The Visualisation of Diverse Intelligence

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1 Introduction

At last years' NATO workshop "Massive Military Data Fusion" in Norway 2002, among others, it was agreed that there is an increasing need for visualisation of data. This need is a increased by obtaining more data coming from more sensors and different sources.

In the intelligence context, the fusion of information is a multi-layer process. First, raw data are collected and filtered and brought to archives. The analysis of the data is the most time consuming process, since it can be automated only in a limited range. Thus, there is a need for a "human-in-the-loop". For humans, the best way to analyse amounts of data is their pattern recognition abilities, thus using powerful algorithms of visualisation. In this paper, we will present our approaches to visualisation in different levels.

First, we will describe data modelling in the intelligence context, presenting our approach of the MEDAV archive as data model and the stages at which visualisation is a powerful means. In the following section, we define approaches to visualisation, and further on, show our approaches to visualisation for different information retrieval tasks.

2 Data Modelling

One of the most important parts of the information fusion task is the data model. The purpose of data modelling is to develop an accurate model, or graphical representation, of the client's information needs and business processes. The data model acts as a framework for the development of the new or enhanced application. Since the amount of data to be analysed can be enormous, the data model as a core of the system must be efficient and well-organised for the domain of diverse intelligence.

Data modelling can be defined as the design of the logical and physical structure of one or more databases to accommodate the information needs of the users in an organization for a defined set of applications. In the intelligence context the basic need is

- to offer possibilities to store huge amounts of data,
- allow access to all data without regard to the type of original data, e.g. recording source, text or speech signal.

The amount of data is rising, since data come from more and more input channels. Channels in a typical application in the intelligence context may be speech from telephones, mobiles, HF and many other sources. Signals are found that might incorporate speech in some parts. Furthermore, information is gathered from texts from different sources, e.g. internet, mails, newspapers. Another source of information is images, such as from satellites. All these sorts of data have to be analysed according to a special task or question. For each of the channels, the way of analysing data may be different, but none of the channels may be neglected.

A good data model finds an efficient way in which input from different channels is stored in a somewhat similar way in order to access the data for further analysis in a similar manner. Usually, data would be stored according to different criteria, e.g. depending on the source of the data. Another criterion may be the type of pre-processing that classifies the data into different categories, and attaches the gathered meta information to each datum.

For the analysis of data, there is a need for a human-in-the-loop, i.e. at some point, a human operator must check and evaluate the data or the automatically gained analysis. The work of the human-in-the-loop can be assisted in different ways, mainly in two different types: 1) pre-selection of data that are of more relevance than other sets in the data. This can be performed automatically up to a certain level.. 2) analysis of data, among others by means of visualisation. The main advantage of the using visualisation at this step of processing is that humans tend to quickly understand complex issues when presented visually. Thus, the process of analysis is speeded up when using visualisation.

In the next section we will describe our approach to data modelling with the MEDAV archive in more detail.

3 Data modelling in the MEDAV Archive

For the past 20 years, MEDAV GmbH has been a developer of intelligence processing hardware and software. We have been engaged in studies and commercial projects for the German Federal Armed Forces and for other German and international government agencies. Our challenge has been to develop hardware and software systems that incorporate the different levels of information fusion within the one architecture.

The need, especially in the intelligence context, is to archive huge amounts of data of different sources and to find all kinds of information regardless of the format the data are stored. The goals are:

- Allow storage of amounts of data coming from a variety of input sources.
- Retrieve information within all data types in the same manner, regardless of the type of source.

The task to be solved by the archive is to search information or documents in the archive and for example to print out the relevant documents. This task can be solved with our data modeling together with the MEDAV archive.

The main principle is, that all data are stored together with attributes. The attributes consist of standard attributes like the date, size of source data as well as with an unlimited number of additional attributes that are defined by the application and by the users. Possible attributes are the author of a documents, the transcription (of sound files for example), keyword or other comments on the content of a data set. New attributes can be added at any time when desired by the user of the archive. The data are compressed and can be encrypted. The access can be limited to special data and a special user group. The access to the archive can be logged.

The search can easily be performed within the attributes. When a datum is stored, it is also entered into a searchable index file. Furthermore, the data can be removed from the archive, but the index can still be searched further on.

Most importantly, the front-end towards the user remains the same for different tools inside the archive. All types of data can be searched in the same way regardless of their origin. No knowledge about data modelling detail or the data architecture is necessary for the user.

An overview of the data modelling in the MEDAV archive is given in Figure 1.

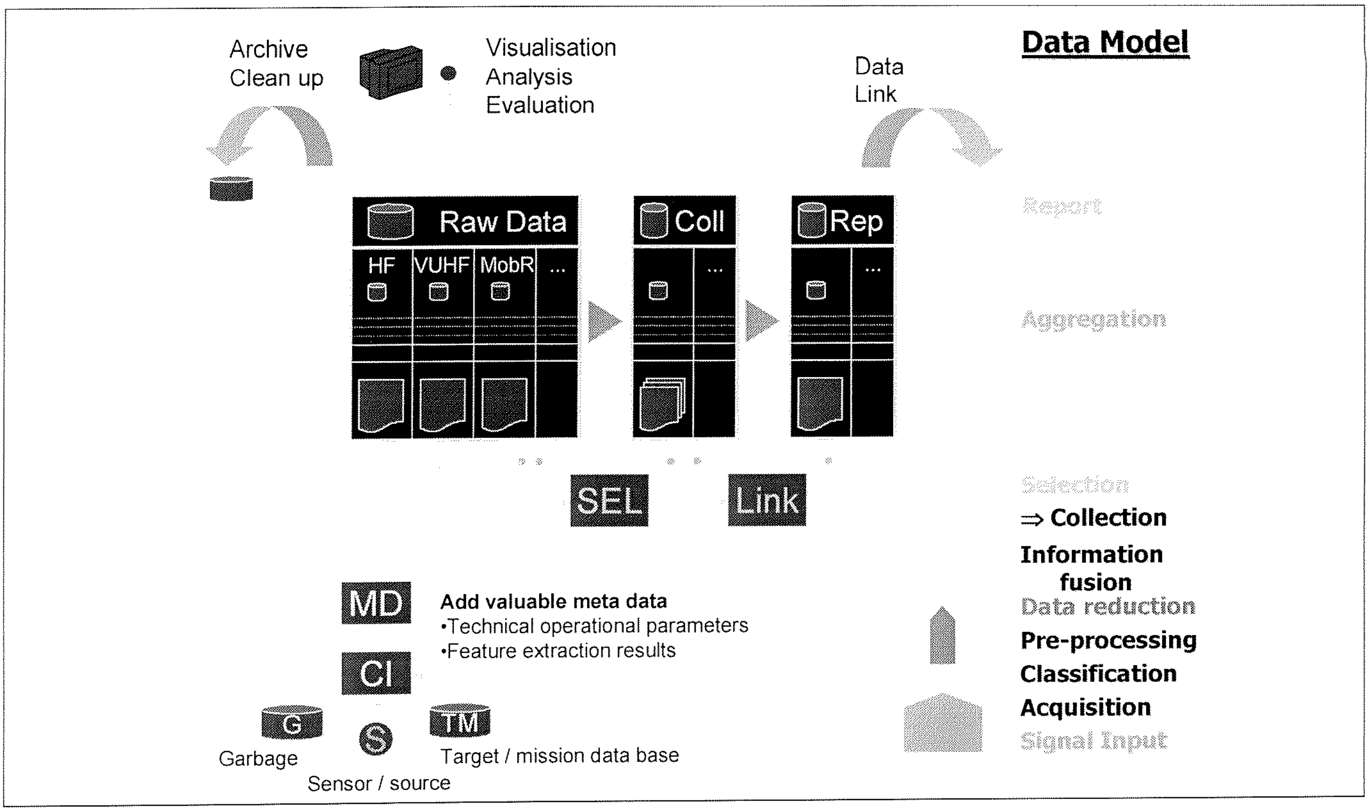

Figure 1 Data modeling in the MEDAV archive

At the bottom on the left the sources *S* are shown. Input is gathered from different sensors. These data pass a pre-processing step, in which they are classified (*CL*) using a target/mission data base *TM*. Data that are not of interest are filtered to the garbage. The kept data are passed to a feature extraction step obtaining meta data information that may be of interest for further analysis.

The data are labeled with additional information like recording time and spoken language. For each data file that is obtained that way, information is attached as meta data (*MD*) that may the used for a faster search than when looking up in the source data. These raw data are stored in an archive.

Each information source is kept separately, as HF, VUHF, MobR in the example in Figure 1. The raw data part of the archive contains the original data together with the additional meta data. For further analysis, a reference to the original data is always added in order to be able to trace the analysis back to the original data, for example for verification.

The next step in the archive is a selection of the data (*SEL*) with respect to the information retrieval. Selected data according to a choice of criteria are put to the *Coll* part of the data base. Selection can be performed automatically for some task as well as manually by a human operator. In this step, information fusion can be performed both by selection of a number of data files as well as by reducing each data file itself, e.g. cutting speech signals to the relevant parts or by summarizing text. Visualisation of data files is a feature that is very helpful at this step. A request to the selection of raw data may be "show all data containing KEYWORD_1 and KEYWORD_2 and make statistics about the frequency of occurrence in a certain time frame". Another application could be to make text summaries of text files containing certain keywords or by a certain author.

The result of the information fusion is a collection of relevant data and/or summaries and statistics of the raw data base. Now, the evaluation is completed by writing a report (*Rep*) to the organisation of the operator. The report contains the evaluation results from the collection part of the data base. Furthermore, the report contains links to the original data in order to be able to check the completeness and correctness of the data and to provide quality assurance.

During the analysis of the raw data base with respect to a certain task, an aggregation takes place from raw data to collection and towards report. This aggregation on the one hand is a selection of the important data as well as a reduction of the data towards to important features for a chosen task.

Evaluation of the data happens in two places: first, in the selection step and further on, in the report. The evaluation can be performed automatically or semi-automatically or manually by the human operator. An interface for automatic evaluation is provided to make the evaluation easier for the operator.

Visualisation in this application can be used at two stages: in the process of selection and in the report. The task of the visualisation is to support the operator to easier find important data and to make the obtained results more visible, i.e. easier to understand at a glance.

4 Visualisation

As we have seen in the previous section, visualisation is an important feature in the analysis of diverse intelligence. In this section, we will present our approach to visualisation. First, we should define our understanding of visualisation and how it can be classified. Therefore, we present a visualisation model. The human operator and the reader of a report are the users of the output of visualisation. An important topic is the human interaction between the human and the visualisation interface as well as the best way to show contents visually.

The goal of visualisation is, generally speaking, to make large data sets more accessible and easier to understand in short time. Different means can be used for visualisation: graphics, that show statistics for example in a histogram, but also compressed texts that are shorter than the original texts and therefore save time to read. Additionally, important parts may be highlighted.

Classifying visualisation by means of output we can find three categories:

- Traditional static predefined displays
- Augmented reality displays (where interactive iconic and textual information are embedded in realistic life scenarios)
- Virtual reality displays (where the user is located within the image and becomes part of it)

The emphasis of this paper is set on the first item, additionally we will show some examples from the other types.

4.1 Visualisation Model

At last years' workshop, a visualisation model was developed that describes the visualisation process, see Figure 2. The user of the visualisation interface accesses the multimedia displays which optimally cover the senses of humans, i.e. visually, aurally and even haptically as appropriate for the application in question. The user interacts with the multimedia displays in several modalities, traditionally with keyboard and mouse, but also with voice and gestures according to the requirements of the application.

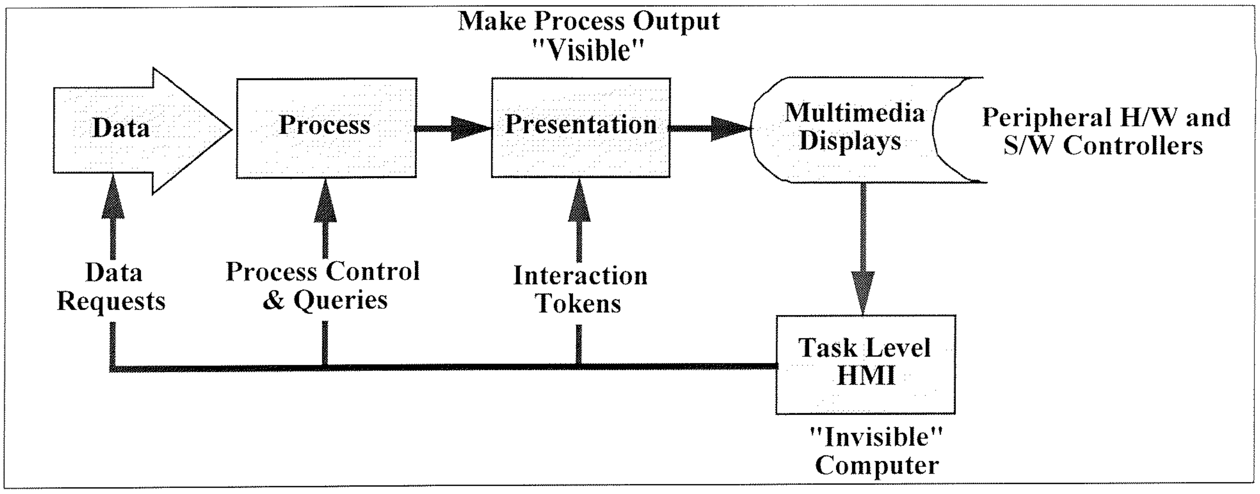

Figure 2 The Visualisation Model

From the multimedia displays, the user interacts with the task level HMI (human machine interface) in the most natural way, since at this level, humans should not be burdened with extraneous cognitive tasks required to operate a computer system — a well-designed HMI should make the computer "invisible" to its users, in the words of Donald Norman [Norman, 1998 #1286]. Using the task level HMI, the user should be able to obtain the desired information in the wanted type of display, the HMI controls the modalities of presentation by interaction tokens.

4.2 Human interaction

The goal of visualisation is to provide easy and fast understanding of complex issues. Therefore, the HMI should be designed corresponding to natural human communication. The first item is to study the results of physiology and psychology. The *grok box* project (http://vader.mindtel.com/concepts.html), among others, deals with these aspects.

A visualisation interface should be understood and handled intuitively. It should be represented by well-known symbols. Ideally, the symbols in the used iconography have a relation to what they stand for, such that understanding the visual representation becomes easier. Furthermore, the human understands best, if several sensory modalities are employed at the same time such as visual, aural, tactile stimuli. This effect can be consolidated by using different colors, different sounds etc.

For optical representation different shapes and colors should be used. Large or frequently occurring aspects should be represented by large symbols, important topics should be placed in the middle and/or be highlighted. Still, we must pay attention not to overload the image with too much information and too complex iconography to keep the image intuitively understandable.

The visual representation depends much on the content that is to be displayed. There is no best set of symbols or way to display information. Some complex data may need more interaction with the user, such that he may want to change the view on the presented data depending on his interests.

4.3 Our approach to Visualisation

The overall principle of our approach to visualisation is to provide an intuitive means for fast understanding of complex issues and facts. The important parts of the presented information should directly come into mind and view.

During the design of a visualisation tool, it is important to specify the preconditions of both the domain of analysis as well as the knowledge and preferences of the user. Thus, an estimation of effort must be done regarding, computing power that might limit the range of possible visualisations. The preferences of the user regarding the type of output, and the display of information must be determined. It must also be estimated if any type of knowledge is needed as a prerequisite for visualisation like a language's grammar or an organisation's structure.

One need that we have found in our studies is to provide a generic tool that can be specified to a certain amount by the user towards his means. On the other hand, the tool should be specific enough to meet the needs of the user providing fast access. We will provide different levels of visualisation ranging from text output to virtual reality graphics. We will use colors and highlighting for making the optical access easier. Drill-down, i.e. interactive focusing on a special part of the image will be provided if desired. Depending on the application and prerequisites we provide different modules for visualisation. In the following section, we will provide examples from our work.

5 Visualisation Examples

In studies with the German Federal Armed Forces, MEDAV has evaluated a variety of information visualisation tools. While it is true that " a picture tells a thousand words", we find that users need to have different views over the same data. For example a graphical display of a military command structure can be usefully complemented by a simple tabular display of other information. However, neither display by itself is adequate. As another example, a graphical content summary of a text document may be useful if the document is large but for small documents (or parts of documents), the user may prefer textual summaries.

In this section, we will demonstrate visualisation tools at different levels of specialization, representation and display from studies we have performed. We can roughly classify the visualisation examples as shown in Table 1. The first two examples show the visualisation of signals.

Visualisation at the signal level is shown in Figure 3. A basic approach is shown in Figure 4, showing a two-dimensional graph of communication structures. Figure 5 and Figure 6 show further solutions for the visualisation of flows. Figure 6 and Figure 7 present interactive visualisation HMIs, the first one with a complex choice of visualisation options. Figure 8 gives an example of a virtual reality application. Figure 9 and Figure 10 show applications that work based on the analysis of the contents of texts and tables using artificial intelligence techniques.

Figure 3 Sonagram in 3D, Eye Diagram in 3D	Signal, 3D
Figure 4 Command Hierarchy	Classical, clustering, static
Figure 5 Bandwidth of a communication network	Flow, static
Figure 6 Transmitter traffic in real sites	Flow, photo, interactive
Figure 7 Communication cube	Cube, interactive
Figure 8 Virtual Reality Application	Virtual reality
Figure 9 Communication of employees	Text mining, interactive
Figure 10 Visual Summary	Visual summary, interactive

Table 1 Visualisation solutions

5.1 Visualisation of Signals

At the level of signals, there is already a use for visualisation. Both example in Figure 3 show that the use of colors, and three-dimensional representation enhance the easy understanding of signals. The sonagram can be visualised in 3D representation on the left side of Figure 3. The frequency is shown from left to right, the time axis is from front to back, and the intensity is shown in the height and colors. Another example is the eye diagram on the right side of Figure 3. The quality of the signal can be seen better using colors and 3D representation.

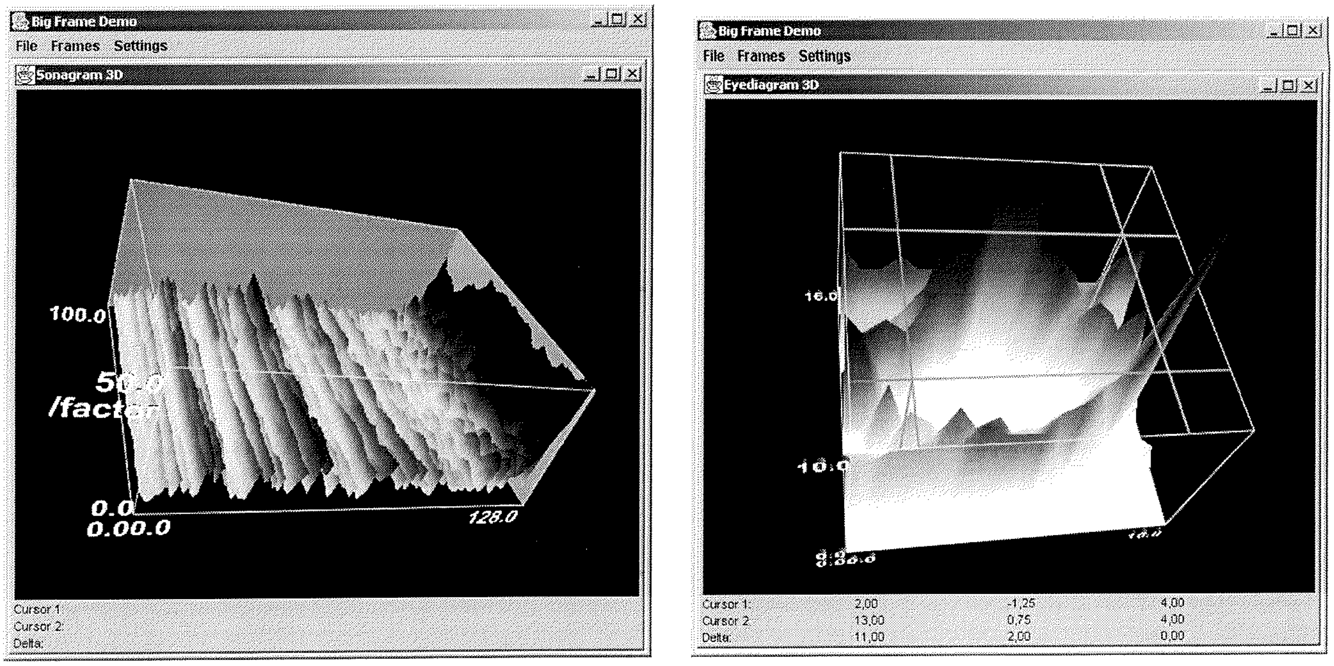

Figure 3 Sonagram in 3D, Eye Diagram in 3D

5.2 Classical visualisation

A very simple and easy-to-realise visualisation is to represent data in a diagram or histogram in 2D or 3D. Colors help to show correlation, additional graphics may emphasize results. Figure 4 shows a representation of a command structure obtained by cluster analysis of communications frequency. The command hierarchy is illustrated in the vertical dimension while the colours and shapes are easily interpreted by reference to the index at top-right. (Führung Ebene 1 = leadership level 1, Bearbeiter = administrative assistant, Admin = administration). The y-axis shows written e-mails, the x-axis shows confirmations (or very short replies) on these e-mails. From the type of e-mails and their answers, conclusions of the hierarchy of a company can be drawn.

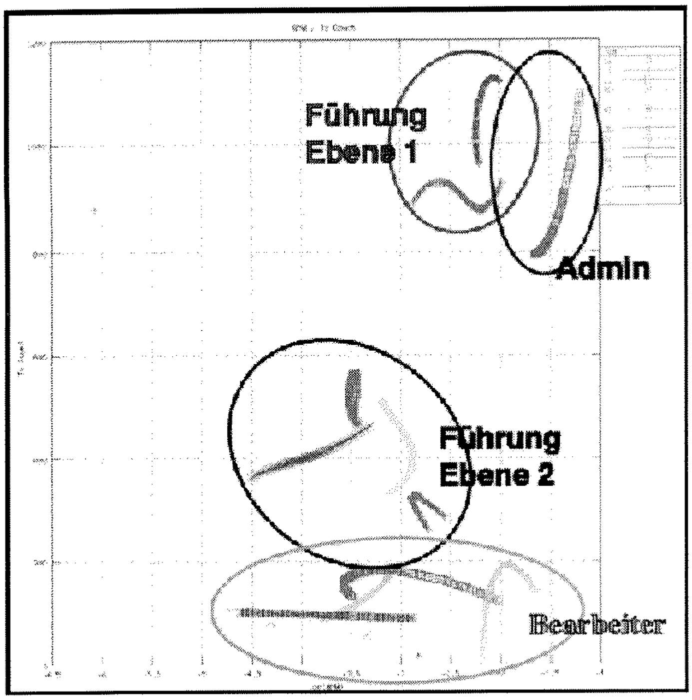

Figure 4 Command Hierarchy

5.3 Communication flows

Communication flows can be visualised by lines with different color or thickness depending on their value. In Figure 5 the bandwidth is shown by the thickness of the lines from different places. For intuitive understanding, the network is projected on to a map of Europe. At the first glance, the main network streams can be identified.

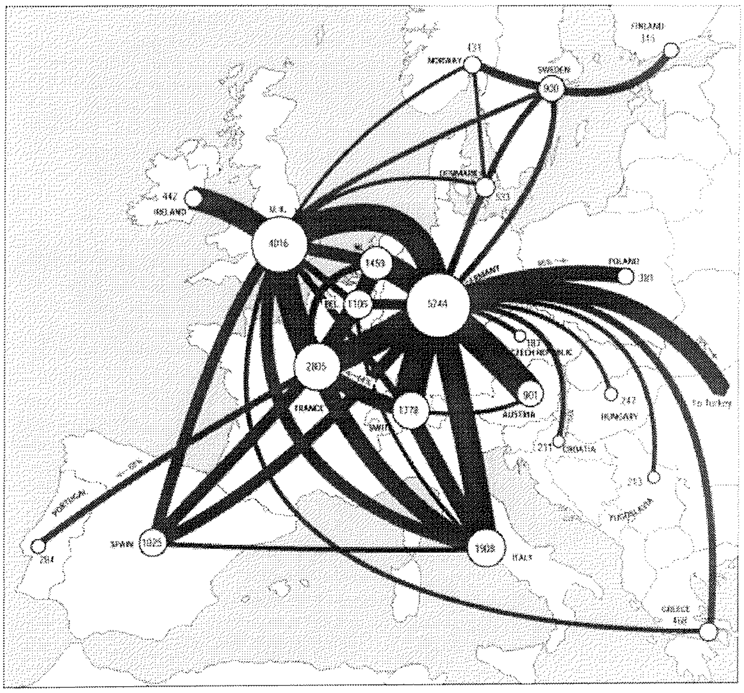

Figure 5 Bandwidth of a communication network

Another example is the interactive view of communication streams in Figure 6. Instead of the map, a high resolution 3D landscape is shown, and the position of the transmitters is projected onto the site.

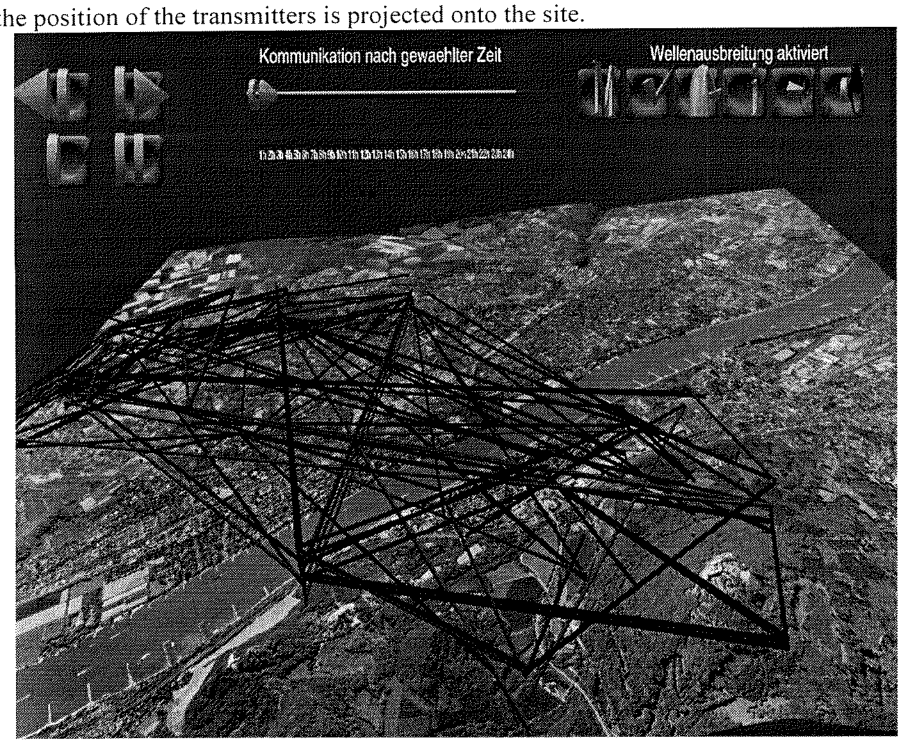

Figure 6 Transmitter traffic in real sites

The user may scroll the icons at top of the graphic and choose a time and place of interest as well as a choice of options for the display of the transmitters. The color of the communication lines distinguish between data and speech communication. The user has several options for interaction with this visualisation interface (top right of Figure 6).

- Text drill-down: the user can select a transmitter and get text information about this transmitter.
- Audio drill-down: the user can listen to the selected channel.
- Wave propagation: shows the wave propagation around a selected transmitter
- Labeling of a transmitter: e.g. for establishing a hierarchy of transmitters.
- Inspection of transmitters: further properties of the transmitter can be studied.
- Message: observation can be recorded as text.

Another example of displaying a communication flow with many data is a communication cube as in Figure 7. For example, the communication flow over time can be visualised in this way. Two axes in this cube represent the sender and receiver, the third axis represents the time window. The intensity is shown by the size of the dots in the cube. Periodically occurring communications can be seen at a glance. The cube can be rotated or moved by the user in order to obtain a better view to his specific field of interest.

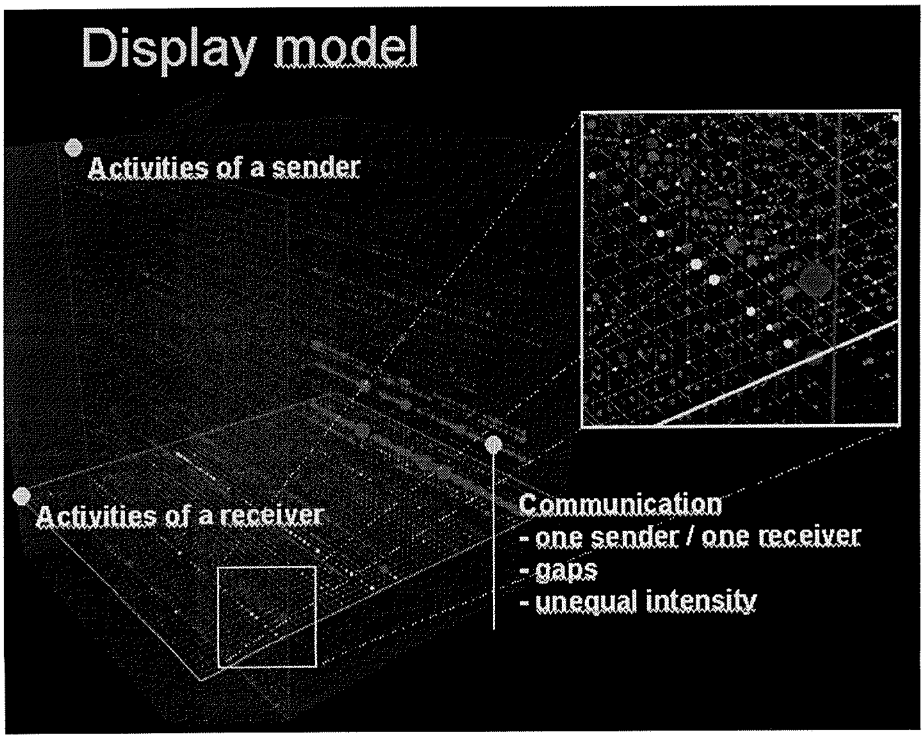

Figure 7 Communication cube

5.4 Augmented and Virtual Reality

In augmented reality, a live vision is combined with additional information gathered from some type of analysis. For example, a photograph of a city is enriched by data classifying the buildings in the photograph. Interactive systems in augmented reality have special requirements concerning real-time processing in order to obtain an alignment between the calculation and the ongoing reality.

In virtual reality, the real image is substituted by a virtual scenery. There is an interaction between the human user and the virtual reality. An example is shown in Figure 8. A special requirement is the fast and exact estimation of new positions, in this case of the position of the hands of the person as well as an estimation of the view and the eye position of the user. In addition, the technique for displaying the virtual reality may be complex for the calculation of the current position and the update after a movement of the user.

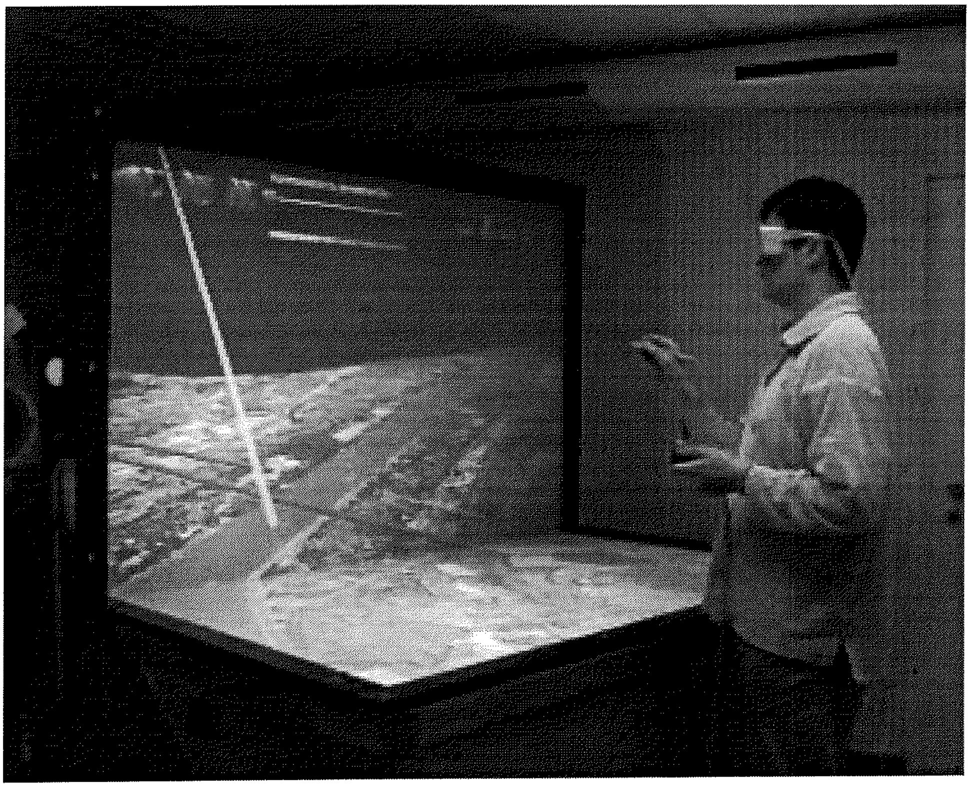

Figure 8 Virtual Reality Application

5.5 Data/Text Mining

In the examples presented until now, the input to visualisation are numbers, signals. The visualisation process presents the data as they were in a format that can easily and intuitively be understood. Text mining as a specialisation of data mining takes texts as input and visualises the *contents* after analysing them according to algorithms deriving from artificial intelligence research.

The data mining technique is employed when large amounts of data must be analysed. After processing of the data and a classification process, correlations, trends, and dependencies can be found.

Automatic clustering can lead to a categorisation of the input data into different classes as the circles in Figure 4, that show to which group of employees a person belongs to with the highest probability. Another strategy is visualisation of dependencies by means of a classification tree. A classification tree is also trained automatically and can draw conclusions after analysing a data base. For example, let us have a data base with information about car drivers including their age, the size of their car and their frequency of accidents. Using this data base, a classification tree can be trained that estimates the probability of a person being involved in an accident.

Association techniques can be used to find correlations between different events. As an example, shopping lists in the supermarket often show strong correlation between different products. As a result, the products in a supermarket can be sorted according to this correlation. This process can be automated.

Another feature is fuzzy search. Looking for a person whose name or orthographic spelling is not known exactly becomes easier when allowing fuzzy search. The suspected name is entered into the category first name or last name and the persons in the data base are returned who most resemble the data entry.

Text mining takes text or tables as input. Given a data base containing data of the internal communication of employees, different results can be found using text mining: Figure 9 shows the habits of communication for two different users. The user on the left side prefers to write the majority of communication in the morning, the user on the right side has a quite stable quota during the day, with a peak towards the evening. This way, people can be identified. Using other views, the hierarchy of the company can be found, explained by the fact, that each employee writes preferably to his boss.

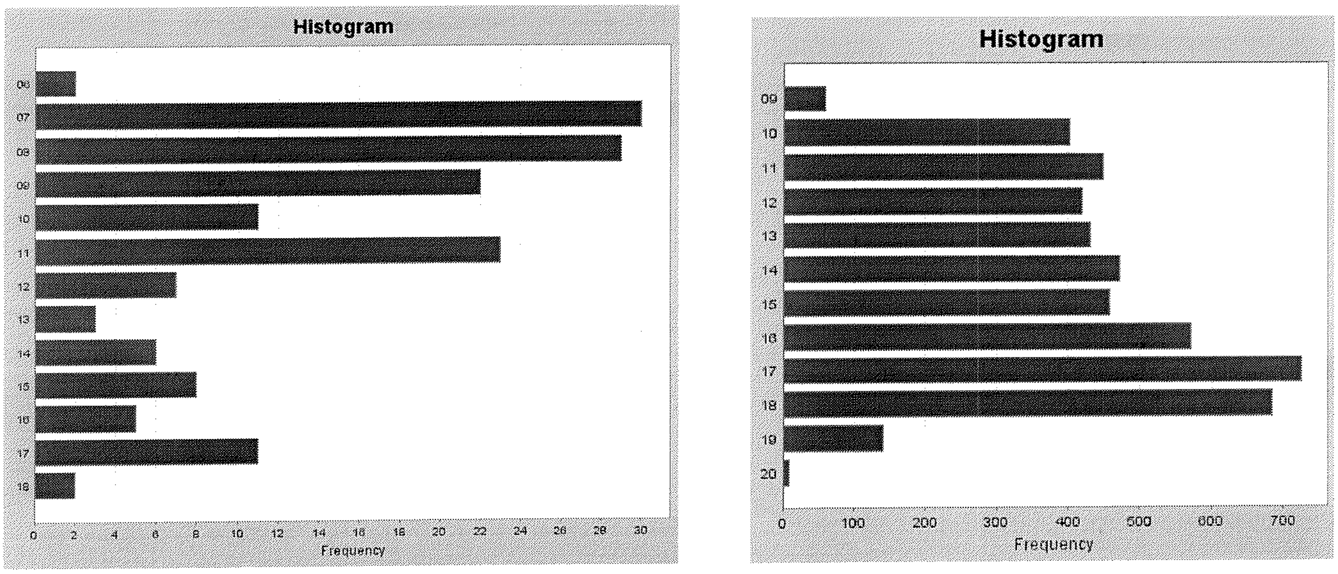

Figure 9 Communication of employees

5.6 Visual Summary

Another application for visualisation is to generate a visual summary from text files of any kind. There are two possibilities:

1. text tagging: from each text, frequent words and keywords are extracted and brought into relation. The output consists of the original text with highlighted keywords. In addition, the highlighted words contain cross-references to other keywords. Statistics of the text are produced.
2. visual summary: the most frequent words of a text or the associations between words are presented as interactive graphic.

For the visual summary, keywords are extracted from texts: these keywords can be determined automatically as the most frequent words in a text. From the list of keywords, function words (the words that are frequent in any text) are removed resulting to a list of words that are important to this special content.

Now, associations between the keywords are estimated, i.e. the frequency of words occurring in each others' neighbourhood. Drawing an image of the keywords with lines between the words as an indication of their association, interesting relations between persons and actions become visible as in Figure 10.

The image shows the frequency of keywords in a source text of 130,000 words. The large dots describe the frequency of the keywords. The thick lines show the associated words. With this type of graphic, the dependencies in complex texts can be found automatically. On the right side more detailed information on each word is given, e.g. the frequency of each word, the most associated words, links to other occurrences of the same word etc.

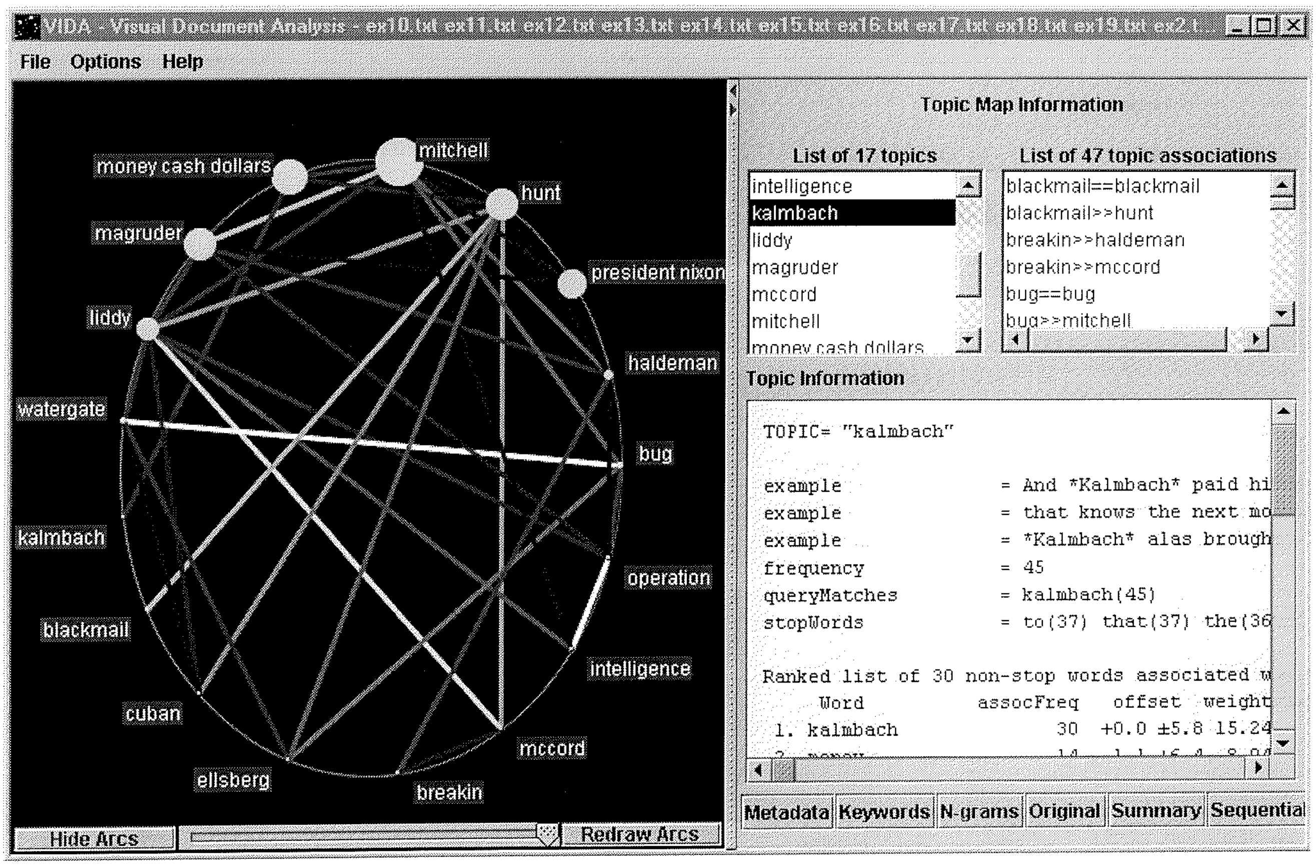

Figure 10 Visual Summary

6 Summary

A picture tells a thousand words. This is true, if the picture is well developed and designed. For information fusion and the visualisation of large amounts of data, it is very important – and becoming more and more important – that there is a good means to reduce the data in a sensible way to quickly obtain the desired information. Some of the ways of designing visual interfaces are intuitive and therefore easy to use. In order to present more complex facts, more of an iconic language may have to be introduced. Still, it seems quite difficult to learn a new iconography that is not obviously intuitive.

This paper showed the results of our work on visualisation that we carried out in order to get the most intuitive visualisation tools for each of the many applications in our studies. As shown, there is a huge potential for the analysis of data bases. Another goal that will be realised in the future is to automatically detect the similarity of data. Using this technique, one can easily find for example all documents belonging to the same topic. For the future, it remains a challenging task for us to continue finding more and intuitive visualisation interfaces for emerging applications.