2 BACKGROUND

In communication, we have different kinds of domains we can use to represent a specific topic or problem. An application domain represents the abstract view of the specific topic. With the textual domain, we can represent the topic or problem by using natural language. It is also possible to express the topic by using pictures from the graphical domain. Both representations refer to the same object.

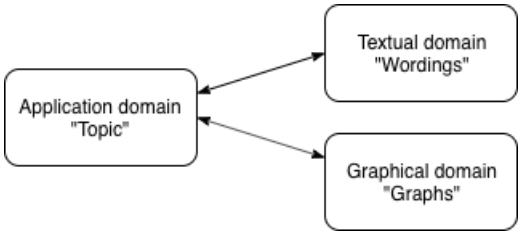

Figure 2: Three domains for communication

In the way natural languages have a semantics, pictures also have semantics when they are used as a medium to help people to communicate. However, there is a distinction between picture semantics and natural language semantics: the semantics of pictures is not fixed by convention. The same picture may have completely different meanings when it is used in different circumstances. Wang et al. (1995) Performed a study on how to assign meanings to pictures when they are used to help people in communicating. In her thesis, she uses the term *visual communication* for communication involving the use of pictures. Intuitively, visual communication involves three parts: a graphical domain (the pictures), an application domain (the problems) and a link that associates the graphical domain with the application domain (the semantics of the pictures).

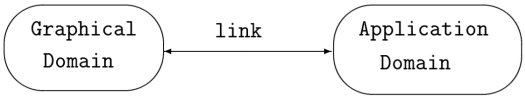

Figure 3: Three parts of visual communication by Wang et al. (1995)

Wang et al. (1995) say that the link between domains plays an important role in visual communication. Without the link, pictures only carry spatial information. It is the link that transfers spatial information into information about the application domain so that in this case, pictures can be helpful in communication. The term *visual communication* forms the basis of this research. I use it to explain the differences between the graphical, textual and application domain together with the links between the domains. The domains represent the way of presentation modality.Wu et al. (2010) say that information graphics (for example, line graphs and bar charts) that appear in popular media, such as newspapers and magazines, generally have a message that they are intended to convey. The intended message captures the high-level knowledge conveyed by the graphic and can serve as a brief summary of the graphic's content. They present a system for recognizing the intended message of a line graph. Where they segment line graphs into visually distinguishable trends which are used to suggest possible messages, and by extracting communicative signals from the graphics and using them as evidence in a Bayesian Network to identify the best hypothesis about the graphic's intended message. In this research, during text analysis, I make use of intention categories of High-Level messages for line graphs.

Demir et al. (2008) say that information graphics, such as bar charts and line graphs, play an important role in multimodal documents. In their study, they present a novel approach to produce a brief textual summary of simple bar charts. For example, *The graphic shows that United States with 24,434 has the highest number of hacker attacks among the countries Brazil, Britain, Germany, Italy, and United States. United States has 4.9 times more attacks than the average of other countries."* Their method simultaneously constructs both the discourse and sentence structures of the textual summary using a bottom-up approach. The result is then realized in natural language. In their research, they illustrate increasing trends in a bar chart, while others Zacks and Tversky (1999) describe trends as designed for line charts. I will discuss this in section 5 Results and discussion.

Burns et al. (2012) performed a study on automatically recognizing intended messages in grouped bar charts.

They say that grouped bar charts are a type of information graphic. They are similar to simple bar charts in that they visually display quantifiable relationships of values; however, they contain an additional grouping dimension. Despite this additional complexity, they still convey intended high-level messages. They describe different kinds of high-level messages and linguistic signals. In this research, I use the signals for trend identification during text analysis.

Zacks and Tversky (1999) performed a study to find out how people are inclined to articulate about bar charts and line graphs. They found out that people are more likely using discrete comparison terms for describing bar charts and trend assessment terms to describe line graphs. In experiment one they presented participants with simple bar and/or line graphs and asked them to describe what they saw. In the second experiment, they manipulated the conceptual domain of the graphs along with the graph types that produced situations in which the bar-line convention conflicted with the content of the data. Again they asked participants to describe the (manipulated) graphs. These two experiments showed that the bar-line convention systematically influenced readers' conceptual understanding of a graph. Participants came up with discrete comparison responses like "Y is greater in a than B", or "The average male is taller than the average female" and trend assessment responses like "As X increases, Y decreases", or "The more male a person is, the taller he/she is". In the third experiment, they wanted to know if the authors of graphs are also sensitive to the bar-line conventions like the readers. Participants were given discrete or continuous descriptions of data patterns together with frames for a graph and asked to draw a graph. They found out that given discrete descriptions, participants tended to draw bar graphs, while given a continuous description, they tended to draw line graphs. The results of this study provide me indicators to identify bar chart and line graph descriptions for textual analysis.

Card et al. (1999) wrote a chapter about information visualization where they explain a model called the 'visualization reference model' shown in figure 4 which can be used to transform raw data into a visual form. They define information visualization as "the use of computer-supported, interactive, visual representations of abstract data in order to amplify cognition"Card et al. (1999). In their chapter, Card et al. (1999) also explains examples of possibilities of what you can do with information visualization. They describe what information visualization is, what it does, why it works and where the historical origins came from. The model shows that if you want to convert data into a visual structure, you, first of all, have to transform data from raw data (data in some idiosyncratic format) into structured data. The data from the structured format can be converted into a visual structure in such a way that visual components can be made such as spacial substrates and other graphical properties. Visual structures can be further transformed by view transformations, constructing the graphical parameters such as positions, scaling, etc, until it finally forms a view that can be perceived. In my research, I use the reference model to transform wordings (from the textual domain) into a structured form so that underlying characteristics can be discovered and used for analysis.

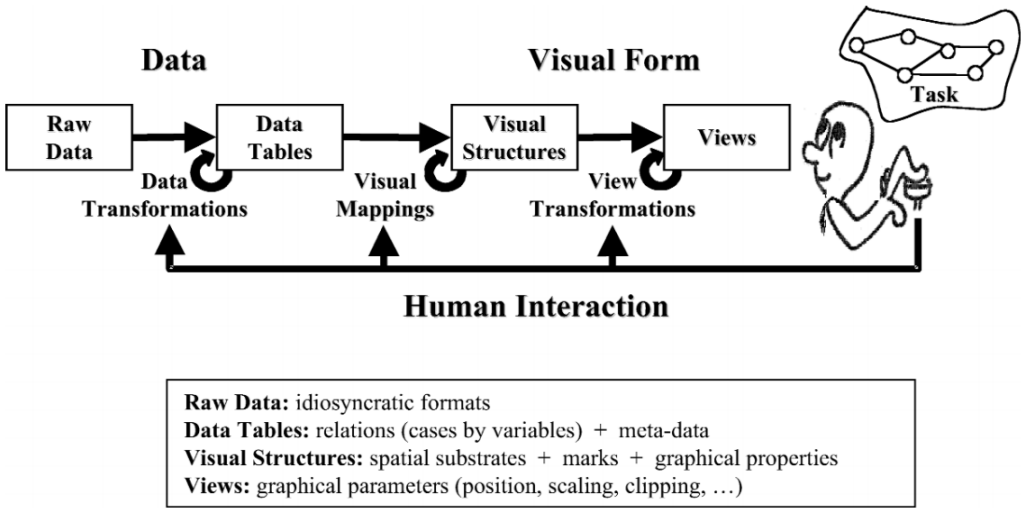

Figure 4: Visualization reference model by Card et al. (1999)

The book Visual language Broek et al. (2012) explains three important theories relating to visual images: Gestalt, semiotics, and visual rhetoric. Using these theories, the book then explores the fundamental elements of visual language: composition, typography, perspective, and color. In the book, they describe visual rhetoric as the meaning of communication.

2.1 KEY CONCEPTS

- Textual domain: A textual perception of a topic represented by natural language, "Wordings."
- Graphical domain: A graphical perception of a topic represented by graphics, "The pictures." Wang et al. (1995)
- Application domain: A specific topic, "The problems." Wang et al. (1995)
- Intended message: The message someone is attempting to send is what we call the intended message. In a graphical domain, Wu et al. (2010) contends that this message captures the high-level knowledge conveyed by the graphic and can serve as a summary of the graphic's content. This is supported by the observation that the overwhelming majority of information graphics from popular media sources appear to have some underlying goal or intended message Elzer et al. (2011).
- Bar chart: A mathematical picture in which different amounts are represented by thin vertical or horizontal rectangles that have the same width but different heights or lengths 2019 (2019a). Characteristics of a bar chart are: Numbers at the Y-axis, categories at the X-axis Broek et al. (2012).
- Line graph: A drawing that uses lines to show how different pieces of information are related to each other 2019 (2019b). Characteristics of a line graph are: Time variable can only be placed at the X-axis, numbers are placed at the Y-axis, time develops from left to right Broek et al. (2012).
- Information Visualization: "The use of computer-supported, interactive, visual representations of abstract data in order to amplify cognition"Card et al. (1999)
- Discrete comparison: Terms that could be used to describe a separated comparison between data points Zacks and Tversky (1999). For example, Male's height is higher than that of females, or: B is bought more often that A.

- Trend assessment: Terms that could be used to describe a specific point in a continuous data sequence Zacks and Tversky (1999). Trend descriptions use terms like function, relationship, correlation, varies, trend; they tend to refer to continuous changes in the variables. It is the widespread practice of collecting information and attempting to spot a pattern. It could be used to estimate uncertain events in the past (or maybe in the future). For example, The graph shows a positive correlation between a child's increases in age and height between the ages of 10 and 12.