SIMPLIFICATION IN GRAPH SKETCHING: A COMPARISON OF RULE BASED GRAPH GENERATION AND HUMAN SKETCHING

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SIMPLIFICATION IN GRAPH SKETCHING: A COMPARISON OF RULE BASED GRAPH GENERATION AND HUMAN SKETCHING

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ABSTRACT

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This study aims to find common levels of graph simplification between a rule based method and humans. A graph simplification method was implemented based on a grammatical set of rules. (Kulik and Egenhofer, 2003) Also an experiment was conducted with human participants. In the experiment, the subjects were asked to simplify a set of line graphs. The outputs of the graph simplification algorithm were compared with the human sketches. The results reveal a systematic relationship between the prediction of the rule sets and human sketches. The level of simplification in human sketches was also influenced by working memory span characteristics.

Keywords: Graph Comprehension, Graph Simplification, Graph Sketching

ÖZ

GRAFİK ÇİZMEDE SADELEŞTİRME: KURALA BAĞLI GRAFİK OLUŞUMU VE İNSAN ÇİZİMİNİ KARŞILAŞTIRMA

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Bu çalışma kurala bağlı bir metot ve insanların gerçekleştirdiği grafik sadeleştirmenin ortak seviyelerini tespit etmeyi hedeflemiştir. Gramer kuralları ile oluşturulmuş bir grafik sadeleştirme metodunun uygulaması geliştirilmiştir. (Kulik and Egenhofer, 2003) Aynı şekilde insan deneklerin de çeşitli grafikleri sadeleştirmesi istenmiştir. Metodun grafik sadeleştirme algoritmasının çıktıları ile insanların sadeleştirdikleri grafik çizimleri karşılaştırılmıştır. Elde edilen sonuçlar, kural setlerinin ve insanların çizimlerinin öngörüsünün arasındaki sistematik ilişkiyi ortaya çıkartmıştır. Denek insanların çizimleri ayrıca hafıza aralığı karakteristiklerinin de tesiri altında kalmıştır.

Anahtar Kelimeler: Grafik Kavrama, Grafik Sadeleştirme, Grafik Çizme

to Joseph

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CHAPTER 1

INTRODUCTION

1.1 Studying graph comprehension in cognitive science

Graph comprehension and graph sketching (generation) have been the subject of many studies in cognitive science and related domains. Understanding a statistical graph (such as a line graph or a bar graph) requires its previous knowledge, as well as set of perceptual and cognitive processes. In particular, perceptual and cognitive processes are required to extract the information from the graph (Pinker, 1990).

There are plenty of graph types to display statistical information; these are line, bar, pie charts, Venn diagrams, flow charts, tree structures, node networks. Despite the differences on visualization of graphs, one common point of all of the types is that each graph communicates to the viewer with a set of values using visual aids (length, position, shape) corresponding to the respective scales (Pinker, 1983). Those visual aids in particular, and the type of the graph in general have an effect on viewer comprehension of the represented information.

Graph comprehension studies focus mostly on visual perception and information extraction processes, and the effect of prior knowledge. However, studies about the effect of graph simplification or generalization on graph comprehension have been limited, except for a few studies on graph smoothing (Acartürk, 2012).

One of the practices that facilitate graph comprehension is graph simplification. By the graph simplification techniques graphs can be understood more easily. Another issue is, how the graph remains in reader's mind after seeing it. This situation resembles simplification of graphs. When the reader sees the graph a silhouette is possibly encoded in the mind. The operational assumption in this thesis is that this silhouette is the simplified version of the graph. How the readers simplify a graph and how it remains as a silhouette compose major research questions of the present study.

1.2 Aim of the Study

The aim of this study is to find the common levels of graph simplification between a rule-based method and sketches generated by human subjects. A graph simplification method is implemented based on a grammatical set of rules offered by (Kulik and

Egenhofer, 2003). Human data were compared with the output of the rule-based method data. In the experiments, 20 subjects were asked to simplify the presented graphs. These results were then compared with the algorithm generated data. These results allowed us to explore the levels of simplification applied by humans to the graphs.

1.3 Hypotheses

The primary aim of these the study is to find common levels of graph simplification between a rule based method and humans. A graph simplification method is implemented based on a grammatical set of rules. (Kulik and Egenhofer, 2003) An experiment is conducted where the subjects are asked to simplify the represented graphs, and then the results are compared to the outputs of the graph simplification algorithm. Hence our first hypothesis is:

H1: There is a common level of simplification (degree of simplification) between the simplified graphs which are the outputs of the program and graphs that are pictured by subjects.

Our prediction is that subjects apply simplification on the graphs that they observe and to what extent this simplification is applied, will be found after the experiments.

We also expect correlation between the Digit Span score of the subject and the level of remembering the graphs. Therefore, our second hypothesis is:

H2: There is a correlation between the subject's level of graph remembering and the score of short term working memory.

Short term memory effects how the viewer remembers the graph that is showed. To assess the working short term memory we used Corsi Block Test and Digit Span Test. Digit Span is related with comprehension of the graphs, so there can be a relation between two variables: Digit Span Score and the score of recalling the graphs.

In these experiments, we also recorded the voices of the participants while they were explaining the graphs, because there can be a correlation between the length of the explanation and the details of the pictured graph. Subjects, who remember the graphs more, can explain the graph verbally in a more detailed way. Therefore our third hypothesis is as follows:

H3: There is a correlation between the number of word used for explanation and the score of recalling the graphs.

The hypothesis will be discussed in the light of statistical analyses in Chapter 4.

1.4 Outline

Chapter 2 consists of three main sections which summarize the literature on graph comprehension. "What is a graph and what forms it" is discussed in the first part.

Second section reviews the studies conducted on graph simplification. Lastly, the literature on graph comprehension and the factors that affect it is reviewed. Chapter 3 consists of four sections: Details of the grammatical method, its implementation, a pilot study and the main study. In Chapter 4, the results are presented in a detailed manner. Lastly, Chapter 5 contains the discussion and conclusion parts.

CHAPTER 2

LITERATURE RESEARCH

The literature overview begins with the definition of graphs and follows with three sections: Graph comprehension, graph simplification and effect of short term memory on graph comprehension. "Comprehension of a graph" requires successive cognitive operations (Freedman and Shah, 2002). One of the methods that facilitate graph comprehension is graph simplification. Graph comprehension might be more accurate if the graph's format is modified (Carpenter and Shah, 1998). Graph simplification may be needed when the graph is too complex; when it has lot of points and fluctuations. For these kinds of situations graph simplification enhances the ability to comprehend graph in less amount of time. Also short term memory has an effect on comprehension of the graphs. There are various graph simplification algorithms. The variables, methods and improvements on graph simplification techniques are presented below.

2.1 What is a Graph?

Many researchers have focused on the subject "What forms a graph" (Guthrie, Weber, and Kimmerly, 1993). Fry (1984) defines graph as the information transmitted by position of point, line or area on a two-dimensional surface. Graphs have been used in many familiar forms, including bivariate plots, statistical maps, bar charts, and coordinate paper, since 18th century (Beniger and Robyn, 1978).

Despite all the differences in visualization of different graph types, one common point is that each graph communicates to the viewer with a set of values using visual aids (length, position, shape) corresponding to the respective scales (Pinker, 1983). Kosslyn (1985) structural identification analysis is elaborated on physical characteristics of the graphs. Kosslyn focuses on the physical components of the graph. He states that knowledge of the structural elements is needed for the comprehension of the graph. A graph consists of four main elements according to Kosslyn:

- Background plane: Plane is generally white, but can be a picture or drawing depending on the he graph.

- Graph structure that composes of Cartesian axes in many graphs. Some graph types do not include axes like pie charts. It provides information about the subsistence represented.

- Pictorial content: The way knowledge is represented through the graph. Rectangles in histograms or circular sectors in pie charts are the examples for pictorial graphs.

- Labels: Words and numbers rank as labels which provide the information needed to read the graph.

Background plane, graph structure, pictorial content and labels are the components of a graph. The components may vary depending on the type of the graph. For example, scatter graphs have the background plane as white background, axes as graph structure, scatters, points or nodes as pictorial content. Labels depend on the context of the graph.

Similarly, Hirsch and Curcio (1989) claims that graph comprehension consists of three elements:

- Necessary information is provided by title, axis labels and scales to understand the subject, relationships represented in the graph.

- Mathematical background (integers, rational numbers, percentages)

- The convention of the graph.

Why are graphs so common and used pervasively? Pinker (1990) suggests that it is a fact about human cognition: Human can process quantitative information easily, when it is in graphic form. Graphs make quantitative information easy to understand. Experimental evidence suggests that, graphic formats present the data for people for easier perception (Culbertson and Powers, 1959). Instead of a graph, if the reader sees the quantitative information formatted as a plain text, it would take much more time for reader to grasp the information.

Bertin (1967) suggested that the reader has to perform successive operations to read a graph. The reader must do three things to understand the graph: - External Identification means identification of referents that the graph delivers. This is the shape, numbers, labels, titles, lines. - Diagnosing the relations that which dimensions correspond to which conceptual variable and that is called ”Internal Identification”. - Perception of correspondence which is obtaining results about the particular levels. These three tasks point that comprehension of a graph requires cognitive skills.

The literature research emphasizes both computational and cognitive aspects of graph comprehension. Understanding a graph requires cognitive operations. Graph is an effective method of conveying information. Pinker (1990) suggests that it is because graphs exploit general cognitive and perceptual mechanism effectively. What is graph comprehension and situations that effects graph comprehension elaborated in ”Cognitive Aspect” subsection below. There are various graph simplification algorithms. These methods will be discussed in Graphs Simplification part in a detailed way.

2.2 Graph Simplification Algorithms

There are various algorithms developed for the simplification of line graphs. The algorithms are used for simplifying complex graphics in science, in geography- maps and for financial analyses (Joao; Huestegge and Philipp, 1998; 2011; **. .**) So there are different approaches for different aims. For example, in the area of cartography it is mostly focused on the speed of the algorithm. For finance, accuracy is more important than the speed rate of the method. In the present study, neither accuracy nor speed rate is the most important concepts, because the study aims to explore the applicable levels of graph simplification methods on humans. To do this, we investigated a set of algorithms for line simplification. Wainer (1992) offered three levels for the process of graph comprehension:

- Primary level - Questions linked with the extraction for information starting with the graph.
- Intermediate level - Questions about that evaluation of patterns dependent upon a part of the information.
- Upper level - Questions regarding profound structure of the total information set, as a rule contrasting patterns and searching for bunches. The recognition between relations of first, second and third class is the foundation of his theory. First class relations investigate a particular variable like weight. Second class describes two things, like the weight of a book. The third class refers to three variables, like the weight of a textbook. In Wainer's levels, primary level questions resemble to first class relations, intermediate to second-class and upper level to the third class.

The graphs that needed to be simplified are generally densely connected and far from planar, which makes their comprehension challenging. For poly-line simplifications there are basically two methods, one is the simplification methods that rank edges and remove smaller fragments for more structured visualizations (e.g., Hennessey et al., 2008). The clustering methods group the sections that are alike and render edges as different groups to clarify the visualization. However, deciding on which algorithm is more effective is a contemporary issue in cartography Skopeliti (2011).

Most of the research on vector generalization focuses on line generalization. One reason is that automated simplification of line features is less intricate, when compared to other generalization methods. Although generalization methods are so pervasive, simplification methods are also used. Line simplification method is used a lot in topographic maps Muller (1991). The model by Kulik and Egenhofer (2003) employs both simplification and generalization methods.

One of the oldest models and yet still used for graph simplification is the Ramer-Dougles-Peucker algorithm (Ramer, 1972). The initial form of the algorithm was developed in 1972 by Urs Ramer and 1973 by David Douglas and Thomas Peucker. The algorithm reduces the number of points by finding similar curve (Zhao, Li, and Jiang, 2001). Neither generalization, nor simplification methods are used for this algorithm.

For Ramer-Dougles-Peucker algorithm, the input of the program is a graph. The algorithm caches on all the points on the graph. The starting curve is an ordered set of lines and the starting point and end point is kept by the program. A temporary line is generated by integrating the start point and end point of the graph. The algorithm divides the graph line recursively. Then, it finds the point which is furthest from the line that connected to the start point and the end point. If the point is closer than the approximation, remaining points other than this point that is not currently marked to be kept would be discarded. If the point is not closer than the approximation point, point will be kept. So, the points that are kept will be connected and simplified graph is formed. When the recursion is completed a new output curve can be generated by connecting the points that are kept. Neither generalization, nor simplification method are used for this algorithm. This simplification method is used for curved methods. This algorithm is slow when compared to other algorithms, but it is not our consideration.

Another routine suggested by Reumann-Witkam is the Reumann-Witkam Routine (Reumann and Witkam, 1974). In this method, the line is divided by using a strip. The strip is displaced on sections with its initial slope, until the strip hits the line. Basically the strip loops over all vertices and calculate their distance from the current strip (Zhao and Saalfeld, 1997). When the key is found it is copied to the output range and current strip is updated. The process is repeated for each section of the line. The process ends when the strip involves the end point of the line. The start point of each section and the end point of the line are kept but the rest are removed. Generalization method is used in this algorithm.

The Opheim Algorithm is very similar to the Reumann- Witkam and can be seen as a narrow version of it (Shi and Cheung, 2006). In this method, also minimum and maximum distance tolerance is used Opheim. For every peak its radial distance to the current point is calculated. The last point in the minimum distance tolerance is used to define a value. If it does not exist, the value is defined as the new key. For each successive peak, current point to key is calculated. After a new key is found, the process is repeated. So points are eliminated if they are in the region of the minimum or maximum tolerance. Only the last original point within the search region is kept. In this algorithm generalization rules are implemented, because it also throws the unwanted or unimportant points. It resembles the method of Kulik and Egenhofer, because both methods look for the following line to generate a result.

The Opheim algorithm takes the first and last points as the search region. The search region forms a segment. Then, it calculates the perpendicular distance to each average point. If the calculated distance is larger than the tolerance, it throws the excluding points. It simplifies the line by reducing redundant points. This process is also recursive, it continues until there are no more average points. Lang simplification applies generalization rules.

For the cartographic generalization, generally six methods are used: Simplification, smoothing, enhancement, displacement, merging and omission McMaster; Buttenfield and McMaster, 1987; 1991. Most of the methods use combination of these rule sets.

In the present research the simplification method of Kulik and Egenhofer was employed. In the simplification method, generalization and simplifications methods are used. The difference between all algorithms and the Kulik and Egenhofer algorithm is that, in Kulik and Egenhofer algorithm, both generalization and simplification rules, in addition to aggregation rules are used. Aggregation rules are for the qualitative description of the line. The method makes use of the shapes to define line. The shapes like mountain, valley, terrace etc. are used. Also the sequence of using generalization and simplifications methods are different than the other methods. The method of Kulik and Egenhofer is explained in a detailed way in the methodology part.

2.3 Graph Comprehension

Graph comprehension and interpreting graphs have been the subject Zhao and Saalfof various papers. Graphs may contain title, labels, axes, values, spacing and pattern. They can vary in complexity. All these parameters effects graph comprehension. One common point of all of the types is that each graph communicates to the viewer with a set of values using visual aids (length, position, shape) correspond to the respective scales

Graph comprehension requires the reader to decode the information that is encoded in the graph. The process called ”Visually decoding the information” is made through a process of graphical perception Cleveland and McGill. When a graph is shown to a reader for a short amount of time, a pattern is visually encoded by the reader. This pattern of encoding can be considered as the simplified version of the graph. That is the operational assumption in the present study. When the format is modified or simplified, the result is more easy and understandable for the reader, and similarly when a graph is shown to the reader, the remained form is the simplified version of the original graph. In the present research, one of the research focuses is how the readers comprehend graphs and how they simplify them.

(Trickett and Trafton, 2006) argue that a comprehensive model for graph comprehension should include spatial cognition. Current graph comprehension models do not have to include spatial process because most of the graphs that are used in the psychology are simple could be understood by perceptual process. On the other hand, in order to understand more complex graph people may need to use spatial process. Spatial process occurs on two situations: When information is not explicit on the graph and when perceptual processes are not enough to understand the implicit information. When visual features do not evoke a relationship or when the graph viewer does not have prior knowledge, information must be retrieved by complex inferential process. Result of the study showed that the graph task interfered with performance on a spatial memory task, but not a non-spatial memory task. In the present study complex graphics are not used. Used graphics have 10 to 15 points. For the future studies graphs that have more than ten or fifteen points may be used.

One study about graph comprehension made by (Mautone and Mayer, 2007) claims that helping aids like signaling and scaffolding techniques enhance students comprehension of scientific graphs. In this study, students are shown cognitive aids before the graphs and then they are asked to tell the main information on the graph. When students get signaling, they made more relational statements about graphs. The ones, who received concrete graphic organizers, resulted in more causal statements. When these two aids are combined together and showed to the students, students generated more casual statements as well as relational statements. Therefore the study found that using both signaling and scaffolding aids together is one of the most effective ways of understanding a graph. So it is known that there are techniques that simplify graph comprehension, but in this study we do not give any prior information about the context or give a clue.

There is another study about enhancement of graph comprehension for students Curcio. In this study, practical ideas are written for teachers to use them in elementary and middle schools. The book has five sections including Levels of Graph Comprehension and Constructing, Interpreting, and Writing about Graphs. The topic, graph form, grade level, graph title, objectives, vocabulary, materials, procedure, questions for discussion, and writing and reading are described for each of the activities.

One study is about processing and usage of statistics to identify important factors of graph comprehension. The writers provide a synthesis of information about nature and structure of graphs. Writers found that there are 4 major factors of understanding a graph. These are: The purpose of using the graphs, task characteristics, discipline characteristics, and reader characteristics Friel, Curcio, and Bright. Studies show that purpose of using the graphs changes the level of understanding. For instance, if the reader knows that he/she must memorize the graph, he/she will look more carefully, therefore the comprehension level increases.

The present study is related also with the qualitative description of the graphs. Expressing a quantitative graph as qualitatively requires cognitive skills. The process of expressing a graph yields creation of grammars for terrains. One way to represent shape features of objects is to specify the features in a formal language Almira, Abu-Helaiel, et al. Such a formal language can be established with shape primitives. Convex lines and straight lines can be given as examples of shape primitives. A language enables qualitative description of the shapes Clementini, Di Felice, and Hernández.

Although quantitative information sounds more accurate then qualitative expression, there can be situations where qualitative information can simplify and speed up the comprehension of the shape, or line. Think about a blind person who wants to read the graph in Figure 2.1. This is a graph showing the increase of the value of Euro in Turkey. Another person will explain the graph to the blind person. If the graph will be expressed by just using quantitative information, the reader would say all the years, and corresponding numbers. -In the year of 1994, Euro was 0. In 1998, Euro is 0,3. In the year of 1998, it is about 0,5. In 2006 it is over 1 TL. etc..

Instead of just giving quantitative information, qualitative description can simplify the understanding of the blind person. The explanation would be like, Euro has started to earn value in 1998, and from past to now, it increases. During the year it has a wavy characteristic. Different levels of granularity level can be told by the reader.

While expressing a graph some of the words are commonly used like: ”Up”. Instead of up, the words increase, rise, grow, jump, go up, improve can be used. However, ”Up” does not give any idea about the slope of the rising in other words, the acceleration of the rising cannot be inferred by saying only ”Up” (Clementini, Di Felice, and Hernández, 1997; Raiman, 1991; Leyton, 1988). Kulik and Egenhofer method makes use of shapes to describe a line; such as mountain, valley and terrace etc. To describe the graph qualitatively grammar rules are applied to the terrain feature. To describe a graph in different levels of details, granularity levels are defined. The coarsest granularity level provides an overview of a terrain silhouette. The rawest

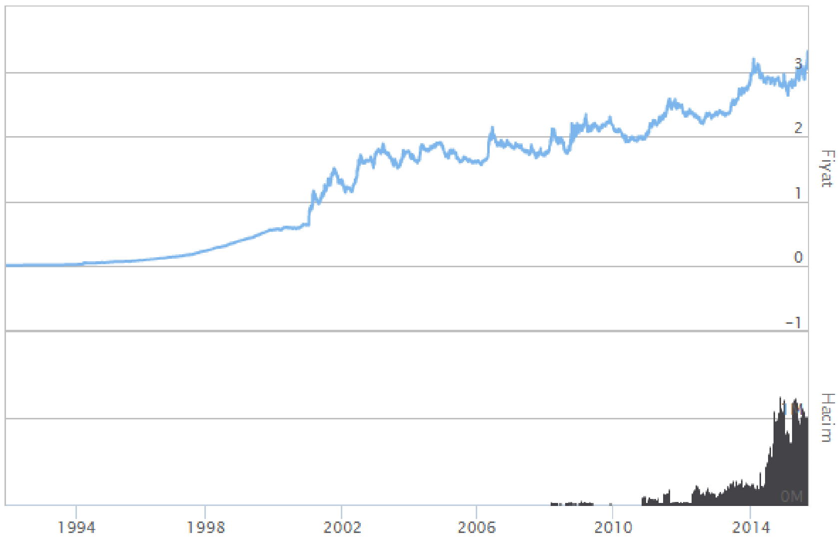


Figure 2.1: Graph Example

level of simplification yields to the coarsest granularity level Kulik and Egenhofer. There can be more than one granularity level for a graph. This depends on how detailed the graph is. The more detailed graph may result in many levels of granularity, and if it is not detailed there may be a single granularity level. In the methodology part, the method and the rules are explained in a detailed way.

Graph is an effective method of conveying information. Graphs have information that is represented in a tidy and compact way. If the reader sees the quantitative information formatted as a text instead of a graphic, it would take much more time for reader to comprehend the graphic. Although it is studied by Pinker (1990) that seeing the information represented in a graph is effective, comprehension of a graph differs from person to person. It is found that if the subject has a prior knowledge, then comprehension would be easier (Schnotz and Kulhavy, 1994; Schnotz, 2002; Körner, 2011).

An experiment is conducted within the framework of this thesis with the aim of finding out the common levels of graph simplification between a rule based method and humans. In the experiment there are 10 graphs is showed to participants. The graphs - called original graphs are showed to the participants for 1,5 seconds and then the participant should draw the graph to papers as he/she remembers the graph. At this point, short memory of the participant should be handled in this study. The remained pattern of the graph may differ from subject to subject. Short term memory effects how the viewer remembers the graph that is showed (Potter, 1976). Seeing the graph, comprehension of the graph and drawing the graph includes the activity of remembering the graphs. Remembering the graphs is related with short term memory. To assess working short term memory there are some techniques.

Corsi Block-Tapping Test

The Corsi block tapping task originated in the early 1970s as a set of 9 identical wooden blocks positioned on a board. The subject was required to point at the blocks in the order they were presented, or tapped. It was based off the Digit Span task, but instead of the verbal form of the Digit Span, it required the use of visuo-spatial memory Corsi.

The Corsi block-tapping test is a test that measures spatial short term memory. It includes participants to tap a sequence of nine spatially separated blocks. First, and there is a sequence of blocks flows on the screen. Participants observe the screen and mimicking the sequence by tapping on the blocks. The sequence starts simple: There are two blocks and it becomes more complex until the subject's performance suffers. The test measures both the number of correct sequences and the longest sequence remembered. The count of the correctly tapped blocks is known as the Corsi Span, and averages about 5 for normal human subjects (Fischer, 2011; Kessels, 2000; Piccardi et al., 2008). Corsi span may differ from subject to subject according to age and educational level (Orsini et al., 1986; Orsini et al., 1987). Studies show that there are no gender differences in Corsi Span Test (Farrell at al., 2006).

The Corsi Block tapping task is used to test a variety of things including memory loss, testing of brain damaged patients, spatial memory, and nonverbal working memory. In this study we use it to measure short term spatial memory.

Digit Span Test

To measure working memory's number storage capacity, digit-span task is used. A series of digits (e.g.,7, 3..) are showed to participants and participants must immediately repeat them with the order. If they do this successfully, they are given a longer list (e.g., '5, 1, 9, 4'). The length of the longest list a person can remember is that person's digit span Baddeley and Hitch. While the participant is asked to enter the digits in the given order in the forward digit-span task, in the backward digit-span task the participant needs to reverse the order of the numbers.

In this study we used forward Digit Span test to measure participant's verbal memory capacity. Age and education level have an effect on Digit Span scores (GrÉGoire and Van Der Linden, 1997; Dobbs and Rule, 1989; Myerson et al., 2003; Hester, Kinsella, and Ong, 2004). In this study there are 20 participants, 10 of them are female and other half is male, ages between 20 and 30. They generally have the level of bachelor degree.

Spatial and verbal short memory of the participant should be handled in this study. Short term memory effects how the viewer remembers the graph that is showed. To assess working short term memory we used Corsi Block Test and Digit Span Test as told. In the Methodology chapter, the main experiment, Corsi Block Test and Digit Span Test is explained in a detailed way.

So far, the history of the scientific approaches to graph comprehension and graph simplification was briefly presented. There are various simplification algorithms, but the present study covers the algorithm offered by (Kulik and Egenhofer, 2003), which is more related with the cognition of the graphs. Also, the relation with short term memory and graph comprehension is explained. The relation between verbal short term memory and graph comprehension will be represented in "Experiment" part which is included in the following chapter.

CHAPTER 3

METHODOLOGY

In this chapter, the information about materials, method implementation, pilot study and the experiment is presented.

3.1 Materials

The implementation is based on the model that is used for qualitative description of two dimensional terrains (Kulik & Egenhofer, 2003). The terrain or the silhouette is a land form seen from the point the observer is found. The silhouette is represented as line segments. Kulik & Egenhofer created a language to define these line segments where rewriting rules are employed to identify terrain features. .The terrain or the silhouette is a land form seen from a point where observer is present. The silhouette is represented as line segments. Kulik & Egenhofer created a language to define these line segments. Rewriting rules are employed to identify terrain features.

This model simplifies poly-lined terrains based on these rewriting rules. The results of simplification are terrains of different levels of granularities. Line primitives are used to indicate the direction of each line. The classification of line primitiveness is done according to three criteria: The alignment of their scope, the orders of magnitude shown as, length and their differences in elevation. After finding line primitives, rewriting rules are applied on them. There are three kinds of rewriting rules: Aggregation, which generate a characterization of the terrain features at different granularity levels. Generalization which eliminate the lines that have a smaller weight on the graph silhouette, And lastly Simplification rules are applied when two neighboring pieces are alike. These rules are stated in the Kulik & Egenhofer's (2003) paper. They are implemented in order to generate different levels of simplified graphs which are then compared with the graphs generated by people, as explained in the Experiment section.

3.1.1 Model and Basics

The model is used to simplify and qualitatively describe two dimensional poly-lined graphs. To simplify the graphs, Generalization and Simplification rules are used. For the qualitative description of the graph, all the three rewriting rules are used.

These rules are applied to each line segment to identify its features, and the result of simplification is terrains of different levels of granularities.

Formalization of qualitative terrain features is described. Since a formal language is determined by its strings with a finite alphabet, capturing lines through a formal language defines terrain features by finite strings of symbols. For lines, the finite alphabet is given for different magnitudes and elevation levels. A mountain for example, is described by an ascending line followed by a descending line. Terrain features are used to describe the graph as qualitative identifications.

The projection of a terrain in two dimensions creates a terrain silhouette. In this research, we focus on the two dimensional poly lined graphs.

As explained before, there are three kinds of rules and it should be noticed that, the methodology which includes them is called ”Simplification”. The ”Simplification Algorithm” is used for simplifying the graphs. However, there is also a term called ”Simplification Rules” which is a specific set of rules as explained in ”Simplification Rules” section. They have the same name, but one is referring to the process and other refers to a set of rules.

3.1.1.1 Primitives to indicate direction

A poly lined graph consists of connected lines. The lines are represented on the X, Y axes. The lines may vary by direction, magnitude, and slope. The line in the graph is called as the horizon De Floriani and Magillo. It is the line that separates the train from the plain background, it is the contour. The horizon has two endpoints. From now they are called as p1 and p2. Since graphs have the orientation from left to right, we can distinguish the start point from its endpoint as x (p1) <x (p2). In order to describe the graph, first thing to do is breaking the line into smaller lines with respect to their direction.

3.1.1.2 The direction of terrain silhouettes

To describe a line graph, the reader should focus on the line alias horizon that is one of the most important components of a graph. Based on the model, oriented straight line segments can have eight different direction values.

We have eight different slope values to describe the direction of a vector. The following notations are used for the line primitives:

Vertical ascending - va

Right ascending - ra

Right horizontal - rh

Right descending - rd

Vertical descending - vd

Left descending - ld

Left horizontal - lh

Left ascending - la

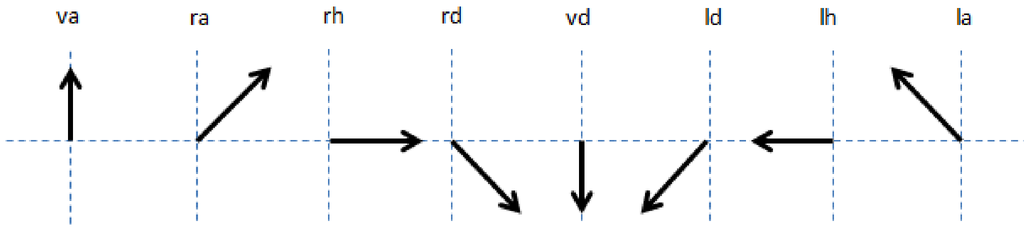


Figure 3.1: Line primitives Kulik and Egenhofer

The poly lined graphs have the orientation from left to right. Since this study focused on the poly-lined graphs, we will not use ld, lh and la since they points to left. The formal language describes terrain features on the basis of these five line primitives: va, ra, rh, re, vd. The formal language yields a granularity level, which is the description of the terrain features.

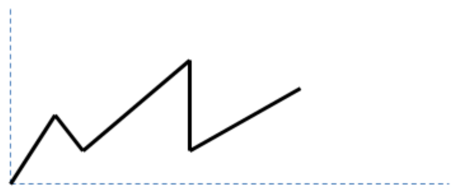


Figure 3.2: Graph Showing Directions

The description by primitive directions of the graph in the Figure 3.2 is a right ascending line, followed by a right descending, right ascending, vertical descending and right ascending which is ”ra rd ra vd ra”.

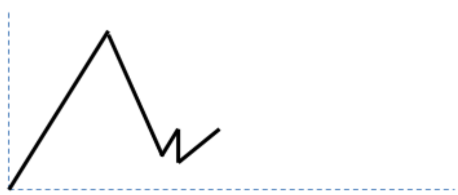


Figure 3.3: Graph Showing Directions - 2

The same sequence is defined for the terrain showing in Figure 3.3 which is ”ra rd ra vd ra”. They have the identical output although they are two exact different graphs. Considering directions only, will not help further inference, because directions have not the information of the length, and differences of the elevations. To extend qualitative descriptions, two more elements are needed: Order of magnitude for length of the line segments and orders for differences in elevation.

3.1.1.3 Magnitude of line primitives

To differentiate the length of a line qualitatively, the orders of magnitude is defined. Categorization of primitives is made according to sizes of the lines. We compare the lines to each other and classify them. The orders can be shown in any symbol or number. Grouping is done considering the magnitude of lines. An example is given below: The graph in Figure 3.4, the first two lines are relatively bigger than the

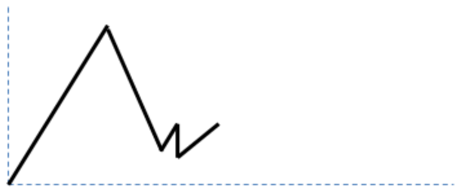


Figure 3.4: Graph Showing the Order of Magnitude Relation

following lines. The grouping can be made by groping first two lines as group 1. The last line is bigger than the 3rd and the 4th line and we can label it as Group 2. 3rd and 4th lines have the smallest length and we can group them as Group3. Denotation can be done for the groups as o, w and x. Order relation is can be showed by symbols ">" and "<". Therefore 1>2>3 or o>w>x relation is established for the graph

3.1.1.4 Elevations of end point

The third information required for the terrain description is the order of elevation. Elevation concept is also related with the scope of the line, but it extends the identification made by scope. Two lines can have the same slope, but one of them could be steeper than the other. This affects the outcome of two generalized lines. The graph

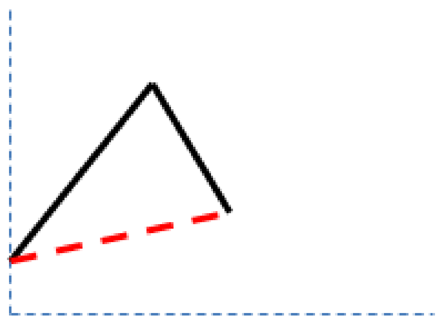


Figure 3.5: Graph Showing the Elevation Relation - 1

consists of a right ascending and a right descending line. With the integration of two lines, we generate a new line which is right ascending. In Figure 3.6, the graph has

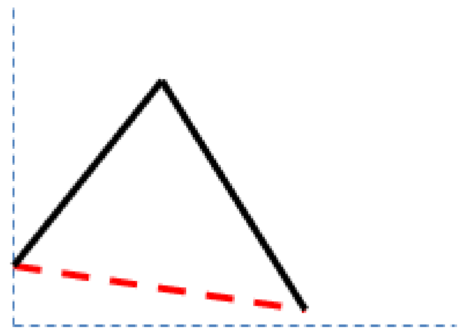


Figure 3.6: Graph Showing the Elevation Relation - 2

same directions as the graph in Figure 3.5 which is ra and rd. Two of the lines of both graphs have the same slope. The elevation makes the difference, and integration of two lines is resulted as a right descending one.

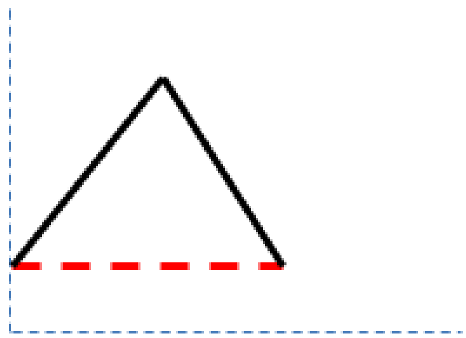


Figure 3.7: Graph Showing the Elevation Relation - 3

In Figure 3.7, same directions and same slopes are used. Elevation differentiates the result as right horizontal line.

Three concepts, direction, magnitude and elevation are used for the rules.

3.1.2 Rewriting Rules

The concepts identify the direction; magnitude and elevation enables to establish simplification rules. To simplify a graph we need two kinds of rule set: Generalization and simplification. Generalization like in other simplification methods neglects the smaller pieces of lines. Simplification joins the similar lines which have the same order of magnitude, or the same type but different orders.

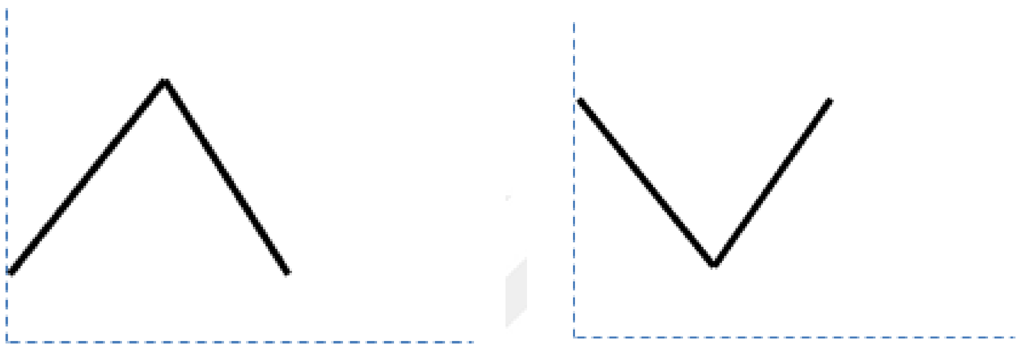
Besides Generalization and simplification rules there is Aggregation rules, which enables to define one, two or more lines as a shape.

3.1.2.1 Aggregation of Lines

In order to define a graph with its terrain features we can use aggregation rules. A sequence of terrain strings is processed. For two consecutive line primitives, it is controlled if two of them make a terrain feature. The exponent symbol x defines the order of magnitude.

$(A1) ra^x rd^x \rightarrow mt^x$

$(A2) rd^x ra^x \rightarrow vl^x$



(a) (b)

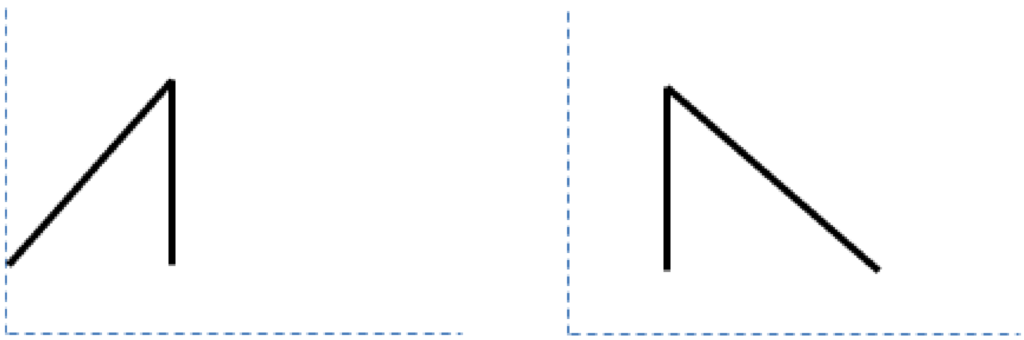
Figure 3.8: Mountain(a) & Valley(b)

A right ascending and a right descending line make a mountain (Figure 3.8 (a)) whereas a right descending and right ascending yield a valley (Figure 3.8 (b)).

$(A3a) ra^x vd^x \rightarrow hn^x$

$(A3b) va^x rd^x \rightarrow hn^x$

A horn is a type of mountain. One side is a sheer face. Formally a horn is represented by a right ascending and a vertical descending line (Figure 3.9 (a)), or a vertical ascending and a right descending line (Figure 3.9 (b)).

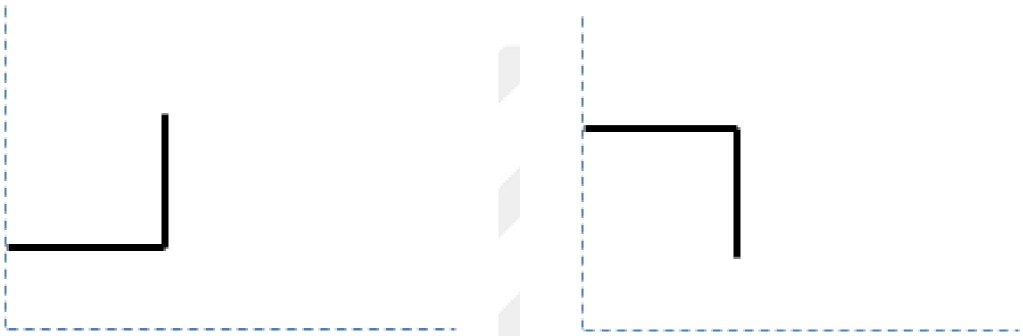


(a) (b)

Figure 3.9: Horn

(a) (b)

Figure 3.10: Ravine



(a) (b)

Figure 3.11: Downward Step(a) & Upward Step(b)

$(A4a)rd^x va^x \rightarrow rv^x$

$(A4b)vd^x ra^x \rightarrow rv^x$

A ravine is a valley with a steep side. A horn can be described by either a right descending (Figure 3.10 (a)) and a vertical ascending line primitive, or a vertical descending and a right ascending line primitive (Figure 3.10 (b)).

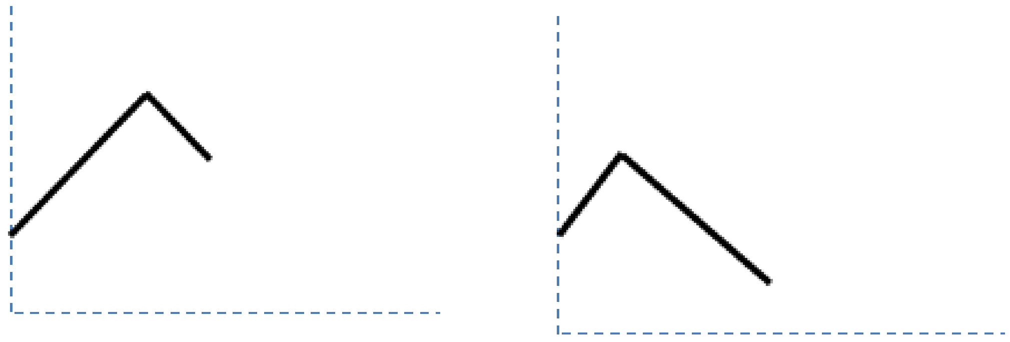
$(A5a)rh^x vd^x \rightarrow ds^x$

$(A5b)rh^x va^x \rightarrow us^x$

A steep difference in altitude starting from a horizontal level is considered a downward step (Figure 3.11 (a)), if it is described by a right horizontal and a right descending line primitive. It is an upward step, if it is a sequence of a right horizontal and a right ascending line primitive (Figure 3.11 (b)).

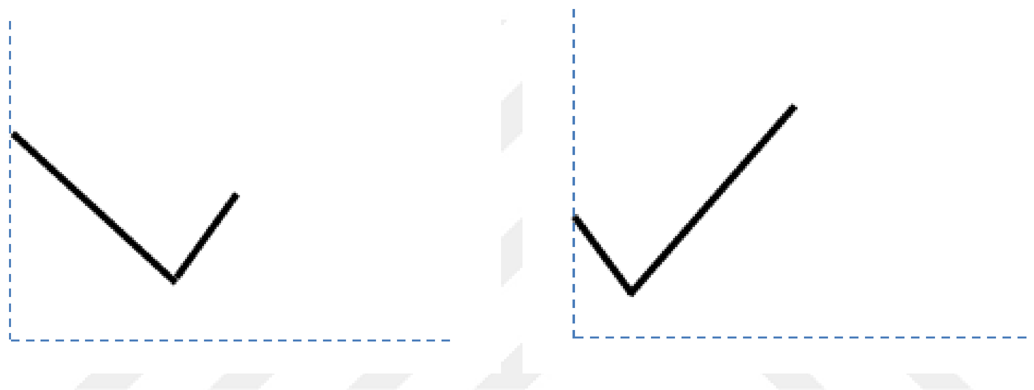
For the rules up to here, the magnitudes of two sequenced lines are equal. For the rest of the rules; the magnitude represented by x is greater than y.

For x>y;



(a) (b)

Figure 3.12: Hillock



(a) (b)

Figure 3.13: Notch

$(A6a) ra^x rd^y \rightarrow hk^y$

$(A6b) ra^y rd^x \rightarrow hk^x$

A right ascending line followed by a right descending line, both of different orders of magnitude lead to a hillock (Figure 3.12).

$(A7a) rd^x ra^y \rightarrow nt^y$

$(A7b) rd^y ra^x \rightarrow nt^x$

Right descending with a right ascending line with different magnitudes considered as a notch. (Figure 3.13). The first or second line may have a higher magnitude.

$(A8) va^x rh^y vd^x \rightarrow bt^x$

A butte (Figure 3.14) has a small uplifted area and it is bounded with cliffs. A butte is represented by a vertical ascending, a right horizontal and a descending line. The ascending and descending lines have a higher magnitude than the horizontal line's magnitude.

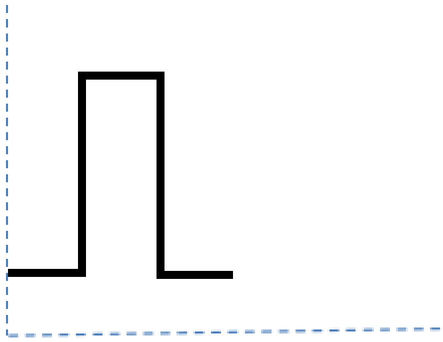


Figure 3.14: Butte

$(A9) va^y rh^x vd^y \rightarrow pl^x$

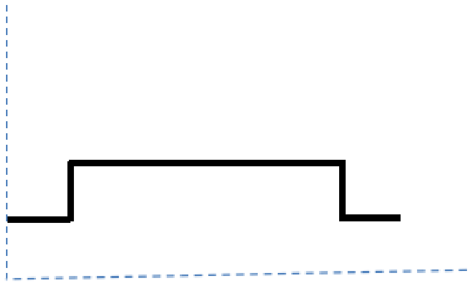


Figure 3.15: Plateau

A plateau (Figure 3.15) has a large uplifted area. The line primitive sequence is same with the Butte (Figure 3.14), but for plateau the magnitude of right horizontal line is greater than the vertical ascending and descending lines.

$(A10) va^x rh^x vd^x \rightarrow ms^x$

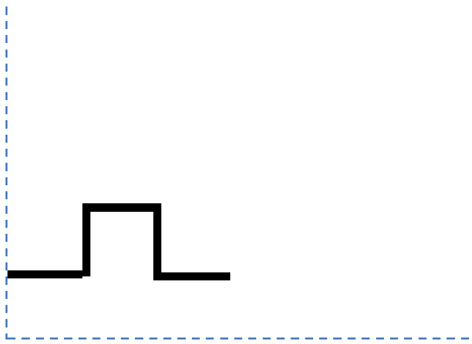
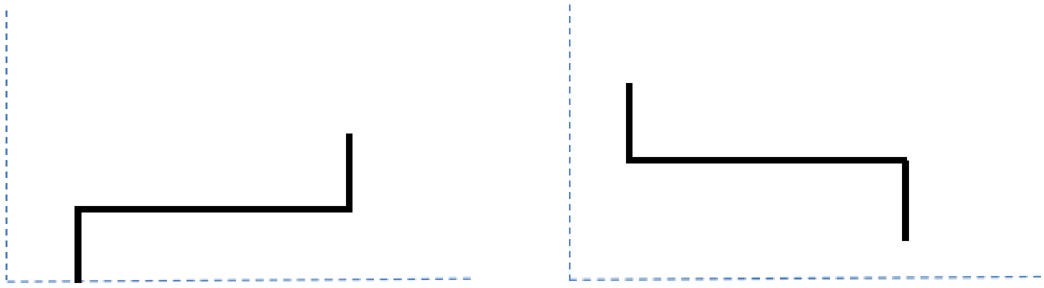


Figure 3.16: Mesa

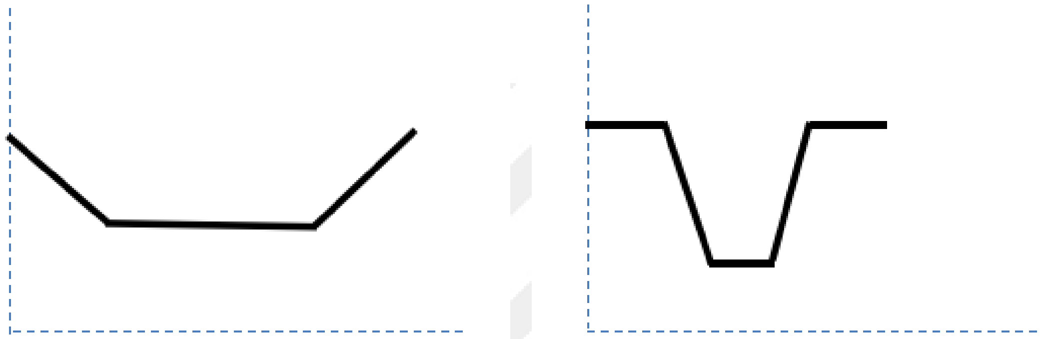
The sequence of the line primitives is same for a Mesa (Figure 3.16). It begins with a vertical ascending line, followed by a right horizontal and vertical descending line. If all of the lines have the same magnitude, it is called a Mesa.

$(A11a) va^y rh^x va^y \rightarrow tr^x$



(a) (b)

Figure 3.17: Terrace



(a) (b)

Figure 3.18: Flat floored valley(a) & U-shaped valley(b)

A terrace is represented by a large right horizontal line surrounded by two small vertical ascending or descending lines (Figure 3.17)

$(A12) rd^x rh^x ra^x \rightarrow fv^x$

$(A13) rd^x rh^y ra^x \rightarrow uv^x$

A right descending line followed by a right horizontal and right ascending line is called Flat floored valley (Figure 3.18). If the sequence is right descending followed by a right horizontal and a right ascending line is called u-shaped valley (Figure 26).

$(A14) rh^z vd^y rh^x va^y rh^z \rightarrow dpy$

Up to now, there are two or three sequenced lines and maximum two different magnitudes. For the depression (Figure 3.19) and canyon (Figure 3.20) we need three kinds of magnitudes. For the rest of the rules; the magnitude represented by q is greater than x. A depression can be characterized by a right horizontal, vertical descending, right horizontal, followed by a right ascending and right horizontal line.

For q>x>y;

$(A15) rh^z vd^x rh^y va^x rh^z \rightarrow cy^y$

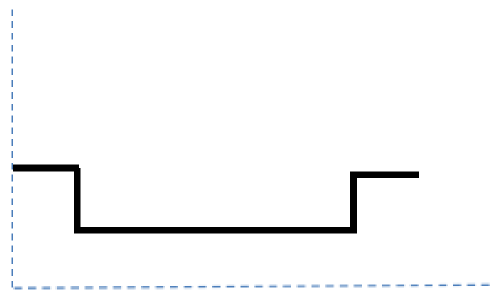


Figure 3.19: Depression

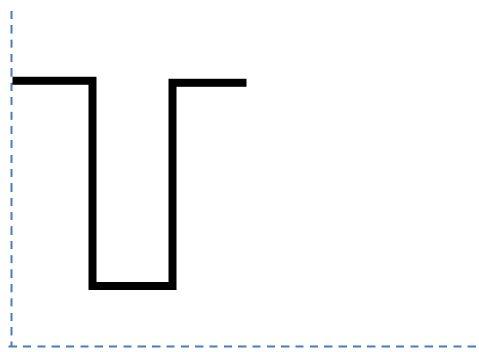


Figure 3.20: Canyon

A canyon (Figure 3.20) appears between two plateaus. It consists of right horizontal line, vertical descending line followed by a right horizontal, vertical ascending and a right horizontal line.

When the sequence does not match with any of the rules which mean it does not constitute a shape, the primitives are handled singly. There are 5 more rules for these kinds of situations:

$(A16) rh^x \rightarrow pn^x$

$(A17a) rd^x \rightarrow dc^x$

$(A17b) ra^x \rightarrow ac^x$

$(A18a) vd^x \rightarrow fc^x$

$(A18b) va^x \rightarrow rc^x$

A right horizontal line describes a plane. Descending line means a descent. Ascending line is an ascent. A vertical descending line describes a falling cliff and a vertical ascending line means a rising cliff. These are the 28 rules represents 28 different shapes used for aggregation of line primitives.

3.1.2.2 Generalization of Lines

Generalization is one of the simplification methods used in most of the simplifications algorithms (Buttenfield and McMaster, 1991; Reumann and Witkam, 1974; Visvalingam and Whyatt, 1993) Different approach may implemented for generalization. In the literature research part, different techniques are explained. In Kulik and Egenhofer method generalization is made through set of rules; rules that established on magnitude and elevation reasoning Kulik and Egenhofer. Two line segments can be generalized only if the line segments have a different level of magnitude. Vertical ascending flowed by a right ascending, horizontal or descending line primitive is generalized to a right ascending line. The magnitude of the sequent is smaller than the first line primitive.

$(G1) va^x ra^y \rightarrow ra^x$

$(G2) va^x rh^y \rightarrow ra^x$

$(G3) va^x rd^y \rightarrow ra^x$

$(G4) vd^x ra^y \rightarrow rd^x$

$(G5) vd^x rh^y \rightarrow rd^x$

$(G6) vd^x rd^y \rightarrow rd^x$

Right horizontal line followed with a vertical ascending or right ascending line primitive is generalized to a right ascending line primitive. If the right horizontal line is followed by a vertical descending or right descending line, it yields to a right descending line. The magnitude of the sequent is smaller than the first line primitive.

$(G7) rh^x va^y \rightarrow ra^x$

$(G8) rh^x ra^y \rightarrow ra^x$

$(G9) rh^x vd^y \rightarrow rd^x$

$(G10) rh^x rd^y \rightarrow rd^x$

A right ascending and a right horizontal line yield to right ascending line. The magnitude of the sequent is smaller than the first line primitive. Similarly, a right descending line primitive followed by a right horizontal or vertical descending who have smaller order of magnitudes generalized to a right descending line.

$(G11) ra^x rh^y \rightarrow ra^x$

$(G12) ra^x va^y \rightarrow ra^x$

$(G13) rd^x rh^y \rightarrow rd^x$

$(G14) rd^x vd^y \rightarrow rd^x$

Generalization rules from 1 to 14 do not require any information about the slopes and elevations of the line primitives. Elevation knowledge is required to deduce the outcome of two sequenced lines. Elevation concept is also related with the scope of the line, but it extends the identification made by scope. Two lines can have the same slope, but one of them could be steeper than the other. This affects the outcome of two generalized lines.

For a pair of a right ascending line and a descending line and if the sequent of the line primitive have a smaller magnitude, there can be three results:

- If the right descending has the higher elevation, it yields to a right ascending line.

- If two of the lines have the same order of elevation, it yields to a right horizontal line.

- If the right ascending line has the higher order of elevation, it yields to a right descending line.

$(G15a) rd^y < ra^x \Lambda ra^x rd^y \rightarrow ra^x$

$(G15b) rd^y = ra^x \Lambda ra^x rd^y \rightarrow rh^x$

$(G15c) rd^y > ra^x \Lambda ra^x rd^y \rightarrow rd^x$

For a pair of a right ascending and vertical descending line and if the sequent of the line primitive have a smaller magnitude, there can be three results:

- If the right descending has the higher elevation, it yields to a right ascending line.

- If two of the lines have the same order of elevation, it yields to a right horizontal line.

- If the right ascending line has the higher order of elevation, it yields to a right descending line.

$(G16a) vd^y < ra^x \Lambda ra^x vd^y \rightarrow ra^x$

$(G16b) vd^y = ra^x \Lambda ra^x vd^y \rightarrow rh^x$

$(G16c) vd^y > ra^x \Lambda ra^x vd^y \rightarrow rd^x$

The outcome is very similar when we have a pair of right descending and a right ascending line or right descending and vertical ascending lines

$(G17a) ra^y > rd^x \Lambda rd^x ra^y \rightarrow ra^x$

$(G17b) ra^y = rd^x \Lambda rd^x ra^y \rightarrow rh^x$

$(G17c) ra^y < rd^x \Lambda rd^x ra^y \rightarrow rd^x$

$(G18a) va^y > rd^x \Lambda rd^x va^y \rightarrow ra^x$

$(G18b) va^y = rd^x \Lambda rd^x va^y \rightarrow rh^x$

$(G18c) va^y < rd^x \Lambda rd^x va^y \rightarrow rd^x$

The generalization rules 1 to 18 shows the 18 combinations for two line primitives of different orders of magnitude.

3.1.2.3 Simplification of Lines

After generalizing a terrain string simplification rules are applied. We have seen that a sequence of line primitives of the same order of magnitude cannot be generalized. For the lines that have the same type of direction, we apply simplification rules.

$(S1) rh^x rh^x \rightarrow k.rh^x$ $(S2) ra^x ra^x \rightarrow k.ra^x$ $(S3) vd^x vd^x \rightarrow k.vd^x$ $(S4) rh^x rd^x \rightarrow k.rd^x$ $(S5) va^x va^x \rightarrow k.va^x$ $(S6) rd^x rd^x \rightarrow k.rd^x$ $(S7) rh^x rh^y \rightarrow rh^{x+y}$ $(S8) ra^x ra^y \rightarrow ra^{x+y}$ $(S9) vd^x vd^y \rightarrow vd^{x+y}$ $(S10) rh^x rd^y \rightarrow rd^{x+y}$ $(S11) va^x va^y \rightarrow va^{x+y}$ $(S12) rd^x rd^y \rightarrow rd^{x+y}$

By the rules defined in the model, we implement the rules to generate different levels of simplified graphs. The input of the program is a graph that can have 3 to 30 points; line segments. The output of the program is three different graphs that have different granularity levels. Level 1 is a coarser version of the original graph. Level 2 is a coarser version of Level 1 and lastly Level 3 is a coarser version of Level 2. In each level there is a qualitative description of the graphic.

3.2 Implementation of the Method used for the Pilot Studies

The method is implemented by using Java in Eclipse Luna. There is one input of the program which is a single Excel file, containing points of x and y axes of the graph. The rules are implemented in this program while the output is simplified versions of the graphs.

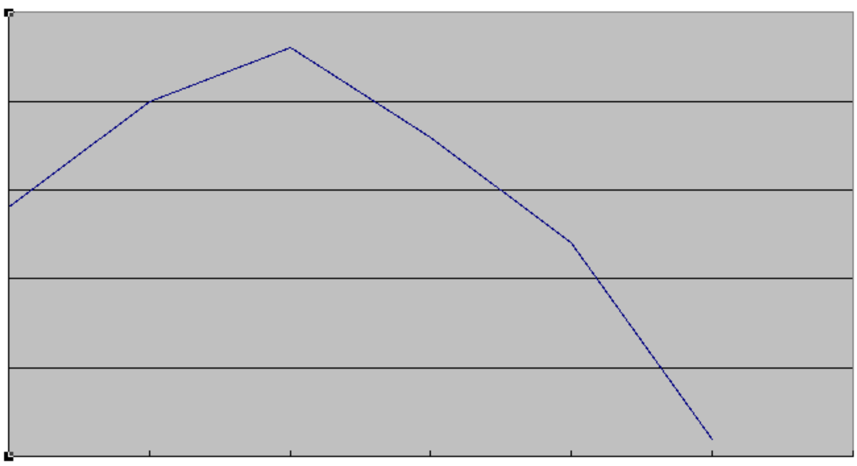


Figure 3.21: The output of the simplification method in granularity Level 1

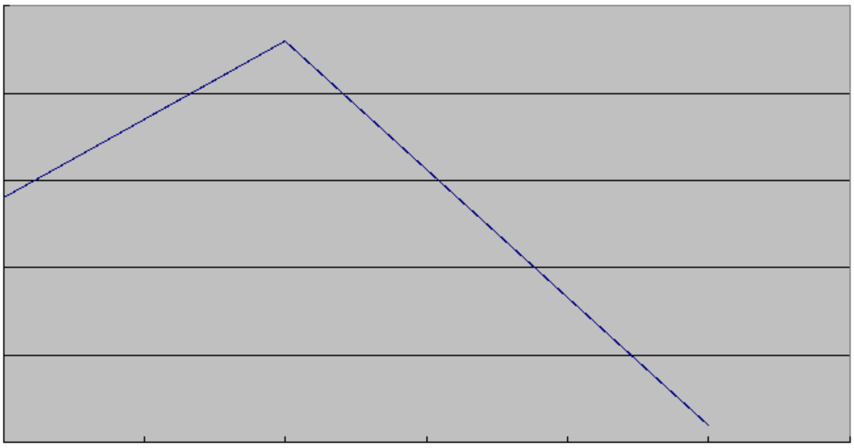


Figure 3.22: The output of the simplification method in granularity Level 2

3.3 Pilot Study

A pilot experiment was conducted within the framework of this thesis with the aim of finding the common levels of graph simplification between a rule based method and humans. There are two kinds of outputs: The ones drawn after the subject sees the original graphs, and the ones generated by the algorithm. 5 poly-lined graphs consisting of 10 line segments are shown to subjects. The graphs are created manually by considering the regions where making a simplification is possible. The input of the implementation is the same 5 poly-lined graphs. The outputs of the implementation are 5 graphs that are simplified according to level 1 and 2. Therefore, there are 10 graphs generated by the program; 5 of them are simplified according to level 1, and 5 are simplified according to level 2. Then we observe the similarities between the simplified graphs drawn by humans and simplified graphs generated by the algorithm. To do this, there is another group of subjects who make the comparison between the code generated graphs and human created graphs. This enables us to explore the applicable levels of graph simplification methods on humans.

3.3.1 Stimuli

5 poly-lined graphs consisting of 10 line segments are shown to subjects. The graphs are created manually by considering the regions where making a simplification is possible. In these graphs, lines have one or two fluctuations which can be simplified.

For the other group the stimuli are the outputs of the implementation and graphs that are simplified by subjects. Two groups of the simplified graphs are shown to the subjects who decide if the output of the algorithm resembles the graphs that are simplified by humans, and if yes, to what level they resemble each other.

3.3.2 Participants

A total of 6 subjects participated in the experiment. Three of them were shown the graphs and asked to draw what remained in their minds. The second group consists of rest three people who were asked to compare the two graphs; simplified graphs drawn by humans and simplified graphs which were the output of the program. Masters students at Middle East Technical University whose native language is Turkish participated in the experiment. Three of these participants are female and three of them are male with ages between 25- 28. They reported not to be under the effect of any kind of drugs that may affect their cognitive abilities.

3.3.3 Software and Equipment

The graphs are shown on the center of a 17-inch monitor (1280 x 1024 pixels) and represented by Microsoft PowerPoint 2007 software. White A4 paper was used in the drawing session. The outputs of the implementation are printed on white A4 paper.

3.3.4 Procedure

3.3.5 Drawing Phase

5 poly-lined graphs consisting of 10 line segments are shown to subjects for 2 seconds. The graphs are created manually by considering the regions where making a simplification is possible. The input of the implementation are the same 5 poly-lined graphs And its outputs are again 5 graphs but are simplified according to level 1 and level 2. Therefore, 10 graphs were generated by the program; 5 of them simplified according to level 1 and 5 of them simplified according to level 2. We observed the similarities between the simplified graphs drawn by humans and those generated by the implementation. To do this, there was another group of subjects to make the comparison between the code generated and human created graphs.

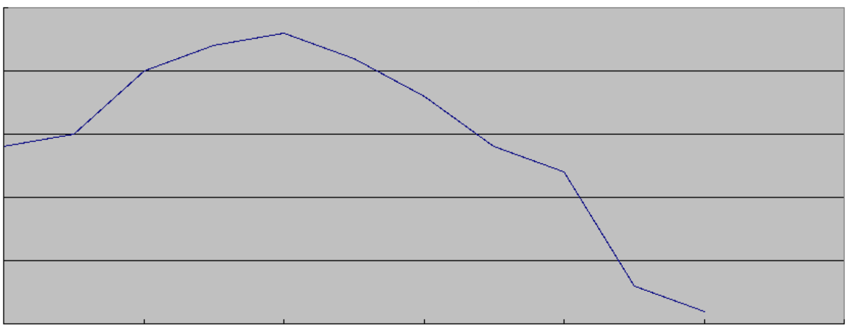


Figure 3.23: Original graph which is shown to subject for 2 seconds

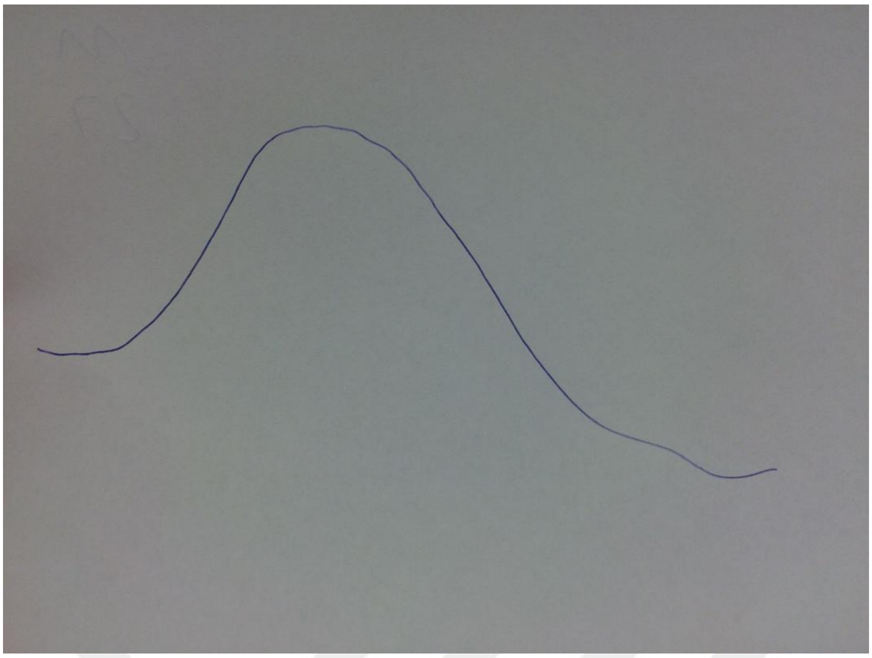


Figure 3.24: The graph pictured by the subject

3.3.5.1 Comparison Phase

In the comparison phase, participants different than those attended to the drawing phase, compared the simplified graphs drawn by subjects and those generated by the program. Two A4 sheets were shown to the evaluator who was asked to evaluate the paper in terms of their resemblance. The evaluator was asked to score them in the scale of 1 to 5. 5 was given if the graphs were almost similar and 1 if they are irrelevant. This scoring is then used to understand which level of simplification is close to the subject's drawings.

The sequence of the experiment is as follows:

1. There are five manually created graphs having ten line segments .These are called the original graphs.

2. Original graphs are introduced in the implementation.

   (a) Five graphs are generated by simplification rules with granularity level one.

   (b) Five graphs are generated with the granularity level two.

3. Original graphs are shown one by one to subjects for two seconds on the screen, and they are then asked to draw the graphic on paper.

4. Other groups of participants were asked to compare the simplified graphs drawn by humans and simplified graphs generated by the program.

3.4 Implementation of the Method

The method is implemented by using Java in Eclipse Luna. There is one input of the program which is a single Excel file, containing points of x and y axes of the graph.

After the pilot study the output graphs did not contain any x axes lines. Also, there are 3 graphs as the output of the program instead of two; the simplified graph at Level 1, Simplified Graph at Level 2, and Simplified Graph at Level 3.

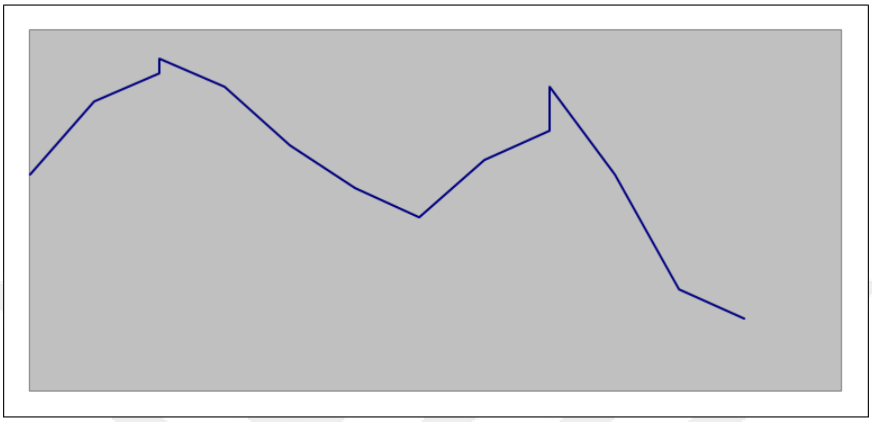


Figure 3.25: The original graph - Input of the program in the form of a graph

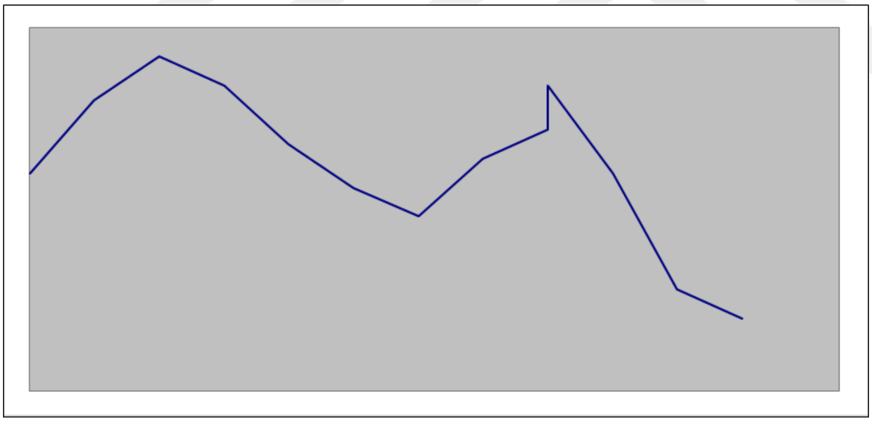


Figure 3.26: The output of the simplification method in granularity Level 1

3.5 The Experiment

After the pilot studies, we noticed some key points and made some experimental changes. The number of presented graphs was increased to 10 to get more accurate results. The presented graphs had the x axes lines in the pilot study, but they were removed in this stage Graphs were showed to subjects for 2 seconds in the pilot study, but in this experiment subjects observed the graphs for 1.5 seconds. There were two outputs of the program which were the simplified versions of the original graph, but

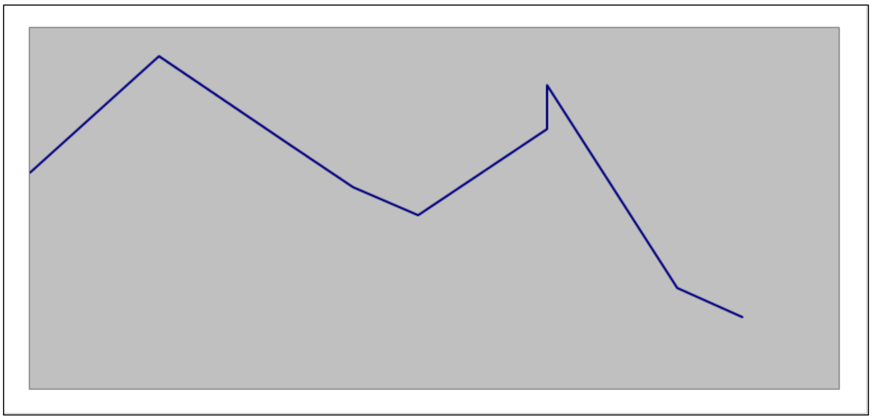


Figure 3.27: The output of the simplification method in granularity Level 2

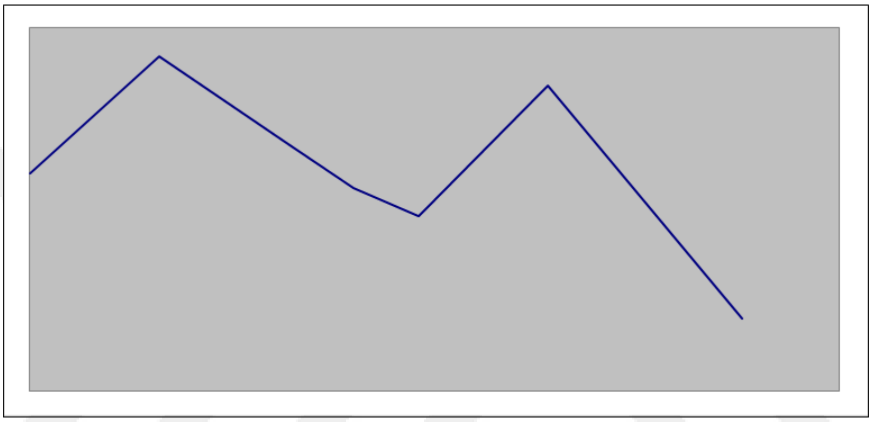


Figure 3.28: The output of the simplification method in granularity Level 3

in the main study they were increased to three In the pilot study subjects used blank A4 paper to draw the graphs. In the experiments, there were boxes on the A4 paper and subjects drew the graphs in those boxes. Also the comparison phase was different from the pilot study. In the pilot study, evaluators rated the graphs in scale of 1 to 5. While in experiments evaluators rated the graphs in scale of 1 to 10.

3.5.1 Stimuli

There are two parts of this study. In the first part, graphs are shown to subjects for 1.5 seconds who are then asked to draw in the way they remember them. Then 10 created manually poly-lined graphs consisting of 10 line segments are shown to subjects. The graphs are constructed considering where making a simplification is possible. In the graphs lines have one, two or three fluctuations, which can be simplified.

For the Second part, the stimuli are the outputs of the implementation and graphs that are simplified by subjects. As explained in implementation part, there are three graphs as the output of the program. These 3 simplified graphs and the original graph -which is shown to the subject and which is also the input of the program- are showed to another group of subjects who decide which of the simplified graph resembles the graph that is simplified by the subject.

3.5.2 Participants

A total of 20 subjects participated in the first part of the experiment. They were shown the graphs and asked to draw what they remembered. Subjects have university degree and their native language is Turkish. 10 of the participants were female and the other 10 males with ages between 25- 31 (M= 26.05). They reported not to be under the effect of any kind of drugs that may affect their cognitive abilities. In addition, written consent was obtained from each of them.

3.5.3 Evaluators

In the second part of the experiment, 4 evaluators participated who were asked to compare the two sets of graphs; the simplified graphs drawn by humans and those generated by the program. The scoring was done as explained in the ”Scoring” section. Evaluators have university degree and their native language is Turkish. 2 of them are female and 2 are males with ages between 24- 27 (M= 25.5). They also reported not to be under the effect of any kind of drugs that may affect their cognitive abilities. In addition, a written consent was obtained from each of them. The decision of the judgements is important. To analyse the consistency of evaluators, Krippendorf’s Alpha analysis was conducted.

Krippendorff’s Alpha

Krippendorff’s alpha coefficient (α) is a statistical measure of the agreement between two things. We used it for measuring the evaluators’ consistency. Krippendorff (1995) presented several chance-corrected agreement measurement methodologies, which constitute Krippendorff’s Alpha agreement coefficient family. To measure α coefficient, the input is the scores given by the evaluators.

Four types of value types are used in Krippendorff’s alpha method: Nominal, ordinal, interval and ratio levels of measurement. In this analysis, ordinal measurement is used, because the evaluators rated the resemblance of the graphs in a scale of 1-9 and this measurement is the suitable one for assessing the consistency of the evaluation. There were 4 evaluators in this experiment, 2 of them female and 2 males with ages between 24- 27 (M= 25.5). These 4 evaluators are denoted as e1, e2, e3 and a4 and the results are shown in the table 3.1.

Table 3.1: Krippendorff’s Alpha Reliability Estimate

Krippendorff’s Alpha Reliability Estimate				
	Alpha	Units	Observers	Pairs
Ordinal	0.9100	200.0000	4.0000	1200.0000
Judges used in these computations:				
e1	e2	e3	e4	

The coefficient (α = 0.91) is positive and close to 1, indicating there is a systematic agreement between the evaluators.

3.5.4 Software and Equipment

The graphs are shown on the center of a 17-inch monitor (1280 x 1024 pixels) and represented by Microsoft PowerPoint 2007 software. White A4 paper was used in the drawing session. The outputs of the implementation are printed on white A4 paper.

A voice recorder was also is used to record participant's voice while describing the graphs.

3.5.5 Procedure / Experiment

3.5.5.1 Drawing and Explaining Phase

10 manually-created poly-lined graphs that consist of 10 line segments are shown to subjects for 1.5 seconds. The graphs are created manually by considering the regions where making a simplification is possible. The input of the implementation are the same 10 poly-lined graphs and while the output are 3 graphs that are simplified according to Level 1 Generalization, Level 1 Simplification and Level 2 generalizations -total of 3 Levels for every graph . It should be noticed that the methodology including these 3 Levels is called "Simplification" which is different from "Simplification Rules". The latter is formed by a set of specific rules. There were 30 graphs generated by the program; 10 of them simplified according to Level 1, 10 according to Level 2 and the last 10 are simplified according to Level 3. We observed the similarities of the simplified graphs which drawn by humans and those generated by the implementation. To do this, there was another group of subjects who made the comparisons as explained in Comparison Phase section.

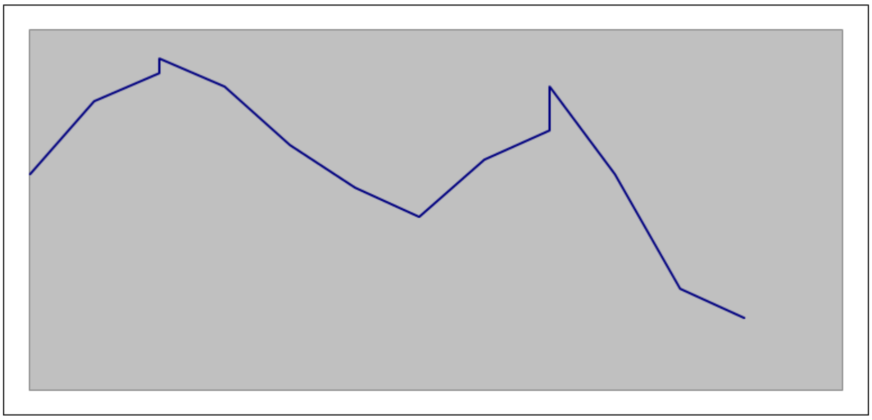


Figure 3.29: Original graph is shown to subject for 1.5 seconds

3.5.5.2 Comparison Phase for Evaluators

In the comparison phase, there were participants different from those that attended the drawing phase. They compared the simplified graphs sketched by subjects and those

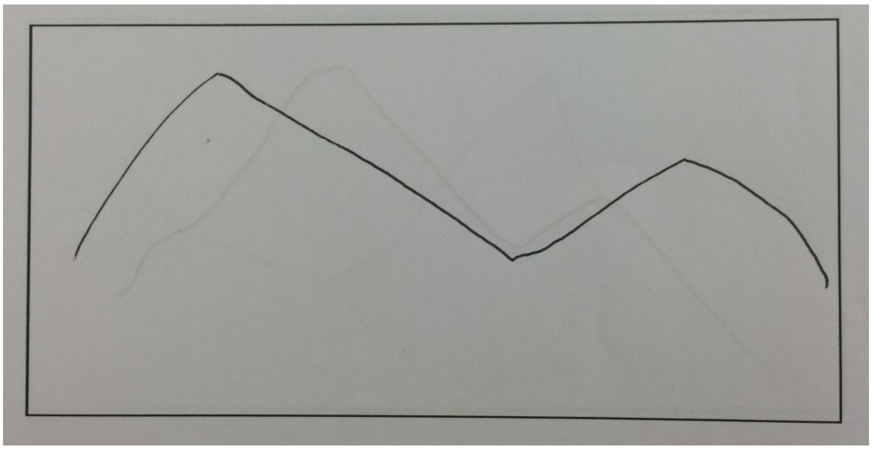


Figure 3.30: The graph pictured by the subject

of the program. It should be noticed that, there are two parts of this study. In the first one, attendees called as subjects who sketched the presented graphs. In the second part, the attendees called as evaluators, who rated the resemblance of sketched graphs in the first part and the output of the simplification method.

Five A4 sheets containing the graphs were shown to the evaluators who were asked to rate them in terms of their resemblance to graphs generated by the program. The scored the graphs in a scale of 0 to 9. 9 points are given if the pictured graph resembled most the original graph and 0 points are given if the drawn graph resembles most to the most simplified graph. The scoring was used to evaluate which level of simplification is closer to the subject's drawings. Below in the "Scoring" section, the table that evaluators generated is shown.

Scoring

There are 10 slots for evaluators to grade the resemblance of the presented graphs and a total of 5 graphs to be assessed by them. One graph is drawn by the participant; one is the original (the most detailed graph) and 3 others are the output of the program. These 3 graphs are the simplified version of the original graph. So, the evaluator compares the drawing with these 4 graphs. If the drawing is almost the same with the original graph, then the evaluator gives 9 as the score. If the drawing is close to the first simplified version (Level 1) of the original graph, then the evaluator gives 6 points. If the drawing is close to somewhere between the original graph its first simplified version, the evaluator gives a point between 6 and 9.

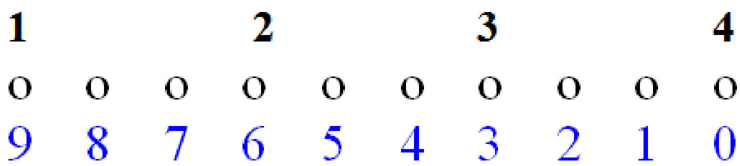


Figure 3.31: Scoring table

If the drawing of the subject resembles the 4th graph, which is the most simplified version of the graph, evaluator gives 0 points for that graph.

The sequence of the experiment is as follows:

1. There are ten graphs with ten manually created line segments called the original graphs.
2. Original graphs are introduced with the implementation. Three graphs are generated from each of the original graph by implementing simplification rules with the granularity Level 1, Level 2 and Level 3.
3. Original graphs are shown one by one to subjects for one and a half seconds from the screen, and then the subjects are asked to draw the graphs to a paper.
4. Another group of participants called as evaluators compare the simplified graphs drawn by humans and those generated by the program. They give a score on resemblance of the graphs as explained above.

3.5.5.3 Corsi Block Tapping Test and Digit Span Test

In Corsi block-tapping test subject's spatial short term memory is measured. In the original task there are at most 9 blocks for the subjects be remember. In this study, there are at most 6 such blocks. Task starts with 2 sequent blocks whose numbers increase as the subject performs the task successfully. There are two trials for each of the sequent count. If the subject fails twice on counting the same sequence, the task ends. The last sequent count that the subject performs successfully is considered as the spatial memory span of the subject (Corsi, 1972).

Digit Span Test is used to measure the subjects' verbal short term memory. In this study there were at most 8 runs. In the first run, two numbers appeared on the screen sequentially and the subject was required to remember those numbers in order. If the subject was successful, the number increased by 1. If the subject failed on the same sequence, the task was ended like in Corsi Block Tapping test. The last sequent count made successfully is considered as the verbal memory span of the subject.

In this chapter, the method developed by Kulik and Egenhofer (2003) was explained in details. The rules of the method were shown with figures and after explanation, its implementation was explained. The Pilot study was presented including all the steps, with their respective examples. Lastly the experiment with its four parts starting with sketching, scoring, Corsi Block Tapping Test and Digit Span Test was explained. The results of the experiment will be presented in the ”Results” chapter.

CHAPTER 4

RESULTS

The results of the study and the statistical analyses are presented in this chapter. Firstly, all the data gathered from the subjects are shown in this chapter in Excel format.The methods used for the analyses of the data are also shown. Results are given according to the order of the hypotheses presented in the first chapter.

The scoring for the resemblance of the graphs is shown in Figure 4.1. As explained in the ”Scoring” chapter, there are 10 slots for subjects to score the resemblance of the graphs presented to them. There are total of 5 graphs to be assessed:one drawn by the participant; one is the original (the most detailed graph) and 3 are the output of the program. These 3 three graphs are the simplified version of the original graph.

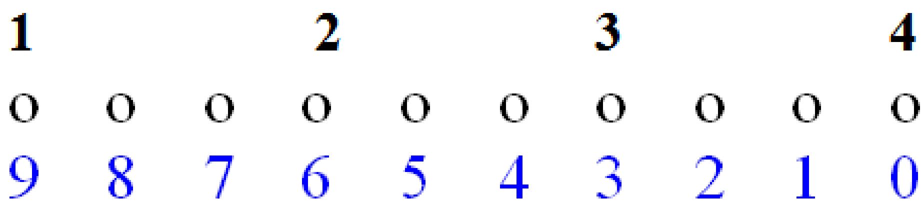


Figure 4.1: Scoring table

$1 \rightarrow Original\ Graph\ (The\ most\ detailed\ graph)$

$2 \rightarrow Simplification\ Level\ 1$

$3 \rightarrow Simplification\ Level\ 2$

$4 \rightarrow Simplification\ Level\ 3\ (The\ most\ simplified\ graph)$

The evaluator compares the drawing with these 4 graphs and scores them in a scale 0 to 9. If the drawing is almost the same with the original graph, then the evaluator gives 9 as the score. If the drawing is close to the first simplified version (Level 1) of the original graph, then the evaluator gives 6 points. If the drawing of the subject resembles the 4th graph, which is the most simplified version of the graph, he/she gives 0 points for that graph. Table 4.11 scores given by evaluator to each comparison

Table 4.1: The Scores for Resemblance of the Graphs

	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	M
P1	1	5	2	6	0	4	6	3	1	0	2.8
P2	0	2	5	3	7	4	4	8	6	5	4.4
P3	8	6	5	5	4	0	5	7	0	5	4.5
P4	6	2	5	4	7	NA	NA	7	5	NA	5.1
P5	0	4	1	0	7	0	0	0	2	1	1.5
P6	0	0	7	0	2	0	0	0	2	1	1.2
P7	1	0	0	3	7	7	0	4	0		2.4
P8	1	0	8	5	8	0	7	7	9	5	5
P9	6	1	0	5	2	2	0	0	1	5	2.2
P10	2	2	3	0	7	5	1	0	0	2	2.2
P11	0	1	1	0	0	1	0	0	4	2	0.9
P12	6	0	0	0	7	1	0	0	7	0	2.1
P13	0	0	8	0	4	3	0	1	5	4	2.5
P14	2	0	0	4	1	3	0	0	4	0	1.4
P15	0	0	6	0	0	0	0	4	5	1	1.6
P16	0	1	2	0	2	0	0	0	4	3	1.2
P17	4	1	1	0	4	0	1	0	5	2	1.8
P18	1	1	4	2	1	4	0	2	0	1	1.6
P19	0	0	0	0	0	0	2	0	0	0	0.2
P20	4	2	5	7	7	2	0	3	7	2	3.9
M	2.1	1.4	3.2	2.2	3.9	1.9	1.4	2.3	3.4	2.2	

The mean values for total of 10 graphs for each participant are showed in the ”M” row and column on the table. NA is given if the pictured graph does not resemble any of the 4 graphs.

The average of the mean values is: 2.4 and that of word count for a graph explanation by the subjects is 23.3 words.

Results of Corsi Block and Digit Span Tests

The results of the Corsi Block and Digit Span Tests are also collected in Excel file as shown in Table 4.3. The scores are normalized between 0 and 1. To be able to see the main schema, participant’s scores from graph sketching and memory span scores were gathered as shown in the table.

The mean score of the graph is 2.4, meaning that the subjects simplify the graphs between the levels 3 and 4. The mean of the Digit Span test is 0.92 and Corsi Block Tapping Test is 0.92. Word count average is 23.3 for one graph. The subject who explained the graphs in the fewest words used 4 words for a graph, and the one who gave the longest explanation used 92.3 words.

The Pearson product-moment correlation coefficient -Pearson’s r- is used to compare results. The r-ratios of between-participants are calculated by taking the mean values

Table 4.2: The Scores of Graphs, Digit Span Test and Corsi Block Tapping Test

	GRAPH	DIGIT	CORSI	WORD
P1	2.8	1	1	4.1
P2	4.4	1	1	21.9
P3	4.5	1	0.83	27.7
P4	5.1	0.88	0.83	21.8
P5	1.5	0.75	0.83	8.4
P6	1.2	1	1	19.9
P7	2.4	1	1	7.1
P8	5	1	1	20
P9	2.2	1	1	29.6
P10	2.2	0.75	1	11.3
P11	0.9	0.88	1	29.4
P12	2.1	0.88	1	40.2
P13	2.5	1	1	23
P14	1.4	0.75	0.83	3.9
P15	1.6	0.88	0.5	4.7
P16	1.2	0.75	0.83	42.5
P17	1.8	1	0.83	92.3
P18	1.6	1	1	27
P19	0.2	1	1	14.6
P20	3.9	0.88	1	17.2

Table 4.3: Correlation Values

Pearson Correlations					
		GRAPH	DIGIT	CORSI	WORD
GRAPH	Pearson's r	-	0.246	0.073	-0.061
DIGIT	Pearson's r		-	0.353	0.19
CORSI	Pearson's r			-	-0.007
WORD	Pearson's r				-

of dependent variables for a participant with respect to the factor being analysed. Also the between-items values are calculated by taking mean values of dependent variable for the items analysed. JASP and SPSS are used to make statistical analyses.

The primary aim of the study is to find common the levels of graph simplification between a rule based method and humans. The outputs of the graph simplification algorithm are compared with human data. Hence our first hypothesis was:

H1: There is a common level of simplification (degree of simplification) between the simplified graphs which are the outputs of the program and graphs that are pictured by subjects.

Table 4.4: Descriptive Statistics of the Data

Descriptive Statistics				
	GRAPH	DIGIT	CORSI	WORD
Valid	20	20	20	20
Missing	0	0	0	0
Mean	2.425	0.92	0.924	21.98
Std. Deviation	1.423	0.101	0.1273	22.3
Minimum	0.2	0.75	0.5	0
Maximum	5.1	1	1	100

The outputs of the graph simplification algorithm are compared with human data and the scores given to the resemblance of these two graphs are collected. The mean value of the scores is: 2.4. It means that the graphs the subjects sketched are close to the simplification of Level 2.

$Original\ Graph \rightarrow 9\ points$

$Simplification\ Level\ 1 \rightarrow 6\ points$

$Simplification\ Level\ 2 \rightarrow 3\ points$

$Simplification\ Level\ 3 \rightarrow 0\ points$

Simplification Level 1 includes ”Generalization Level 1 Rules”, Simplification Level 2 includes ”Simplification Level 1 Rules” and lastly Level 3 includes ”Generalization Level 2 Rules” mentioned in Methodology part.

From the results It can be inferred that people apply Generalization Level 1 and Simplification Level 1 rules when making a simplification.

Short term memory has an effect on how the viewers remember the graph shown to them. To assess the working short term memory we used Corsi Block Test and Digit Span Test. Digit Span is related with comprehension of the graphs, so there can be a relation between these two variables: the Digit Span score and the score of recalling the graphs. Our second hypothesis was as follows:

H2: There is a correlation between the subject’s level of graph remembering and the score of short term working memory.

A linear regression analysis is used to see if there is a significant correlation of the results. When the data of participants is analyzed, it is seen that there is a slight correlation between the level of remembering graphs and Digit Span test scores of the participants.

In Figure 4.2, Pearson’s r is 0.246 when comparing Digit Span score and graph score, meaning there is a slight correlation between the Two scores.

The density for Digit Span Scores can be seen on Figure 4.3 in first graph. The correlation between the Digit Span Score and Corsi Block Tapping Test and Word Count are shown in the second and third graphs.

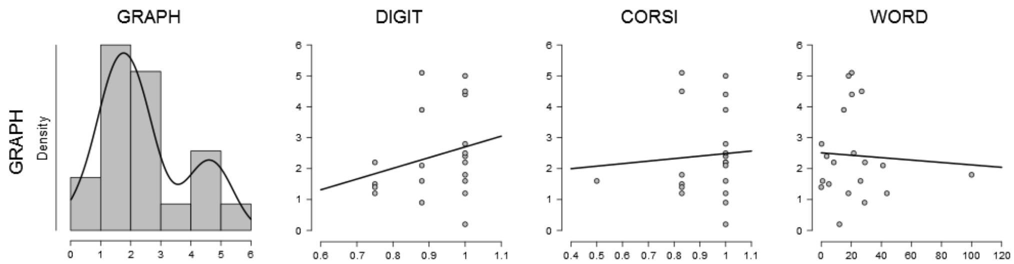


Figure 4.2: Correlation between the graph score and Digit Span Score, Corsi Block Tapping Test, Word Count

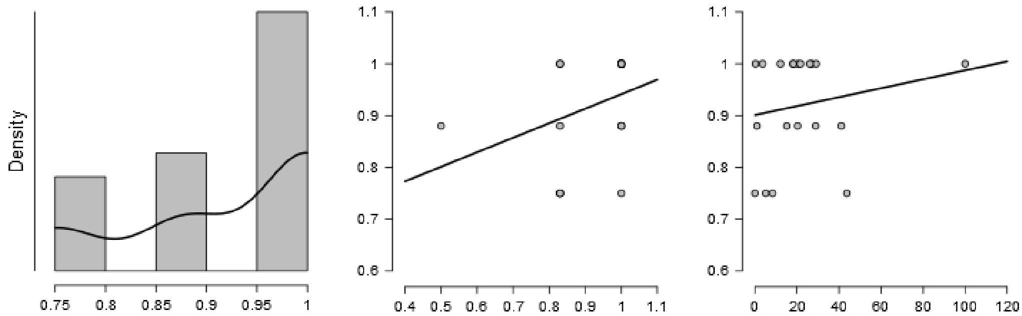


Figure 4.3: Correlation between the Digit Span Score and Corsi Block Tapping Test and Word Count

Pearson's r is 0.073 when comparing Corsi Block Tapping Test score and graph score, meaning there is almost no correlation between them.

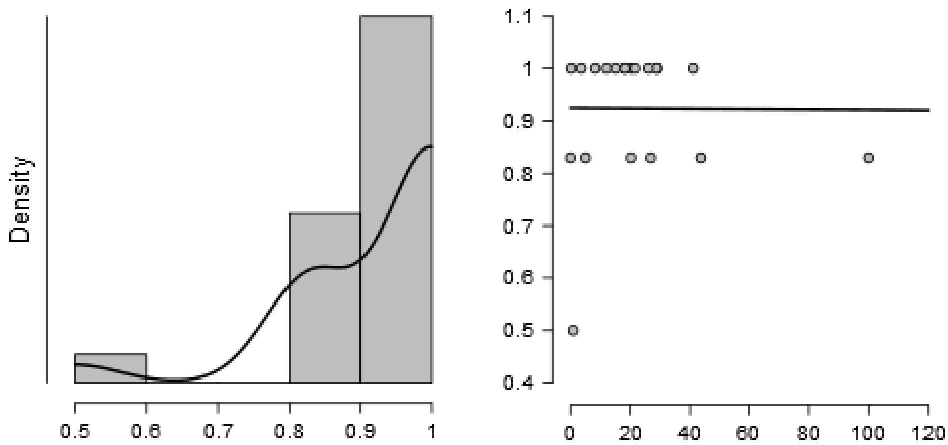


Figure 4.4: Correlation between the Corsi Block Tapping Test and Word Count

The density for Corsi Block Tapping test scores can be seen on Figure 4.4, first graph, where the correlation between the Corsi Block Tapping Test and Word Count can be seen in the second graph.

The voice of the participants while they explained the graphs were recorded, as there

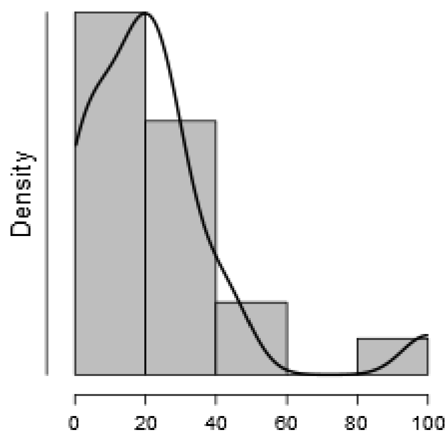


Figure 4.5: Density of the word count

can be a correlation between the length of the explanation and the details of the pictured graph. Subjects, who remember the graphs more, can explain the graph verbally in a more detailed way. Therefore our third hypothesis was:

H3: There is a correlation between the number of word used for explanation and the score of recalling the graphs.

We conducted regression analyses to see if there was any relation between the word counts and graph scores. Pearson's r was found to be -0.061 which means there is almost no correlation between the word counts and graphs scores.

In addition to linear regression analyses, multiple regression analyses was performed to see if there are multiple correlations between the variables. Two such regression analyses were performed within this study.

In the first analyses, the dependent variable is graph recalling. Independent variables are selected as Corsi Block Tapping Test Score, Digit Span Score and the number of words that the subject uses. In reality, the number of uttered words is a dependant variable, but here we use it as an independent in order to see if there is any effect of word number to the graph recalling score.

In the second regression analyses, dependent variable is the number of words uttered by the subject. The independent variables are Corsi Block Tapping Test Score, Digit Span Score. This analysis is made in order to see the effect of memory span scores on subject's explanation of the graphs.

In the second regression analyses the effect of Digit memory score, Verbal memory score and the word count uttered by the subject on the graph recalling score is investigated. As seen in table 4.5, the correlations between the variables are poor. The values are close to 0, meaning the correlations are not significant.

In the Table 4.6, The R value is 0.71, meaning there is almost no correlation between the three independent variables and the dependant variable overall. Durbin-Watson value equals to 1.611 (1.5 < Durbin-Watson (N) <2.5) which means there is no auto correlation between the variables.

Table 4.5: Correlations

Correlations

		GRAPH	DIGIT	CORSI	WORD
Pearson Correlation	GRAPH	1.000	.242	.074	-.061
	DIGIT	.242	1.000	.354	.190
	CORSI	.074	.354	1.000	-.003
	WORD	-.061	.190	-.003	1.000
Sig. (1-tailed)	GRAPH	.	.152	.378	.399
	DIGIT	.152	.	.063	.211
	CORSI	.378	.063	.	.496
	WORD	.399	.211	.496	.
N	GRAPH	20	20	20	20
	DIGIT	20	20	20	20
	CORSI	20	20	20	20
	WORD	20	20	20	20

Table 4.6: Model Summary

Model Summary[b]

Model	Change Statistics					Durbin-Watson
	R Square Change	F Change	df1	df2	Sig. F Change	
1	.071	.408	3	16	.749	1.611

Table 4.7: Coefficients of Collinearity Statistics

Coefficients[a]

Model		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		Beta			Tolerance	VIF
1	(Constant)		-.188	.854		
	DIGIT	.272	1.032	.317	.838	1.193
	CORSI	-.022	-.086	.933	.870	1.150
	WORD	-.113	-.459	.653	.958	1.043

Tolerance values for the Digit memory score, Verbal memory score and the number of words uttered by the subject are 0.838, 0.870 and 0.958 respectively, meaning that there are no major correlations between the variables.

Table 4.8: Anova Statistics

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.735	3	.912	.408	.749[b]
	Residual	35.723	16	2.233		
	Total	38.457	19			

a. Dependent Variable: GRAPH

b. Predictors: (Constant), WORD, CORSI, DIGIT

In Anova Analyses the p value is 0.749 which means it is not significant. If the effects are found to be non significant, then the differences between the means are not great enough to make further interpretation.

In the second regression analyses, the effect of Digit memory score, Verbal memory score on the number of words uttered by the subject.

As seen in Table 4.9 the correlations are poor in this analyses too. The values are close to 0 which means the relations are not significant. There are also negative values indicating there is no correlation.

Table 4.9: Correlations for the Second Multiple Regression Analysis

Correlations

		WORD	DIGIT	CORSI
Pearson Correlation	WORD	1.000	.190	-.003
	DIGIT	.190	1.000	.354
	CORSI	-.003	.354	1.000
Sig. (1-tailed)	WORD	.	.211	.496
	DIGIT	.211	.	.063
	CORSI	.496	.063	.
N	WORD	20	20	20
	DIGIT	20	20	20
	CORSI	20	20	20

In the Table 4.10, The R value is 0.232, meaning there is almost no correlation between the three independent variables (Digit Span Score, Corsi Blok Score and Graph remembring score) and the dependant variable (word count) overall.

Table 4.10: Model Summary of the Second Multiple Regression Analysis

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.232[a]	.054	-.123	20.8944	.054	.305	3	16	.822	1.469

a. Predictors: (Constant), CORSI, GRAPH, DIGIT

b. Dependent Variable: WORD

Table 4.11: Coefficients of Collinearity Statistics

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-5.036	48.469		-.104	.919		
	GRAPH	-1.593	3.473	-.115	-.459	.653	.941	1.063
	DIGIT	5.979	6.483	.246	.922	.370	.828	1.208
	CORSI	-2.111	6.752	-.081	-.313	.759	.875	1.143

a. Dependent Variable: WORD

When we analyse table 4.11, tolerance values for the Verbal memory score, graph remembering score and digit memory score are 0.941, 0.828 and 0.875 respectively, meaning that there are no major correlations between the variables.

Table 4.12: Anova Statistics for the Second Multiple Regression Analysis

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	399.018	3	133.006	.305	.822[b]
	Residual	6985.224	16	436.576		
	Total	7384.242	19			

a. Dependent Variable: WORD

b. Predictors: (Constant), CORSI, GRAPH, DIGIT

In table 4.12 Anova analyses is shown. The p value is 0.822 which means it is not significant. There is no enough information to make further interpretation.

In this chapter results and statistical analyses were provided. Results of the first part of the experiment revealed that there is a common level between the human simplification mechanism and the method. Participants sketched close to the graphs that the method generated. The findings of the Corsi Block Tapping and Digit Span test slightly revealed that participants who have scored more on Digit Span Test, sketched more detailed graphs.

A general discussion on results and future studies is presented in Chapter 5.

CHAPTER 5

GENERAL DISCUSSION

The present study gave rise to commonalities of human graph simplification mechanism and the method created using grammatical set of rules offered by Kulik and Egenhofer (2003). We found that, human subjects apply certain set of rules while simplifying a graph. The level of simplification in human sketches was also influenced by verbal memory span characteristics. Below there is the hypothesis with their discussions and conclusions.

The first finding of the study is that, there is a common level between the mechanism of human simplification and the implemented method. Subjects sketched the graphs apply certain rules like the method did. The average of the given scores is 2.4 which means the graphs that the subjects sketch is close to the simplification Level 2 of the implemented method.

$Original\ Graph \rightarrow 9\ points$

$Simplification\ Level\ 1 \rightarrow 6\ points$

$Simplification\ Level\ 2 \rightarrow 3\ points$

$Simplification\ Level\ 3 \rightarrow 0\ points$

Subjects do not remember the graphs with all the details; simplification is made at while the subject comprehends the graph. The mean of the scores is 2.4 which indicate that simplification occurs at the same time as the simplification made by the method between Level 2 and Level 3. After seeing a graph, a silhouette appears on one's mind and that silhouette is the simplified version of the original graph. It can be inferred from the results that subjects applied Generalization Level 1 and Simplification Level 1 rules while sketching them.

The second finding is related with Digit Span Test and Corsi Block tests. We expected that there may be a relation between the amount of recalling the graphs and short term working memory, because short term memory has an effect on subject's remembering the graphs. Digit Span Test which is used to measure verbal short time memory is related with the task of comprehension of the graphs. It is thought that, if the score of the short term memory is higher, than the details of the sketched graphs would be higher, too. Statistical analyses showed that there is a slight correlation between the Digit Span Test scores and graph scores.

When the relation between the Corsi Block Tapping Test scores and graph scores are evaluated, it is seen that there is no correlation between them. Corsi Block Tapping Test is used to measure spatial short term memory. Comprehension of a graph and remembering a graph is more related with verbal memory instead of spatial memory.

The method offered by Kulik and Egenhofer (2003) includes grammatical set of rules and also terms that is used for the verbal and qualitative description of a graph. The present study also investigates the verbal explanation of the graphs. To do this, the voice records of the participants are gathered and examined. It is noticed that, human subjects prefers using shapes while describing a terrain feature. There are people saying ”Mountain” to a terrain feature, which is defined in the method offered by Kulik and Egenhofer (2003).

When the voice records are analysed, it is seen that there is no correlation between the word count that the subject uttered for describing a graph and subject’s graph scores. The hypothesis claims that there is a correlation between the length of the explanation and the details of the pictured graph. Subjects, who remember the graphs more, may describe the graph verbally, in a more detailed way. After the statistical analyses, it is observed that there is no correlation between word counts that the subject uttered and subject’s graph recalling scores. However, the study may propose other relations if further study is made on the gathered data. An algorithm can be developed which describes a graph verbally.

One finding is that, people tend to sketch curvative lines instead of angular lines.

The present study explores the applicable levels of graph simplification methods in human-generated sketches. A method offered by Kulik and Egenhofer (2003) is implemented in order see the simplified versions of the graphs. The input for the program is one graph to be simplified, and outputs of the program are three simplified graphs at three different levels. The graphs are simplified according to defined rules.

An experiment is conducted and presented within the present study. Subjects are presented graphs and they asked to sketch the graphs. Sketched graphs are evaluated by another group of people. Evaluators give a score on the resemblance between the outputs of the program and the sketches of the humans. So, the two outputs one is from humans and the other one from the method was compared. To deduce information from the data represented, regression analysis was applied during the evaluation of the results. The analyses suggests that subjects sketched the graphs are applying certain rules like the method did. As told in hypothesis part, there are commonalities between the method and the way of human simplification.

As a further study, the description of the graphs made by human subjects could be examined and the shapes that human subjects tend to prefer can be found. By this way, a description of the graph can be compared with the output of the implemented method. The most frequent used words can be deducted by analysing the voice records. So that the language developed by Kulik and Egenhofer (2003) can be improved.

Other experiments may also conducted as a future study by changing some of the parameters. There are various variables in this study. In the experiment part, subjects saw the graphs for 1.5 seconds. If the observation time is increased or decreased, the sketched graphs would be different. In the pilot study, subjects observed the graphs for 1, 2 and 3 seconds. 1.5 seconds is selected because this amount of duration is more suitable in terms of feasibility of the method. If the duration is higher, the graphs would be sketched probably in a more detailed way.

One other parameter is that, if the subjects do not have prior knowledge about the process, results may be different. If the subjects are not told that they are going to memorize a graph, and graphs are showed unexpectedly, their sketches would be different.

In the study, subjects first do the sketching and then describe the graph verbally. So the sequence is, first sketching and then verbalizes the graph. If the sequence is opposite, the results may differ. The sketches would be less detailed but the explanations could be done in a more detailed way. However, these are not the definite results. The results are obtainable only after making related experiments.

The sketched graphs could be examined deeply, so that the distortion of the sketches could be discovered. When the subject draws the graph, distortions may occur in terms of size, length, proportion and angularity. It is already noticed that, subjects tend to draw curvative lines. Also, the size of the seen graph and sketched graph may differ. Although the sizes of the presented graphs and the boxes that subject use to sketch the graph have the same sizes, the graph's size may differ. This could be found after a detailed investigation of the sketched graphs.

In conclusion, comprehension of the graphs has been the subject of many studies in cognitive science and related domains. This thesis aims to find common levels of graph simplification between a rule based method and sketches generated by human subjects. So far, the aim is achieved. However, there is still room for enhancements both in conceptual sense and practical sense

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