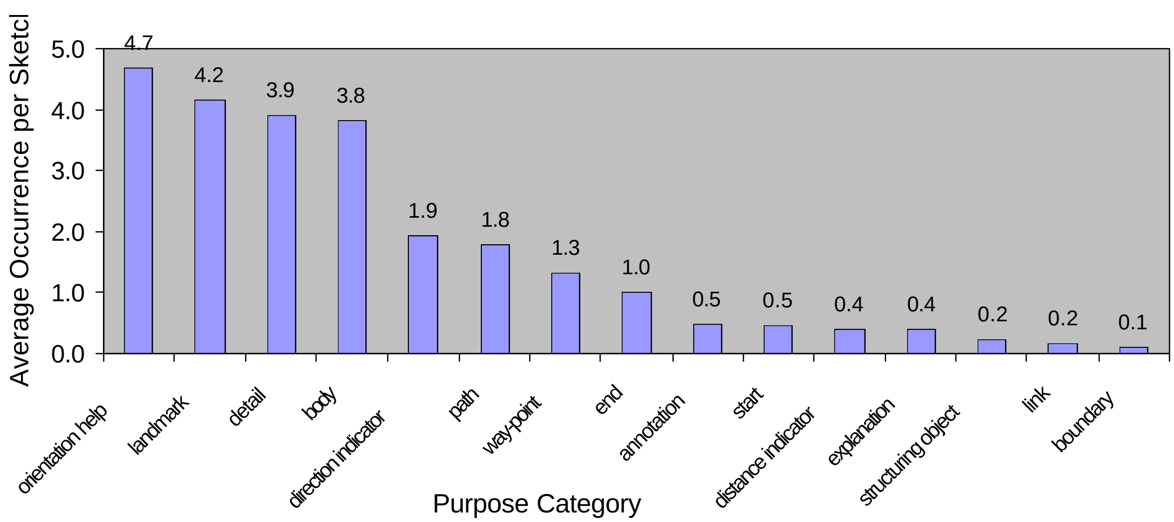


Figure 70 This graph shows the relation between the number of occurrences of the 15 purpose categories based on the entire set of objects from all sketching scenarios. The frequency is depict on a per sketch basis. See also Figure 20$ in the Technical Report. (Scenarios 1, 2 & 3).

Purpose *(averaged per sketch)*	**All Scenarios**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Std Dev**	**% of Average**
orientation help	4.7	5.2	6.1	3.3	2.9	63%
landmark	4.2	4.1	4.7	4.2	2.6	61%
detail	3.9	4.6	4.0	3.6	2.9	74%
body	3.8	4.6	3.9	3.4	2.3	60%
direction indicator	1.9	2.7	1.4	1.9	1.6	84%
path	1.8	3.6	0.5	1.5	2.5	136%
way-point	1.3	2.4	0.4	1.3	1.7	126%
end	1.0	1.0	1.2	1.0	0.4	34%
annotation	0.5	0.7	0.5	0.4	0.8	164%
start	0.5	1.0	0.2	0.1	0.6	130%
distance indicator	0.4	0.3	0.1	0.9	1.0	235%
explanation	0.4	0.5	0.2	0.5	0.9	218%
structuring object	0.2	0.5	0.1	0.1	1.0	406%
link	0.2	0.4	0.0	0.1	0.6	375%
boundary	0.1	0.0	0.3	0.1	0.4	324%

Table 46 This table shows the average number of sketch objects with a specific purpose tag for all scenarios and for each individual scenario. E.g. In scenario 2 every sketch has, in average, 4.0 objects with a *detail* tag. The last two columns indicate the standard deviation in respect to all scenarios and the ratio between standard deviation and average in percent. The interval with the limits *average value +/- standard deviation* represents 68% of all cases of a category. A small percentage signals a small variation and a relatively steady number of objects with a specific purpose tag in a sketch. The standard deviation is calculated over all scenarios and all objects.

11.5 Object Relations

11.5.1 Philosophical Thought about Reality, Knowledge, Spatial Relations, and Space Perception

The following abstracts originate mostly from the standard edition of the *Encyclopedia Britannica* and provide interesting thoughts about impulses in respect to how people perceive, interpret, and process the space and reality they live in.

Reality

Nagarjuna, and Indian Philosopher, States that *the one reality is ineffable*. He undertook a critical examination of all the major categories with which philosophers had sought to understand reality and showed them all to involve self-contradictions. The world is viewed as a network of relations, but relations are unintelligible. If two terms, A and B, are related by the relation R, then either A and B are different or they are identical. If they are identical, they cannot be related; if they are altogether different then they cannot also be related, for they would have no common ground. The notion of "partial identity and partial difference" is also rejected as unintelligible. The notion of causality is rejected on the basis of similar reasonings. The concepts of change, substance, self, knowledge, and universals do not fare any better.

Origin and nature of knowledge

David Hume argues that *Human thought concerns two kinds of things: relations of ideas and matters of fact*. Relations of ideas can either be intuited, that is, seen directly, or deduced from other propositions. That *a* is identical with *a*, that *b* resembles *c*, and that *d* is larger than *e* are examples of propositions that are intuited. The opposites of true propositions expressing relations of ideas are contradictory. Arithmetic and algebra are the subjects about which there can be the most certainty. In his *A Treatise of Human Nature* (1739–40) Hume says that geometry is almost as certain as these, but not quite, because its original principles derive from sensation, and about sensation there can never be absolute certainty. In contrast with relations of ideas, matters of fact are derived from experience. Experience, however, would be quite limited if it did not include causal relations, which go beyond what is experienced.

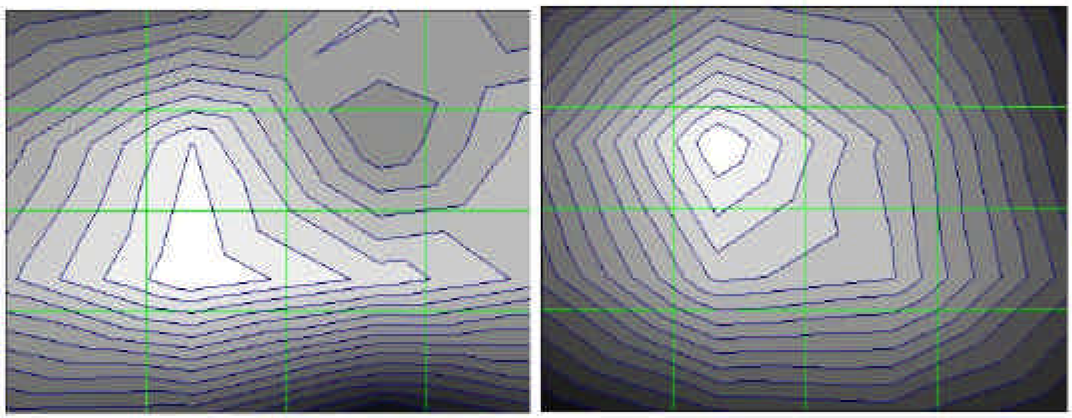
Perception of Space

Space perception is the process through which organisms become aware of the relative positions of their own bodies and objects around them. Space perception provides cues, such as depth and distance, that are important for locomotion and orientation to the environment. Detailed understanding of space perception has only come in the last hundred years. In the 18th century the British philosopher George Berkeley proposed that since the image on the retina is two-dimensional, an individual must learn to interpret visual data so as to deduce the spatial relations between objects of sight. Psychologists now believe, however, that there are certain innate elements in the ability to perceive space. The current study of space perception is concerned with a variety of complex issues, including the ability to judge the full shape of objects of which only one side is visible, and how pilots can compensate for unusual perceptual cues while navigating airplanes or spacecraft.

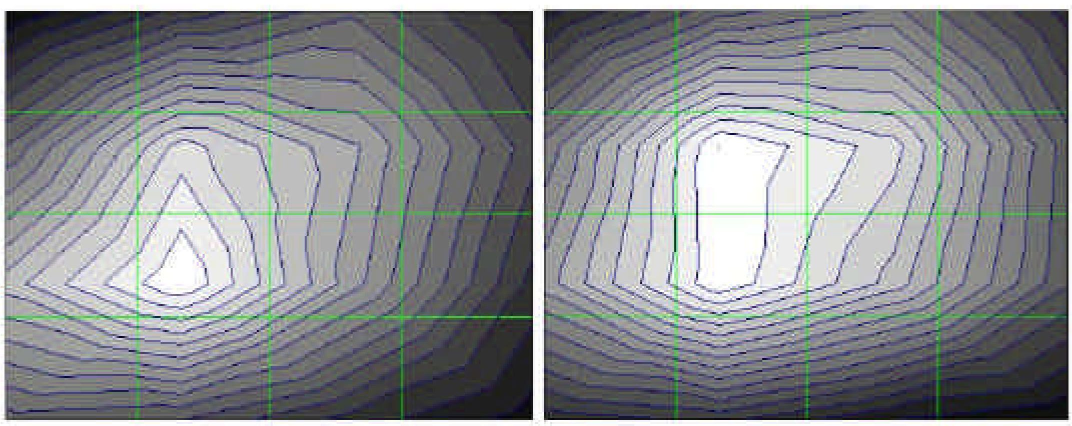
Space perception is thought to serve the general purpose of orientation, i.e., of aiding an individual to grasp his position in relation to the objects around him. Perceiving one's spatial relation to a given object is more important the more relevant the object is to one's needs. For example, organisms are particularly sensitive to stimuli that warn them of dangers along their paths. Thus, space perception involves, in a central role, the selection of relevant sense data. Sense data that do not bear on one's needs are excluded, so that the incoming flow of information is not overwhelming.

Another important feature of space perception is its ability to account for motion. When an object moves in relation to the perceiver, or vice versa, the stimuli presented to his senses are changed. However, he interprets the change in shape of an image on the retina, for example, not as a change in the shape of the given object, but as evidence that the object has changed its position in space, relative to the eye. That is, space perception relies on perceptual constancy, without which the world would seem inconceivably chaotic.

11.5.2 Object Location

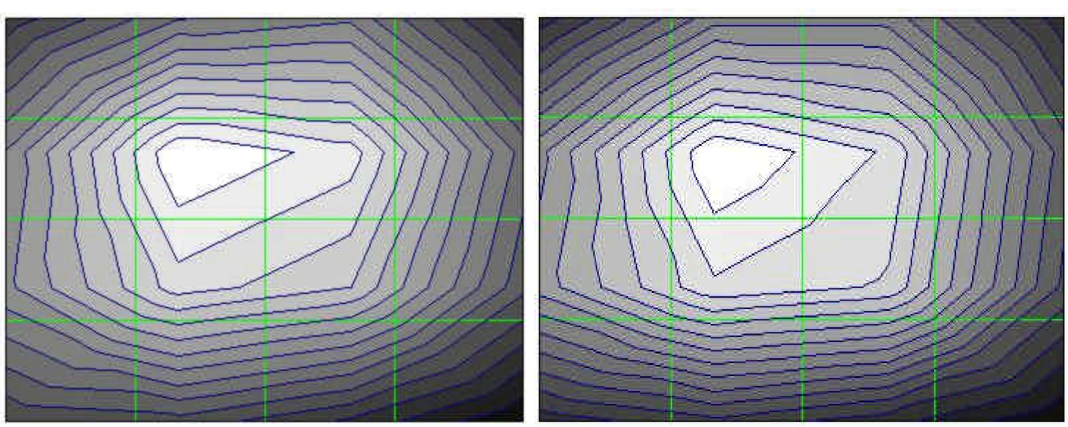


(a) (b)

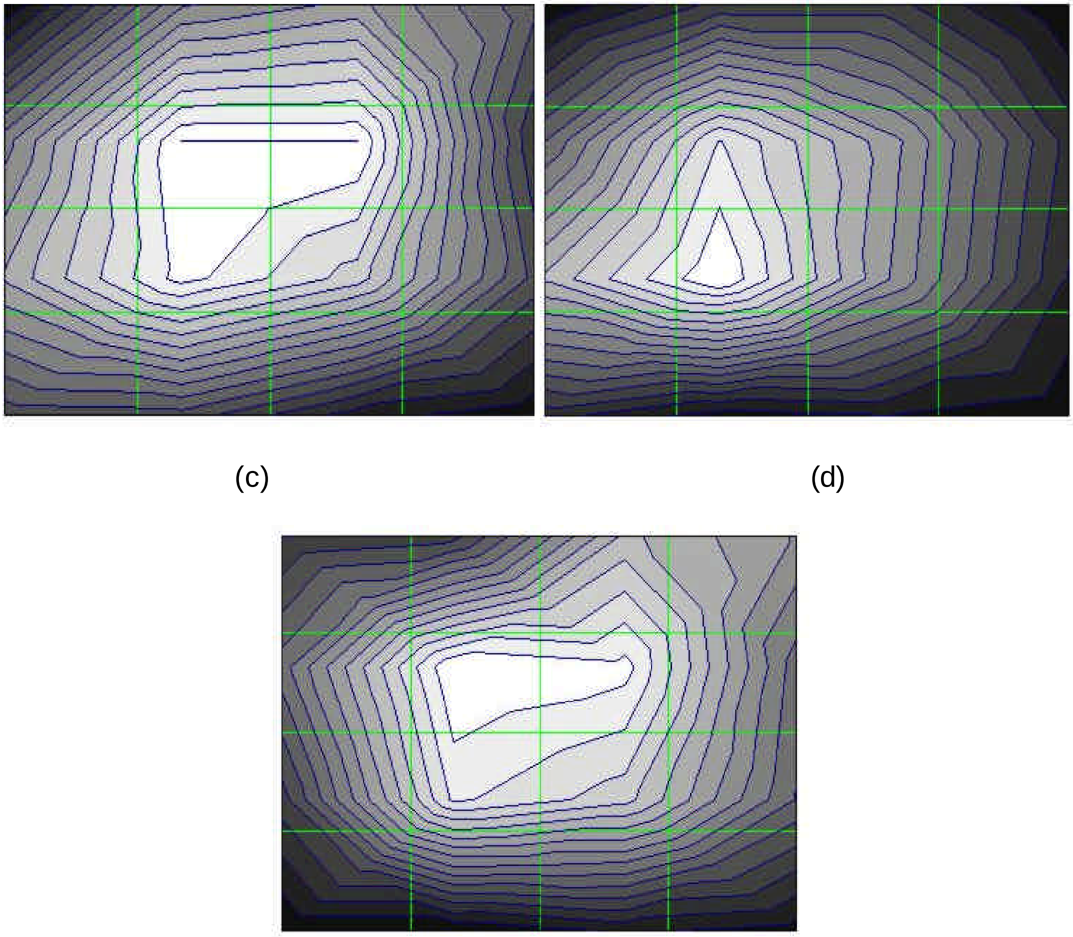


(c) (d)

Figure 71 Contour plot of the frequency with that objects were drawn on the particular scenarios (Scenario 1 = (a), Scenario 2 = (a), Scenario 3 = (c)) and averaged over all three scenarios (d).



(a) (b)



(c) (d)

(e)

Figure 72 Contour plots showing the frequency of objects depending on their purpose class: body objects (a), orientation-help objects (b), landmark objects (c), detail objects (d), and direction objects (e). (Scenarios 1, 2 & 3).

11.5.3 Object Orientation

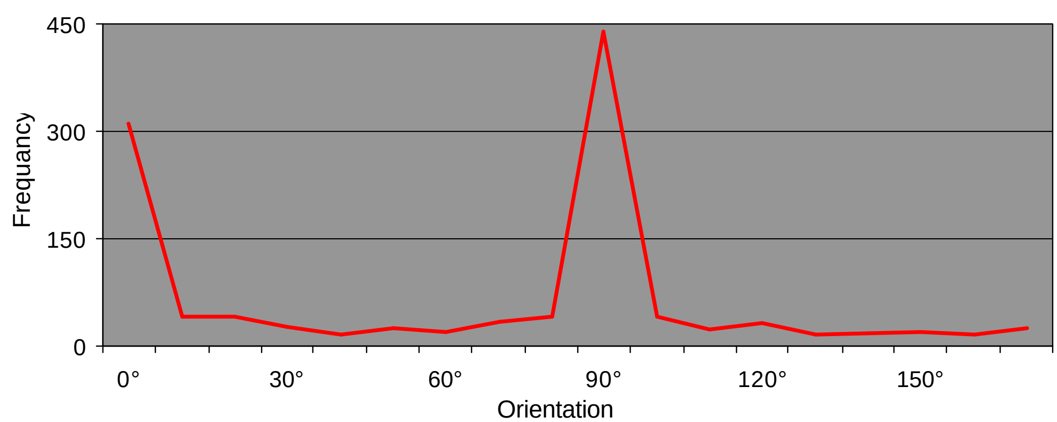


Figure 73 This graph shows orientation and occurrence frequency of all sketched object over the entire survey.

11.5.4 Object Direction

Sketch Orientation	Count	Sketch Orientation	Count
0°	**78**	**180°**	**39**
10°	10	190°	3
20°	9	200°	3
30°	11	210°	3
40°	6	220°	1
50°	5	230°	1
60°	8	240°	1
70°	4	250°	1
80°	12	260°	2
90°	**81**	**270°**	**66**
100°	5	280°	5
110°	3	290°	5
120°	6	300°	8
130°	6	310°	
140°	4	320°	7
150°	2	330°	3
160°	4	340°	1
170°	5	350°	4

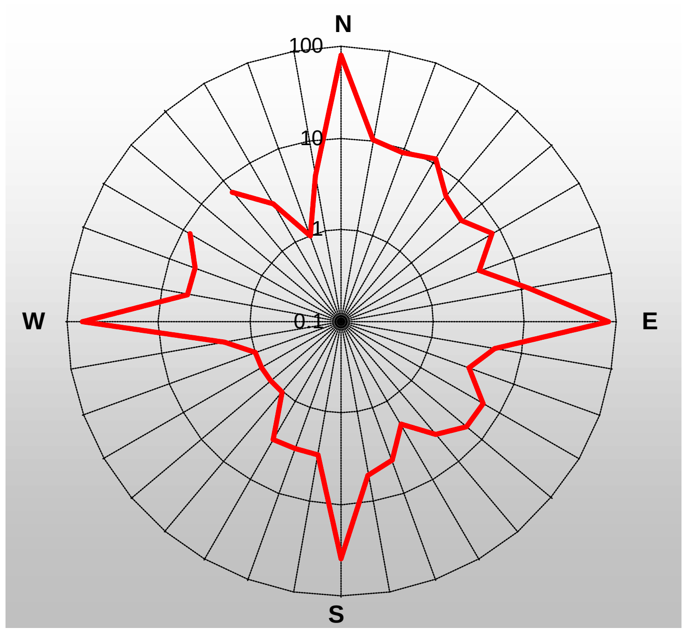
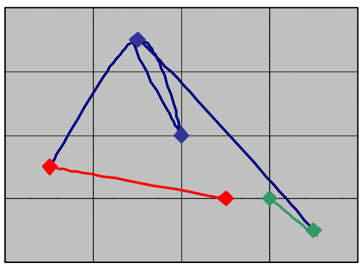


Figure 74 This radial graph has a logarithmic scale and represents the frequency of objects with an indicated directions. (Scenarios 1, 2 & 3).

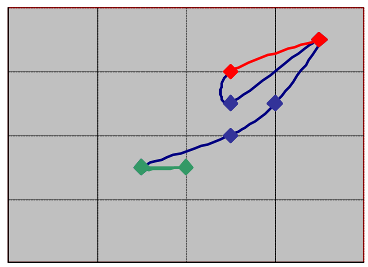
11.5.5 Spatial Object Sequence

The polygons on the graphs below depict the temporal sequence in which the objects have been drawn. The first two objects drawn are marked with a green diamond, connected with a green arc. The last to objects are represented with a red diamond and connected with a red arc. All objects in between have blue diamonds and arcs. Objects that covered more than four cells are excluded, as are objects that stretch over four cells in a row (e.g. all cells of the top row). The expressed location of an object is defined as the geometrical center of the cells it was contained in.

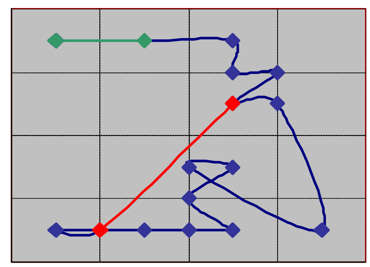
Object Sequence in Scenarios 1



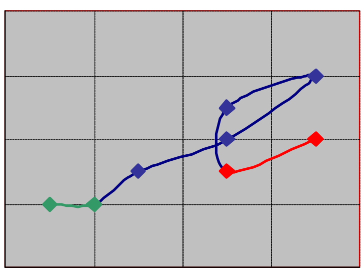
1 (Loop)



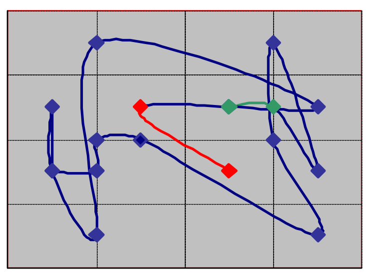
2 (S-path)



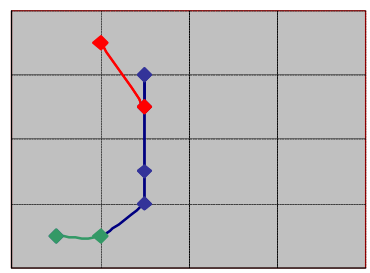
3 (Zigzag)



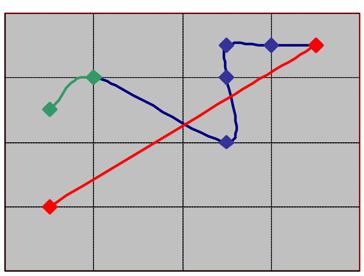
4 (Loop)



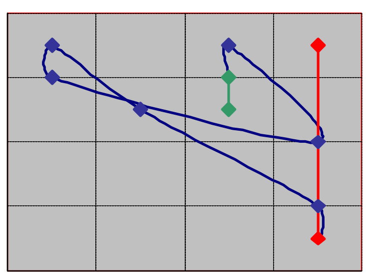
5 (Zigzag)



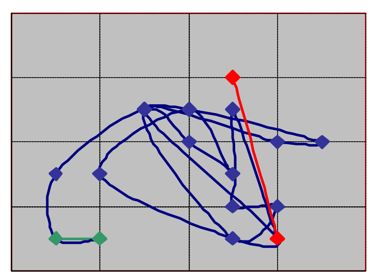
6 (Curve/straight)



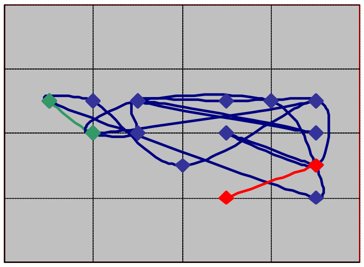
7 (S-path)

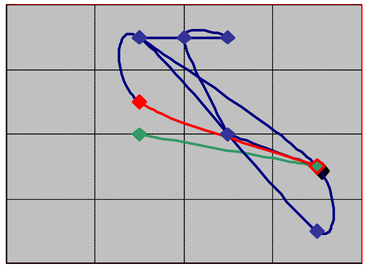


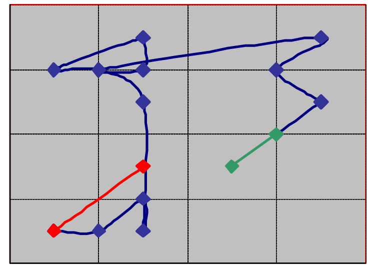
8 (Loop)

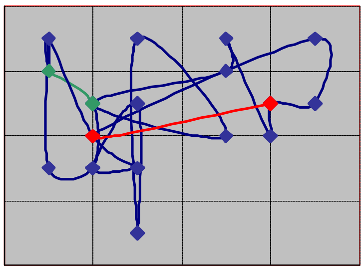


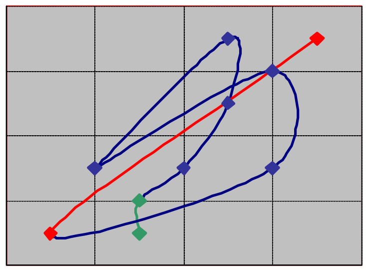
9 (Random)

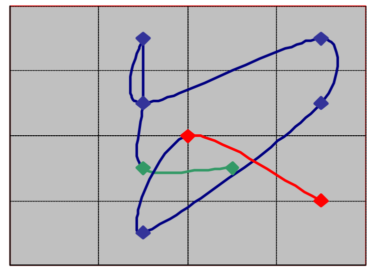

10 (Random)

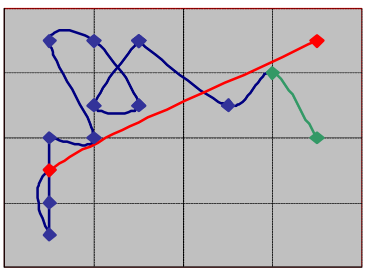

12 (Random)

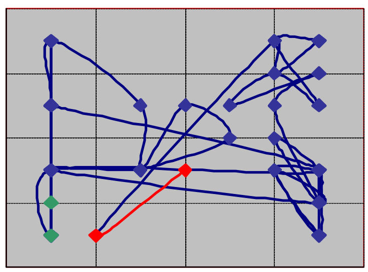

13 (Zigzag)

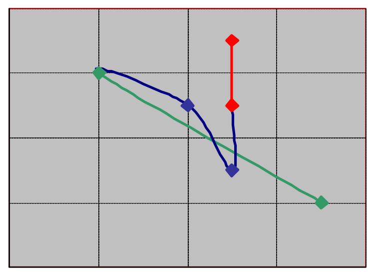

14 (Zigzag)

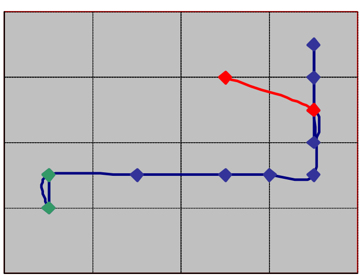

15 (Loop)

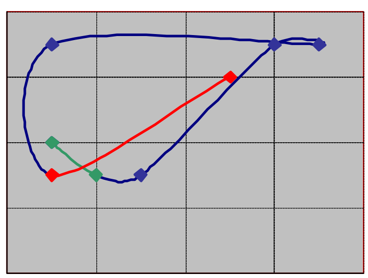

16 (Loop)

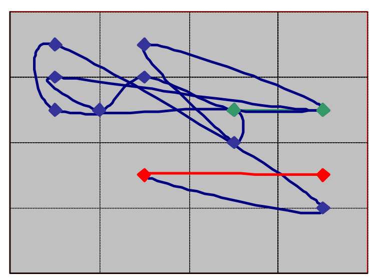

17 (S-path)

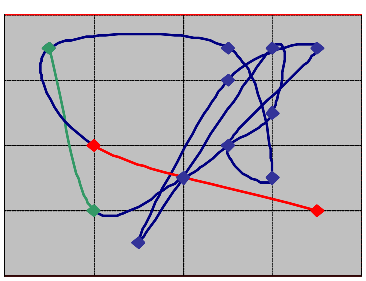

18 (Zigzag)

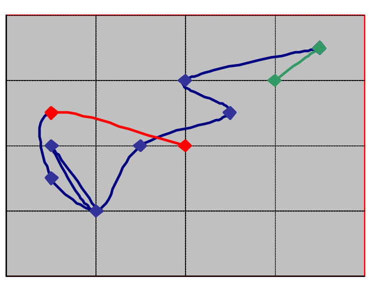

19 (Loop)

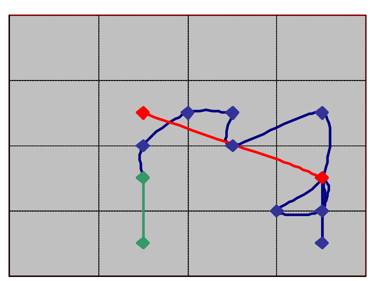

21 (Curve/straight)


22 (Loop)

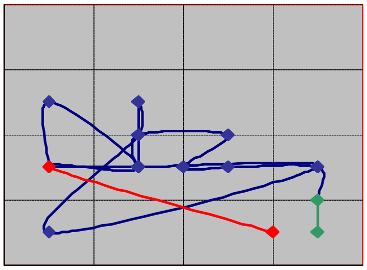

23 (Random)



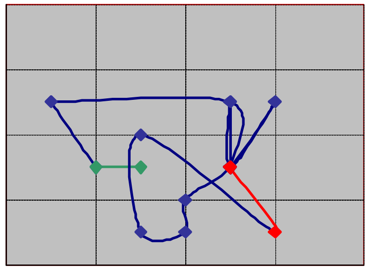




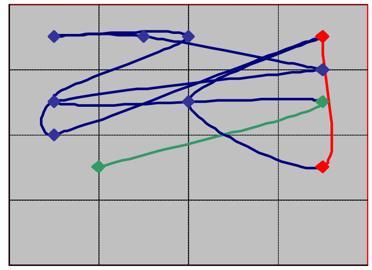
24 (Loop) 25 (S-path) 26 (S-path)



27 (Zigzag)

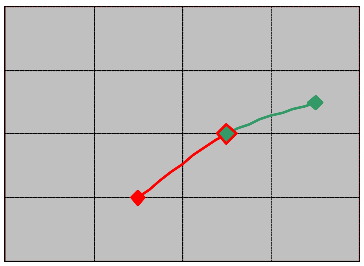


28 (Loop)

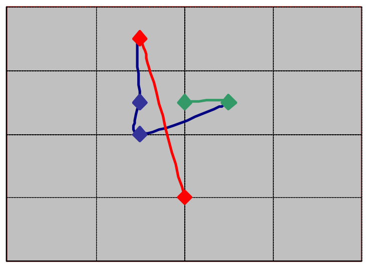


31 (Random)

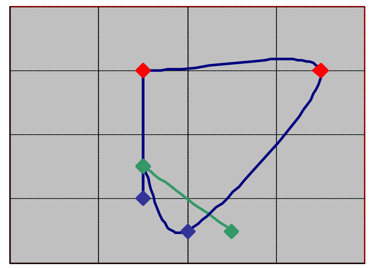
Object Sequence in Scenarios 2



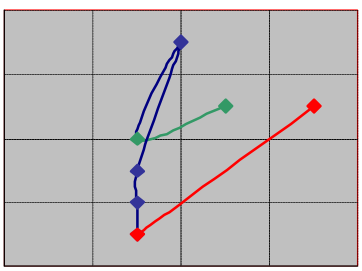
1 (Curve/straight)



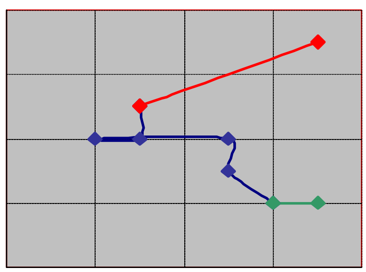
2 (Loop)



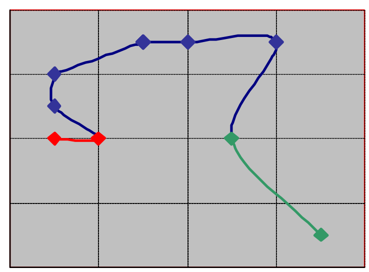
4 (Loop)



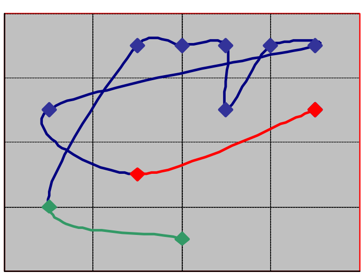
5 (Loop)



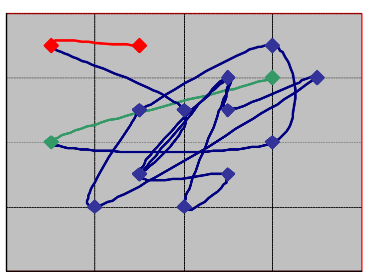
7 (Curve/straight)



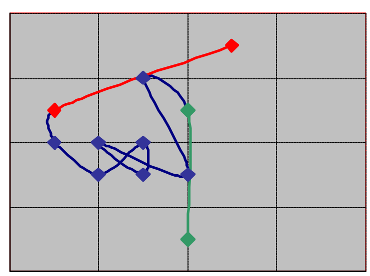
9 (Curve/straight)



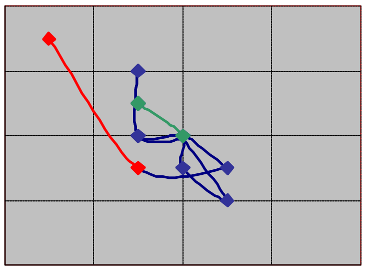
10 (S-path)

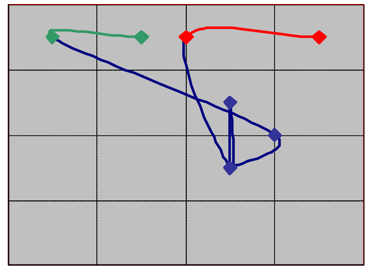


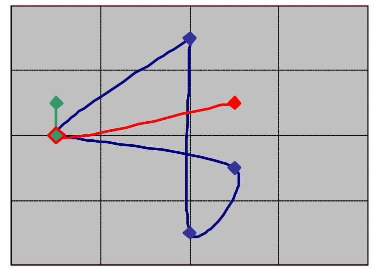
12 (Random)

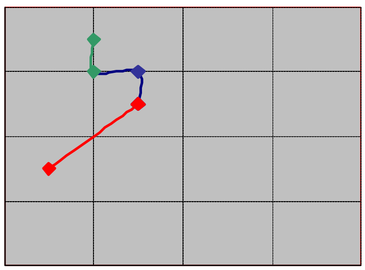


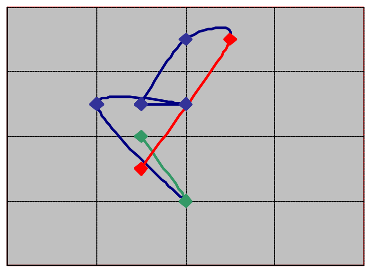
13 (S-path)

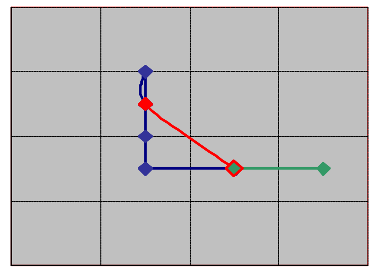

14 (Zigzag)

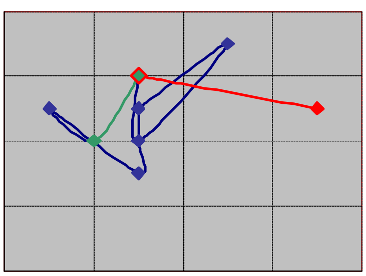

15 (S-path)

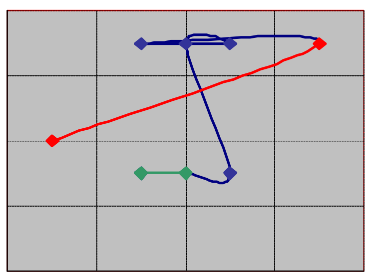

16 (S-path)

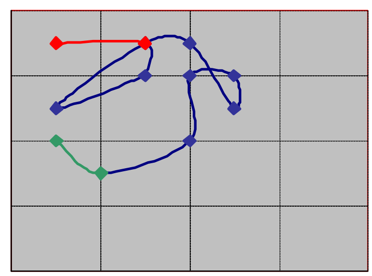

17 (Curve/straight)

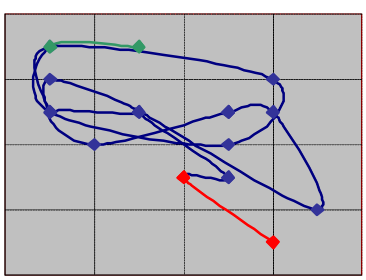

18 (Loop)

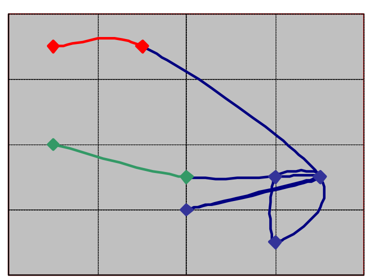

19 (Loop)

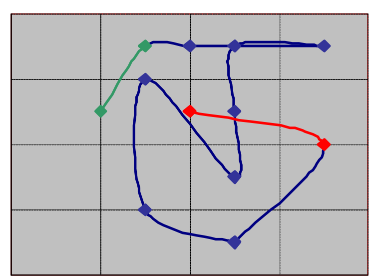

20 (S-path)

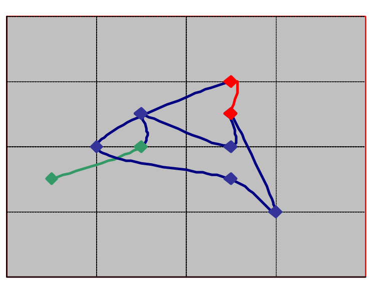

21 (S-path)

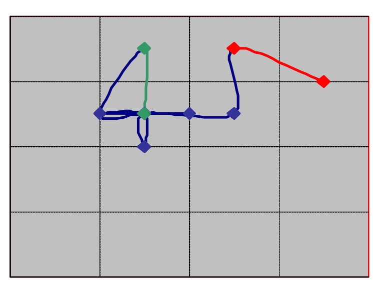

22 (Loop)


23 (Loop)


24 (S-path)


26 (S-path)





28 (S-path) 31 (Zigzag)

11.5.6 Temporal Object Sequence

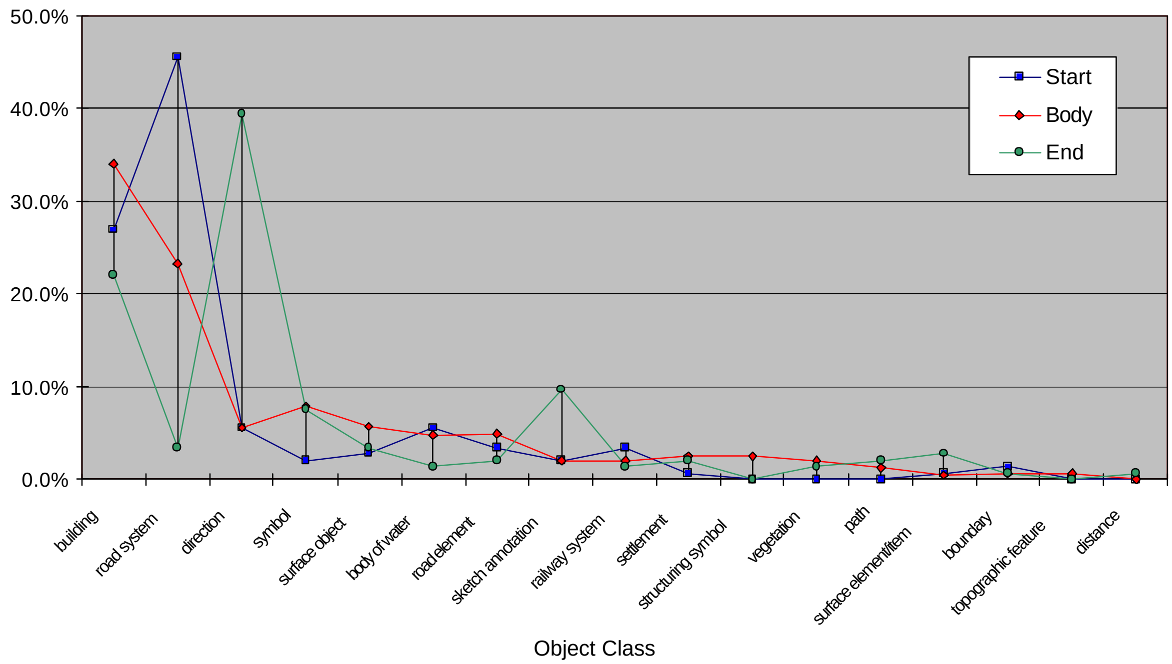


Figure 75 Distribution of object classes during the three distinguished sketching phases. The different lines represents the distribution of objects over the three different phases: start (blue), body (red), and end (green), so that the sum of every phase is 100%. (Scenario 1 & 2).

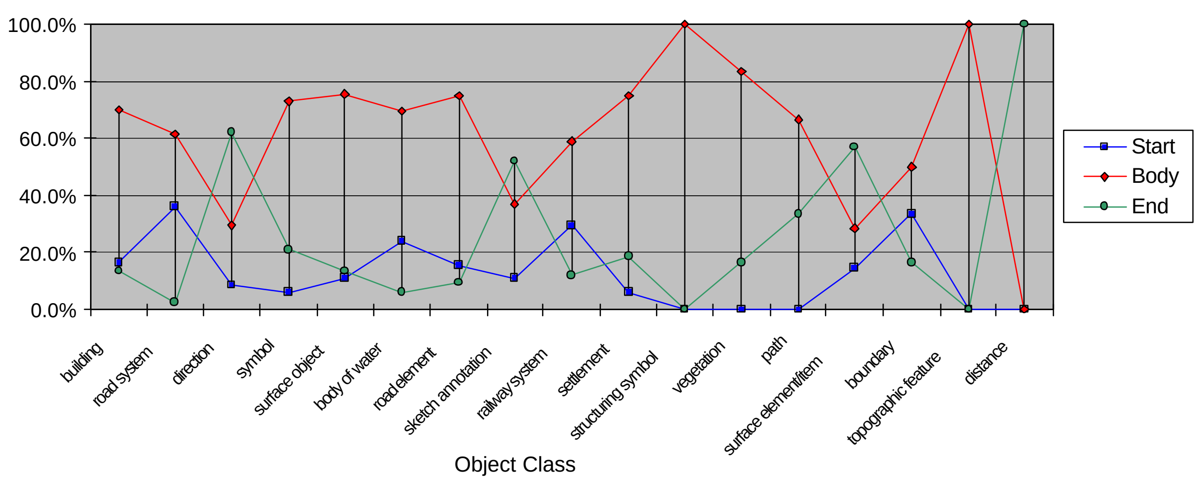


Figure 76 This figure is similar to the graph above. It is based on the same data, but shows this time the relation of the occurrence frequency for each object class separately, in that the sum of each object class is 100%. The colored lines

belong to the three phases: start (blue), body (red), and end (green). (Scenario 1 & 2).

11.5.7 Parallelity and Rectangularity

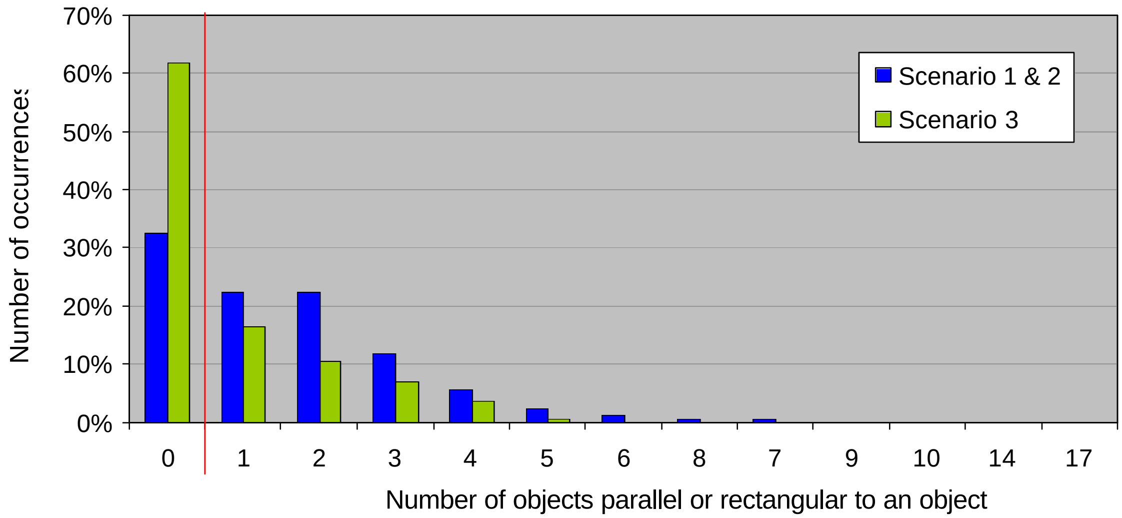


Figure 77 This figure shows the influence of urban and rural environment on the number of objects parallel or rectangular to each other. The blue bars represent objects from scenario one and two (mostly rural environment), while the green bars depict objects from the third scenario (barely developed). The two first bars represent those objects with no parallel or rectangular objects in their vicinity.

11.6 Annotations

11.6.1 Writing Direction of Annotations

Count	Az	Count	Az	Count	Az	Count	Az
37	0	**287**	9	**32**	18	**5**	27
9	1	**20**	10	**0**	19	**1**	28
15	2	**8**	11	**0**	20	**1**	29
16	3	**3**	12	**0**	21	**1**	30
10	4	**5**	13	**0**	22	**1**	31
22	5	**4**	14	**2**	23	**0**	32
33	6	**3**	15	**0**	24	**1**	33
43	7	**2**	16	**0**	25	**2**	34
58	8	3	17	0	26	**1**	35

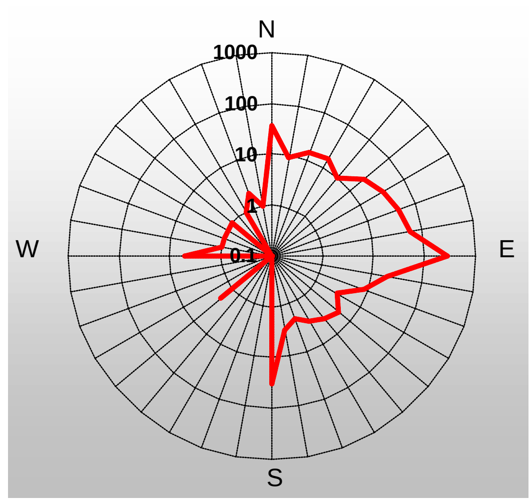


Figure 78 The table and chart show the distribution of the writing direction of annotations encountered in our survey. The referencing system of the measurement is the drawing device and the scale of the graph is logarithmic. (Scenarios 1, 2 & 3).

11.7 Sketch Questionnaire Responses

The two next section show the set of questions originally asked in the scope of our survey.

11.7.1 Sketch related Questions

These six questions had to be answered within the scope of every sketch after noting the sequence of objects.

1. How much time did it take until you started to sketch?
2. How much time did it take you to draw the sketch?
3. Did you make a draft of your sketch before you made the definitive sketch? (y/n)
4. How many times (if ever) did you start over? (Ø for no start-over)
5. Would you have liked to explain your sketch verbally? (y/n/partially)
6. Can you specify the north direction in your sketch? (pl. indicate North direction on sketch)

11.7.2 General Questions of the Questionnaire

✍ What do you think, what size should an electronic sketching device for the purpose of sketching have?
(You may also draw such a device and make specifications)
Length: ____________ Width: ____________ Depth: ____________

✍ Could you imagine working with a sketching device like this, in addition to your office equipment of today? E.g. to query a spatial database, to take notes or in general as a substitute for scratch paper.

____

✍ What was so far the most difficult (a) and what the easiest (b) part in this survey?

a) ____

b) ____

✍ Would you have liked using an editing tool (deleting, moving, re-shaping objects, etc.) while you were sketching the scenarios? And what operations should this tool provide?

____

✍ Were there other tools, which you would have liked using while you were sketching the scenarios? (e.g. zoom or pan)

____

✍ Which method (gesture) would you prefer for deleting a drawn object on a electronic device?
(Select all that apply)
✍ crossing out ✍ scribble out ✍ Eraser ("Rubber Gum") ✍ other :_________________

✍ Imagine you made a mistake during sketching an object, would you rather prefer to erase the object and redraw it, or would you preferably move and edit the object until it fits the sketch, or would this depend on the situation?

____

✍ Would you have liked to explain your sketches verbally? _______

If *Yes*: Would you rather explain your sketch during drawing, or after you have finished it?

____

✍ How would you classify your sketching talents on a scale from 1 to 10? (1 worst, 10 best)

1: ✍ 2: ✍ 3: ✍ 4: ✍ 5: ✍ 6: ✍ 7: ✍ 8: ✍ 9: ✍ 10: ✍

✍ Do you sketch more for pleasure or work-related (business)?

✍ pleasure ✍ business ✍ other _______

✍ How often do you usually sketch? (To choose an interval, mark two neighboring circles)

pleasure:	*once a*	✍ year	✍ month	✍ week	✍ day	✍ more ________
business:	*once a*	✍ year	✍ month	✍ week	✍ day	✍ more ________
other:	*once a*	✍ year	✍ month	✍ week	✍ day	✍ more ________

✍ How old are you? ______ years.

✍ What is your learned profession? ____

✍ Did you learn how to sketch during your professional education? ___________________________

If *Yes*: Was there an emphasis on sketching? ____

11.7.3 Sketch related Comments

Scenario 1

1 It was difficult to draw because of the distance I had to cover and because I don’t always remember the exact distances between landmarks or the names of roads, etc. In fact I don’t think there is any way to draw the directions on a single map, because of the scale and need to illustrate decision points with more detail than other parts of a map.

2 a) some time ago I did a similar sketch but with the street system the other way round (office ✍ home)
b) rubber was used in some places 3) sketch is supposed to be self explanatory

3 already done sketch (for people visiting me)

4 Couldn't use Sketch Cockpit, because one screen is too limited

5 description of way / I did not plan my map well, hence did not use space efficiently

6 forgot to put a scale on sketch, …

7 I draw sketch upside down!

8 I drew two ways for better explanation: The vehicle path was easier, because there are several references and vehicles can move on fixed routes. Pedestrian path is more difficult because there are different way to do it.

9 I try to keep extremes detail to a minimum, since I find it distracting

10 it was difficult to maintain any kind of constant scale while drawing

11 presumption: person understands my language!

12 The problem I faced was that I used too much space to sketch my home area and the major roads, so I didn't have enough to draw the campus area. I was very optimistic about the drawing space - but was wrong. I think the same could have happened if I had started from working area ✍ home area.

13 this was quite a simple sketch since I live close to where I work, but still, my house is almost off the page

14 would have liked do add comments verbally rather than by written annotation

15 would like to indicate departure times for train

Scenario 2

1 had problem to re-locate a store from memory, hence I choose a booth

2 I had a hard time to remember the names of the streets and deciding the city where I felt as foreigner. It was difficult to determine the north direction. I saw a map that time (when I was there) so I guess it (the N direction) is correct.

3 I would want to verbalize, since this is a very busy shopping area and I am unfamiliar (as a tourist) with most store names.

4 it was difficult to imagine a situation since this as it has not "appeared with me exactly"

5 it was hard to find a city which had an airport nearby, … took San Francisco

6 it was hard to remember where things were in relation to each other. I could not have explained how to get to Edinburgh from the airport, since I never actually drove.

7 no scale drawn

8 not so sure about north direction / distance indication vague.

9 the hard part was to find the situation

10 the limits of this scenario seem unrealistic.

11 this scenario was difficult because I haven't been on vacation for two years. just used a place that I went last weekend

12 vague sign is there to explain that this situation is around Lynn or Saugus.

13 would have liked do add comments verbally rather than by written annotation

Scenario 3

1 don't know if sketch is usable

2 flow of river assumed / would have liked to explained my assumptions e.g the relation between river and the plain.

3 giving the days in duration of walking time is not necessary since one will probably use a helicopter

4 hard to draw the canyon because it requires an indication of depth. Also hard to translate time into distance and altitude.

5 I can not show the altitude and the time scale

6 I combined plan view with perspective, jungle and delta were left out by purpose because they are not necessary, forgot to put the scale on sketch.

7 I didn't know how to specify the ambiguities in the descriptions

8 I found It necessary to do a draft while reading to keep track of all the details and then draw the sketch from the draft

9 I had to suppose or assume certain objects; e.g. where the stream finished, where was east, I had problems imagining the delta. Did I cross one bridge before the delta, Distance on the sketch has no scale or proportion with time.

10 If I had know how many miles could be covered per day, I could have estimate distances. Choice of stream direction was arbitrary.

11 north only true for mountain peak

12 scale and representing three dimensions made this much more difficult - no city blocks for reference!

13 the 3D part is surprising (river and mountains)

14 the delta and the big rock were added at last - they did not seem too important - the suspension bridge seemed like a more critical element somehow

15 there is no static reference, I did not have any reference structure to stick with.

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