Alternatives for the Presentation of Information in a Mobile Environment

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Abstract:
This paper presents the concept of alternative presentation components in the context of mobile visualization. A criterion for distinguishing between media with respect to their preparation for the presentation of information is introduced and the conventional visualization pipeline is extended to accommodate the needs of mobile information presentation. The concept is illustrated by some examples concerning multimedia document presentation and scientific visualization. A functional approach to the problem of finding an appropriate information presentation technique considering the current resource situation of the mobile environment is presented and formally described. Some problems arising when applying it in practice are discussed.

Keywords: Information, Visualization, Mobile computing, Presentation, Media

1 Introduction

The field of scientific visualization has progressed rapidly during the last few years. Today, there exist many visualization techniques for scientific data, and powerful visualization systems are commercially available. Information visualization, coined in 1994 by Gershon [GER94], is a field of current research which deals with the visualization of other information classes than scientific data. As a global universe of information the World Wide Web gained great importance over the last few years. Multimedia technology is widely available. It offers potentials for presenting information which have not been exhaustively explored by now. Last but not least, GSM networks place the idea of ubiquitous, mobile information access within the reach of current technology.

2 The Problem

Two contradictions are inherent in information access from „everywhere“ and information presentation on a mobile computer system:

- The bandwidth demands of the transmission of large volumes of data conflict with the low bandwidth of GSM and wide area networks.
- The resource demands of the presentation of large volumes of information conflict with the potentially poor resources of the mobile end system.

One can think of various mechanisms to trade-off the two sides of the conflicts to a certain degree.

First, one can decrease the bandwidth demands of video and still image transmission by *accepting lower image quality*. Current research at our institute investigates the parameters which affect bandwidth demands and quality, measures for image and video quality and the relation between quality and bandwidth demands. The goal of this research is to develop a protocol for the quality and resource controlled transmission of video and still images (see [GRI96]).

A second opportunity for coping with limited resources is offered by the concepts *detail-on-demand* and *progressive refinement*. When using detail-on-demand, the user is presented an overview which he can refine interactively as he wishes. In order to exploit detail-on-demand, the presented information has to be structured hierarchically. When using progressive refinement, presentation starts with a coarse-grained representation, which is refined automatically. The refinement is stopped by a user interaction. This technique is well-suited for the transmission of still images. The JPEG standard, for instance, supports a „Progressive Mode“.

Third, the *distribution of the presentation* between a server and the mobile client enables the use of demanding rendering algorithms like ray tracing. This technique has been applied for instance in the field of fluid flow visualization.

The rest of this paper illustrates the concept of *alternative presentation components*. We assume that there are multiple visualization techniques (presentation components) which show the user what he wants to see but have different resource demands. From this range a component is selected which is content with the available resources.

3 Alternative Presentation Components

3.1 Information Presentation

Media are used to store and present information. The MHEG standard [STE93] introduces five different media types: perception medium, representation medium, presentation medium, storage medium and transmission medium. Information presentation means to map a representation medium (which is a data type with an encoding, e.g., a bitmap) to a presentation medium (which is a medium with some controllable and perceivable property, e.g., the color of a pixel on the screen).

Intuitively, one can classify representation media by whether they have been prepared for the presentation or not. In the case of *prepared media*, the encoding of the representation medium can be directly mapped to the presentation medium (e.g., a bitmap which can be directly mapped pixel by pixel on the screen). The preparation involves transformations of the initial information which is usually lost in that process. This initial information is stored in *unprepared media* - but they cannot be mapped directly to a presentation medium. An example for this type of media is a set of volume data. Before it can be presented, a scientific visualization algorithm has to transform it into a bitmap.

Information presentation using conventional media like text, image, audio and video is widely used. A rich set of experiences from print media design and radio and TV broadcasting can be drawn on.

The new field of information visualization (see, e.g., [GER94]) on the other hand tries to apply the well-understood visualization techniques for scientific data to new classes of information. These are more abstract than scientific data, by which most authors mean the absence of a space-time domain. Information visualization is the creation of a graphical representation from a set of information to support the localization, the retrieval and the understanding of information. Several prototypes exist (see, e.g., [CAR91], [BEN95], [CHA95], [KEI94], [HEM93]), but - as opposed by the field of scientific visualization - there is neither a commonly accepted definition nor a framework for information visualization.

Thus, for our research into information visualization in the mobile context, we did not cover the whole range of information classes but limited ourselves to the well-understood classes of scientific data, geographically related data and structured multimedia documents.

3.2 Mobile Information Presentation

Information presentation in the context of limited resources may require to drop parts of the information or to encode it in a resource-saving way. For prepared media, a conversion to another not so resource-consuming prepared medium (often called a *media translation*) may be necessary. For unprepared media, a technique with a reasonable cost-benefit ratio has to be selected (i.e. a technique which meets the interpretation goals of the user and has adequate resource demands). The realization of the presentation using the selected technique requires piping the data through all or some parts of the visualization pipeline (see figure 1).

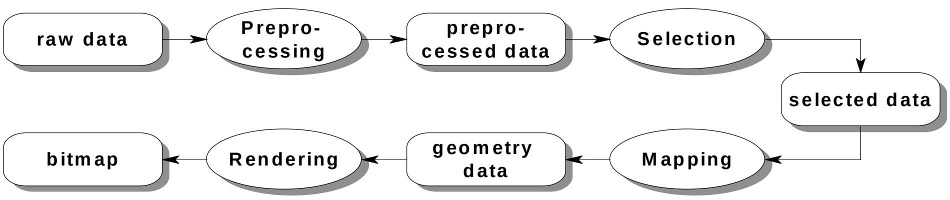

Figure 1: The visualization pipeline

In the mobile context, the conventional visualization pipeline shown in figure 1 (cf., e.g., [NIE90]) needs to be extended to cater for the use of alternative presentation components, the use of prepared media and the distribution of the processes across the network. Thus, we add the presentation stage after the rendering stage (see figure 2). This model allows to accommodate prepared media (called presentable data in figure 2) and the different forms of unprepared media (called raw data, preprocessed data, selected data, and abstract presentation data in figure 2). We see an alternative presentation component as any part of the presentation pipeline which includes the presentation stage.

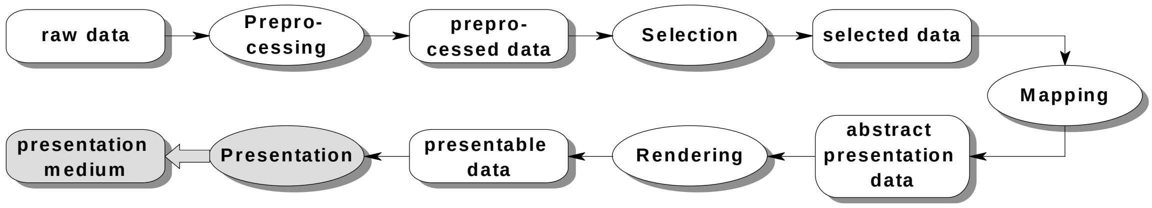

Figure 2: Extension of the visualization pipeline

Take a prepared medium, like a video stream. Its presentation in the context of limited resources may - as stated above - require a media translation. That means, the presentable data have to be converted from one format into another with the goal, that the result of the conversion is presentable in the current resource context. In this case, the selection of an alternative presentation component corresponds to the selection of a format of presentable data, and the realization of the presentation corresponds to its display on the mobile system. Table 1 shows possible alternative formats for presentable data which are equally or less resource-consuming compared to the original format.

	Alternative formats			
Original format	Video / animation	Image series	Still Image	Text
Video / animation	X	X	X	X
Image series		X	X	X
Still Image			X	X
Text				X

Table 1: Alternatives for prepared visual media

Depending on the network bandwidth and the resources of the mobile system, the video stream could be presented as a video, as an image series (a sort of a „slide show" featuring important frames), as a still image (either a bitmap or a vector graphics whatever needs less resources) or as a descriptive text. Since the more abstract information (like the film script of the video or the data model underlying the animation) is lost in the process of video rendering, the media translation has to be prepared by storing alternative representations of presentable data. To a certain degree, this might be done automatically - but often with unsatisfactory results. The example of an animation sequence showing a rotating brick illustrates this point. Supposed that we can only display one frame of the video, picking a frame at random will only show a brick in space, not the fact of rotation. When preparing such a key frame manually allows to add arrows or motion blur to indicate rotation. Since every medium has its own means of expression, the information provider would have to prepare and store the video, the slide show, the image and the descriptive text. To summarize, an alternative presentation component for prepared media consists of *the presentation stage and its input, the presentable data*.

Take, on the other hand, an unprepared medium like scientific data. Here, alternative presentation components can be *any trailing part of the presentation pipeline*. Depending on the current resource situation, the presentable data are generated from the available more abstract data (e.g., a volume data set). This approach offers the advantage of generating alternatives automatically - their preparation by the information provider is not necessary.

We will now give two examples to illustrate the concept of alternative presentation components for unprepared media. The first example is drawn from the field of environmental data visualization in a geographical context. It is a prototype of a forest information system which enables the user to pick an area of the forest and get various pieces of information about that area. A hierarchical structure underlies the spatial organization of the forest. At the highest level, the forest is divided into districts. A district is further subdivided into units, which themselves consist of subareas. At the finest resolution, a subarea contains a number of sections, whose geographical coordinates are not given. Figure 3 illustrates the concept of the visualization on a fully-featured workstation. The map is displayed at full resolution, and by picking a subarea the user can query information. An two-dimensional color-coded icon is used to represent the information. A row of the icon is associated with a section of the picked subarea, a column corresponds to an actual variable (like exploitation class, production target and frequency of intervention), whose value in that section is represented by the color of the cell. Thus, the user is enabled to relate the values of several variables and in different sections.

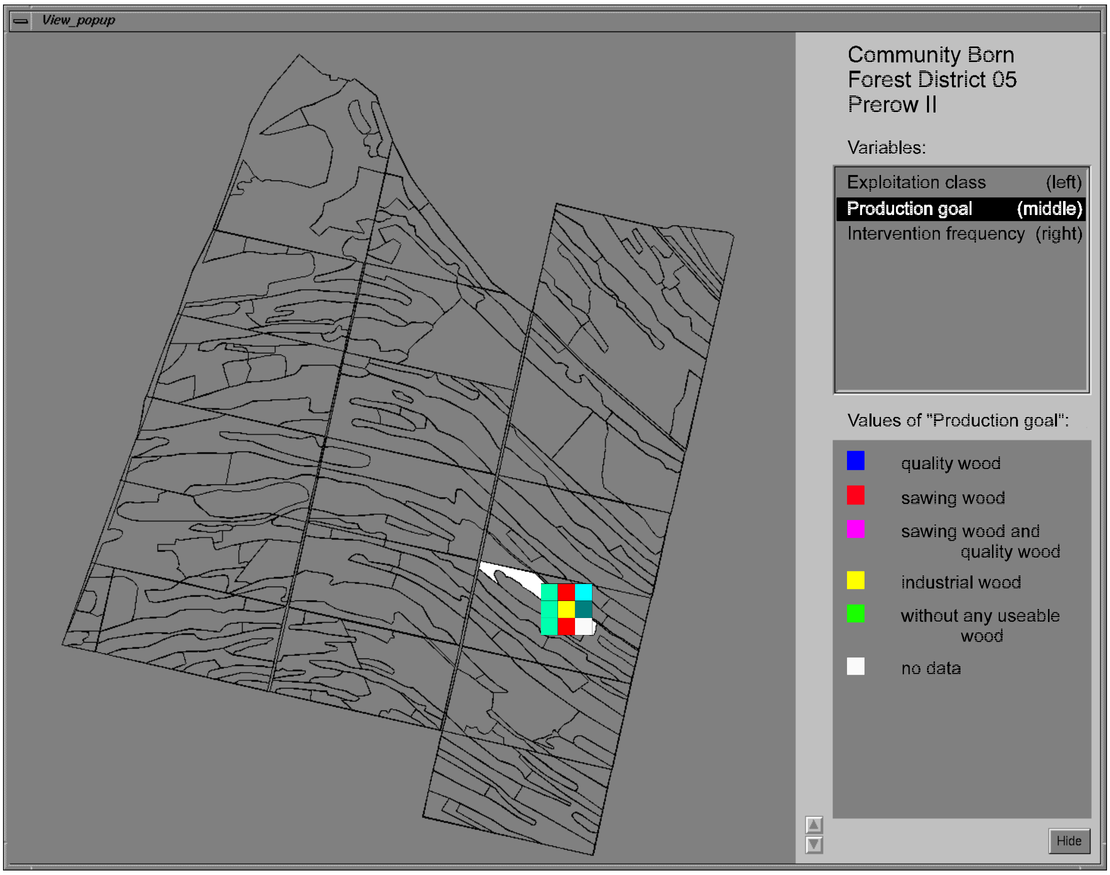

Figure 3: Forest data visualization (workstation)

On a mobile data terminal with a small screen, a different approach must be taken because it's impossible to display the map at full resolution. A straightforward concept would be the introduction of a zooming facility. This would, however, lead to a loss of context. Thus, we reduce the display and pick resolution of the map (only the units of the district are shown and pickable) and use a modified icon as it can be seen in figure 4. The columns of the icon now correspond to the subareas of the picked unit and the rows are associated with the sections of the according subarea. Since we use the two dimensions of the icon to represent spatial context, only one variable at a time can be represented by the cell color. If the user wants to look at multiple variables, he would have to do so one after the other and relate them mentally

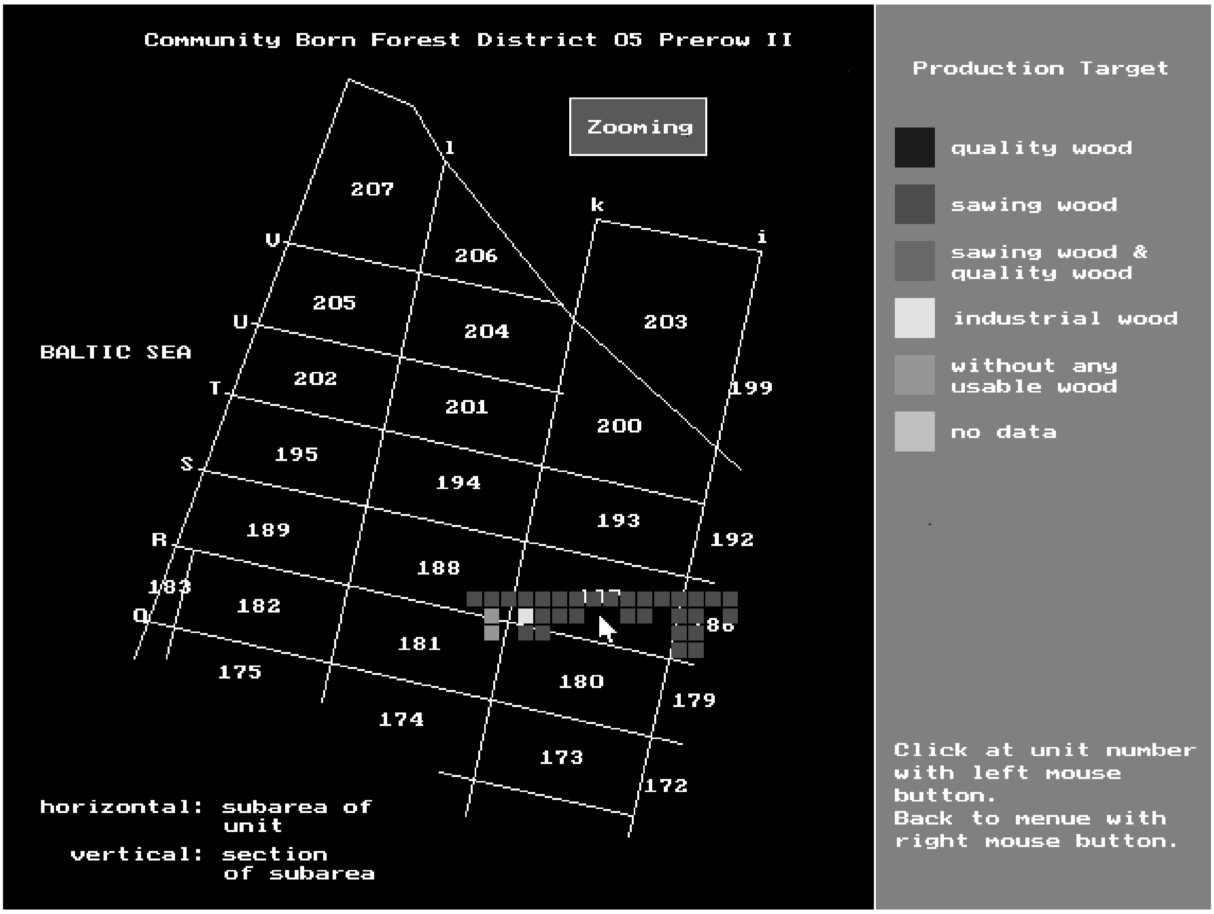

Figure 4: Forest data visualization (mobile computer)

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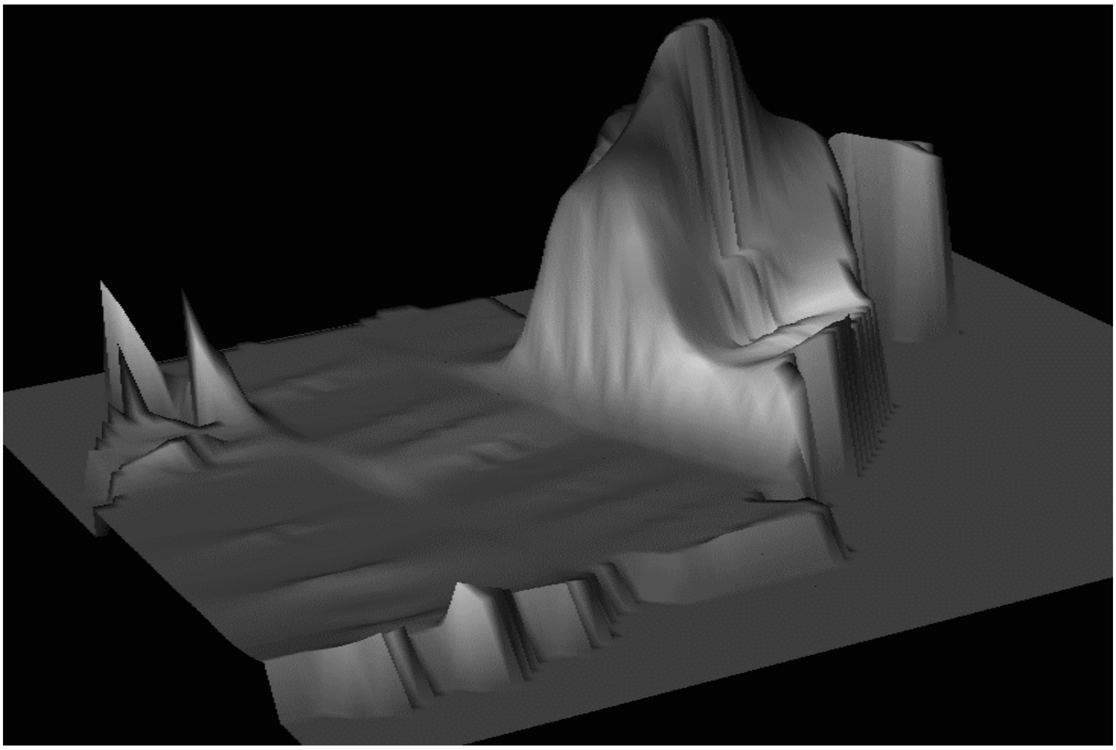

Figure 5: Fish data visualization: color coded height map

As a second example, we illustrate different opportunities to visualize a set of volume data. The data set used to produce the figures 5 to 7 represents the fish population in different depth levels of the Bautzen water reservoir. The figures show alternative visualizations of the density of the fish population in one depth layer. On an end system which supports 3D interactive graphics (like the system IRIS-Explorer™), one can use a color-coded height map (see figure 5) to visualize the data. This technique visually supports the localization of areas of high population density, the identification of the actual population density in one area and the comparison of the population density in different areas.

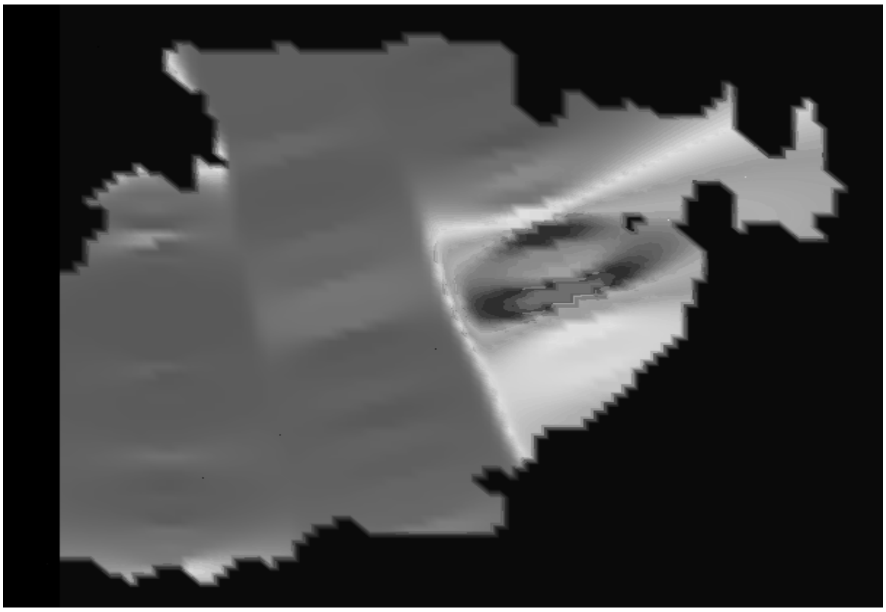

Figure 6: Fish data visualization: color coded flat map

Using an end system which supports color but no 3D graphics, a color-coded flat map (see figure 6) is the choice. Here, localization and identification of high population density are easy for the user just by looking at the colors, but the quantitative comparison of the population density in different areas can only be based on estimates because of the human non-linear perception of color. For a precise comparison, a different technique like a diagram or numerical display of picked values would have to be used.

Figure 7: Fish data visualization: contour lines

On a monochrome display, one could still visualize the data set using contour lines (see figure 7). Areas of high population density can still be easily localized. However, the actual population density of an area of interest can only be estimated by considering contour line annotations or by counting the contour lines between that area and the area of lowest density. The same is true for a comparison of the population density in different areas.

The examples given above illustrate the possibility to support a user's goals using different visualization techniques tailored to different resource situations. On resource-poor end systems, the techniques tend to get simpler, thus shifting the user's cognitive tasks from visual perception to conscious interpretation.

In the following section we will present an approach to solve the problem of *finding* (or selecting) an adequate information presentation technique considering the available resources. However, when dealing with information presentation on a mobile system a second problem arises, that of *realizing* the presentation on the mobile computer considering the resource dynamics. Here further research has to be done.

3.3 Selection of an alternative visualization technique

There are several approaches to an automatic or semi-automatic generation of visualizations from a description of the application problem. Most of them (as discussed in depth in [ARN94]) were developed in order to support the user in finding an appropriate, or ideally the best way to visualize his data.

These approaches start from different aspects of the visualization problem, e.g. from a description of the data set to be visualized, or from a specification of the analysis task to be performed. Moreover, they differ in the degree up to which they consider the various factors influencing the visualization decision:

- data characteristics,
- interpretation goals of the data analyst,
- perceptual capabilities of the observer,
- expressiveness, effectiveness and appropriateness of the generated visualization,
- preferences and conventions of the underlying application,
- characteristics of the hardware and software used.

Dealing with mobile visualization, further influencing factors have to be considered:

- the resources available to generate the visualization,
- time and quality requirements of the observer.

To choose an appropriate visualization technique considering all of these aspects, it is necessary to balance the *cost* and the *benefit* of the visualization to be generated. The benefit of a technique represents the relation between its capabilities and the requirements it is faced (by the application, the user, the data etc.). The cost of a technique expresses the relation between its demands to the mobile environment and the capabilities of this environment.

However, estimating the cost of a technique can not be reduced to the consideration of the requirements of the pure technique. Analyzing only the data characteristics in order to determine the benefit of a technique is not sufficient, either. Contrarily, both the cost and the benefit depend on data as well as on resource characteristics. Take for example a color coded map of some geographical data. This technique is potentially well suited for the localization and comparison of the color coded data values. But even for a well-sized map on a workstations screen one can imagine a smaller screen which is unable to display it. Thus, the suitability of a technique for a given visualization problem is resource dependent. On the other hand, the resource demands of e.g. the technique „isosurface" depends essentially on the size of the volume data set to be visualized. That means, the resource demands of a visualization technique are data dependent.

Looking at the data characteristics with respect to their implications for the readability of the resulting image, one has to consider their potential interrelations. As an example, take the visualization of some measured data by the means of icons. The number of icons is determined by the number of measurements, the complexity of an icon depends on the number of variables measured. The space required by the visual representation - and so its readability - hinges on both the number and the complexity of the icons. However, decreasing the first allows up to a certain degree to increase the latter, and vice versa.

On the other hand, there are interrelations between resources, too. A reduced color depth can be balanced by a high screen resolution using an appropriate dither algorithm, reduced memory capacity may be offset by high processing power utilizing adequate data structures.

So we need a technique selection mechanism which is able to consider all the characteristics given above and to handle the interrelations between them.

In [LAN95] we developed a functional approach to the selection problem for multi-dimensional data sets. It starts from a description of the visualization problem given by the data characteristics and the interpretation goals of the user and sufficiently handles the interrelations between different data characteristics. Integrating resource characteristics into this approach allows not only to incorporate the resource interrelations, but also to cover data dependent resource demands of a technique as well as its resource dependent suitability for a given problem. Further characteristics can be included. Especially user characteristics like quality and time requirements have to be considered.

In the rest of this section we formally describe the extended functional approach.

Let be:

DC	set of data characteristics,
RC	set of resource characteristics,
UC	set of user characteristics,
P(Set)	set of all subsets of *Set*,
I	ordered set of interpretation goals,
n	number of interpretation goals in *I*,
T	ordered set of visualization techniques,
m	number of techniques in *T* and
S	ordered set of suitability values.

Then, we can define for each technique $i \in T$ and for each interpretation goal $j \in I$ a function f_{ij} which determines the suitability of the technique *i* for the goal *j* under consideration of the characteristics given by *DC*, *RC* and *UC*. This suitability is represented by a suitability value:

$$f_{ij}: \quad P(UC) \times P(RC) \times P(DC) \rightarrow S$$

We are using the set of all subsets since there is usually more than one element in each set of characteristics which influences the suitability for a given pair *(i, j)* and since it does not necessarily have to be the whole set.
To determine the suitability of a given technique $i \in T$ for each of the *n* interpretation goals in *I* we derive a function g_i which produces a vector of *n* suitability values:

$$g_i: \quad I^n \times P(UC) \times P(RC) \times P(DC) \rightarrow S^n$$

Thus, a mechanism which determines the suitability of each of the *m* techniques in *T* for each of the *n* goals in *I* can be represented by a function *h* producing a $m \cdot n$-matrix of suitability values:

$$h: \; T^m \times I^n \times P(UC) \times P(RC) \times P(DC) \rightarrow S^{m \cdot n}$$

Let *W* be a set of weights. The user can specify his interpretation goals by weighting each of the *n* goals in *I*, which results in a vector of *n* weights:

$$w: \quad I^n \rightarrow W^n$$

Having once specified the capabilities of the *m* techniques in *T* and the weights of the *n* goals in *I* by applying the functions *h* and *w* respectively, we can relate them and determine the degree of their conformity.
So, let *D* be a set of distance values. Then, we can define a function *d* which produces a vector of *m* values each of which represents the distance between the associated technique's capabilities and the user's goals:

$$d: \quad S^{m \cdot n} \times W^n \rightarrow D^m$$

The resulting vector of distances can serve as a criterion to order the techniques according to their suitability for the given visualization problem. However, to decide whether or not a technique has to be regarded as suitable, its distance has to be compared to a certain user defined threshold *H*. Doing so for each of the *m* techniques in *T* leads to a function *s* which determines a vector of *m* Boolean values:

$$s: \quad D^m \times H \rightarrow \{0,1\}^m$$

When applying the functional approach in practice several problems arise:
First, the suitability functions f_{ij} may be very complex because of the quantity of their parameters. Therefore, we suggest to hive off such parameters which induce simple feasibility decisions and handle them in a preprocess.

Let *TR* be the set of minimal resource demands of the techniques. To check the feasibility of each of the *m* techniques in *T* we define a function *r* which compares the techniques' demands to the capabilities of the mobile environment represented by its resource characteristics. This results in a vector of *m* Boolean values each of which indicates whether or not the associated technique is feasible in the given environment:

$$r: \quad (P(TR))^m \times P(RC) \rightarrow \{0,1\}^m$$

Applying this feasibility check will usually reduce the parameter set of the suitability functions f_{ij}, g_i and *h*, but not necessarily by *all* of the parameters of *r*, since *r* considers only the *minimal* resource demands. However, even if a parameter is handled by both the preprocess and the suitability functions, the number of operations to be performed by the latter on this parameter may decrease.

Reducing the complexity of the suitability functions is important to the solution of a second problem which arises in practice: to get all the needed information. The main difficulty is to design the suitability functions f_{ij} per technique and goal. At the moment, this is done heuristically by the developer of the technique or by a visualization expert and then evaluated e.g. by interviews. The remaining part of the selection mechanism works independently of the number of techniques and thus has to be provided only once even if techniques are added.

At runtime, the characteristics of the data, the user and the resources being parameters of the suitability functions have to be available to the selection process. Several sources of information are possible. Data characteristics can be derived from the meta data stored with the data, user characteristics can be drawn from a user profile, and resource characteristics can be requested from configuration files or monitoring programs etc. The user should be given the opportunity to interactively complete the descriptions. Especially, the interpretation goals should be specified interactively. The description of a technique's minimal resource demands which is needed by the feasibility check may be generated by the developer filling in a predefined form, or automatically by using the resource characteristics of the machine it was originally supplied for. Figure 8 outlines the selection mechanism and the origins of its parameters.

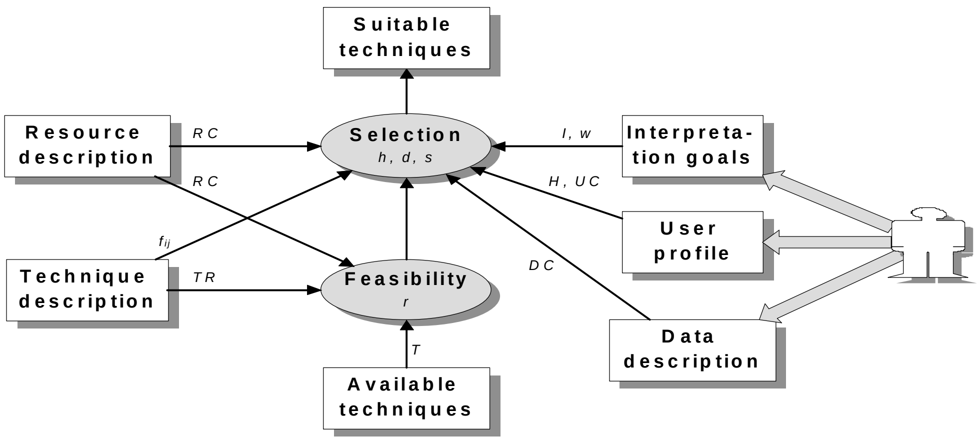

Figure 8: The selection mechanism and its parameters

A problem finally to be mentioned is that the functional approach we introduced does not consider dynamic aspects of e.g. resource characteristics. It uses a snapshot of the system's state to make its decisions, but it does not adapt them afterwards.

4 Conclusions

This paper dealt with alternatives for the information presentation in the mobile context. We identified limited resources to be the key problem of mobile visualization and introduced the concept of alternative presentation components which allows the presentation of the same piece of information using different techniques depending on the current resource situation.

We presented a criterion for distinguishing between media with respect to their preparation for the presentation of information and extended the classic visualization pipeline to accommodate the needs of mobile information presentation. Some examples taken from the fields of multimedia document presentation and the visualization of environmental data were used to illustrate the idea of alternative presentation components for both prepared and unprepared media.

To solve the problem of finding an appropriate information presentation technique we presented a functional approach which considers not only the application specific visualization problem but also the resources being available in the mobile environment as well as the resource demands of the desired visualization. A formal description of the approach was given and some problems arising in practice were discussed.

Future work will focus on the investigation of further alternative techniques, the implications of cooperative visualization and the potential of the Internet (especially the WWW) to support mobile access to visualization systems.

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References

[ARN94] Arndt, S.; Lukoschek, K. and Schumann, H.: *„Design of a visualization support tool for the representation of multi-dimensional data sets"*, in: Göbel, M.; Müller, H. and Urban, B.(eds.): „Visualization in Scientific Computing", Springer, Wien 1994

[BEN95] Benford, S. et al.: *„VR-VIBE: A Virtual Environment for Co-operative Information Retrieval"*, in: Proceedings of EURO-GRAPHICS '95, Maastricht, 1995

[BRO92] Brodlie, K. W. et al. (eds): *„Scientific Visualization - Techniques and Applications"*, Springer, Berlin 1992

[CAR91] Card, K. S. et al.: *„The Information Visualizer, an Information Workspace"*, in: Proceedings of the CHI '91, ACM, New York, 1991, pp. 181-188

[CHA95] Chalmers, M.: *„Design perspectives in visualizing complex information"*, in: Proceedings IFIP 3rd Visual Databases Conference, Lausanne, Switzerland, Chapmann-Hall, 1995

[GER94] Gershon, N. D.: *„Information Visualization: The next frontier"*, in: Proceedings SIGGRAPH '94, Orlando, Florida, 1994

[GRI96] Gries, V. and Schultz, R.: *„Quality and ressource controlled transmission of video and still images"*, Poster, this volume

[HEM93] Hemmje, M.: *„A 3D Based User Interface for Information Retrieval"*, in: Proceedings of IEEE Visualization '93, Workshop on Database Issues for Data Visualization, San Jose, California, October 1993

[KEI94] Keim, D. A.: *„VisDB: Database Exploration Using Multidimensional Visualization"*, in: IEEE Computer Graphics and Applications, September 1994, pp. 40-49

[LAN95] Lange, S.; Schumann, H.; Müller, W. and Krömker, D.: *„Problem-oriented visualisation of multi-dimensional data sets"*, in: Scateni, R. (ed.): „Scientific Visualization´95", World Scientific, Singapore 1995

[NIE90] Nielsen, G. M. et al. (eds): *„Visualization in Scientific Computing"*, IEEE Computer Society Press, Los Angeles, 1990

[ROS94] Rosenblum, L. et al. (eds): *„Scientific Visualization - Advances and Challenges"*, Academic Press, London 1994

[ROT93] Roth, S. F. and Hefley, W.E.: *„Intelligent Multimedia Presentation Systems: Research and Principles"*, in: Maybury, M. T. (ed.): „Intelligent Multimedia Interfaces", MIT Press, Massachusetts 1993, pp. 13-59

[STE93] Steinmetz, R.: *„Multimedia-Technologie"*, Springer, Berlin 1993

[WEN91] Wendt, S.: *„Nichtphysikalische Grundlagen der Informationstechnik"*, Springer, Berlin 1991