Explorative Analysis of Medical Study Data

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ABSTRACT

We present an application that allows users to interactively visualise data of medical studies. This application enables the users to get a "'first view"' on the data set, to interact with the data in an intuitive way and to analyse it collaboratively. The goal of these first studies of the data sets is to find relations between measured values.

CR Categories: I.3.7 [Virtual Reality]: ;— [I.3.6]: Interaction Techniques—;

Keywords: visualisation, virtual environments, interaction

1 INTRODUCTION

During medical studies many values are usually measured in parallel several times. These physiological examinations usually measure several quantities to answer a certain question. Much more information could be extracted by asking questions like "'does measured quantity *A* relate somehow to measured quantity *B*?"', "'Which quantities are largely independent of the others?"' and the like. If any, these questions were tackled by entering the data into a spreadsheet programm and using its built-in graphical presentation abilities. This proved to be difficult because of missing visualisation features and complicated non-intuitive interaction. We proposed a conversion of data into parallel coordinates, the usage of stereoscopical visualisation and the usage of an inituitive interaction device. In this application sketch we present our solution.

2 DATA AND REPRESENTATION

The source of data was from studies of bone metabolism in humans accomplished by the Institute of Aerospace Medicine at the German Aerospace Center – DLR. A certain excitation was applied to probands and the relevant parameteres of the bone metabolism were measured, like vasopressin and aldosteron concentration. The measurements were repeated each day for several days.

Thus, abstracting from the source the task was to handle timevariant, multivariate data. As all relevant data was measured as a concentration they all had the same unit. This means they were directly comparable.

The multidimensionality of the problem (many data values at a certain time) prevented the direct threedimensional visualisation. One solution for this problem is the projection of manydimensional values into threedimensional space, possibly a series of projections [3]. Parallel coordinates [1] on the other hand are a twodimensional representation of manydimensional data. Every n-dimensional cartesian coordinate $(a_1,\ldots,a_n)$ with coordinate axis $x_1,\ldots,x_n$ is transformed into a twodimensional chain of connected line segments in parallel coordinates. Each line segment starts at a now vertical coordinate axis x_i at coordinate a_i and ends at the neighboring vertical coordinate axis x_{i+1} at coordinate a_{i+1} with $1 \leq i < n$ (c.f. figure 1 for a sixdimensional example).

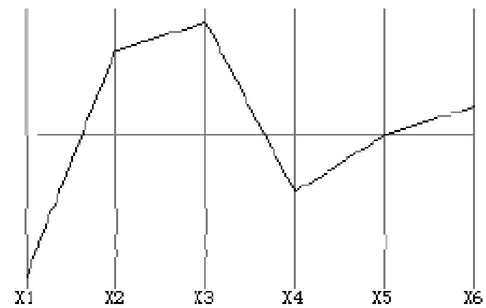

Figure 1: Parallel coordinates of a point in $\Re^6$.

We decided to visualise the measured data in parallel coordinates for the following reasons:

- Parallel coordinates are well suited to visualize multidimensional data with not too many dimensions. The medical study provided always less than 20 dimensions.
- The representation in parallel coordinates does not fix the number of dimensions of the data. In the future, the number of dimensions (measured parameters) might change significantly.
- Extruded parallel coordinates extend parallel coordinates into the third dimensions to avoid intersecting line segments. The use of the third dimension makes extruded parallel coordinates ideally suited for visualising data in a virtual environment.
- They allow for some of the explorative data interactions needed for this application (see below).

With parallel coordinates, *k* n-dimensional data values map to $k-1$ two-dimensional line segments in the plane. This might lead to the potential problem that two line segments intersect a certain vertical coordinate axis at the same coordinate. At this point the two line segments are no longer distinguishable (c.f. figure 2).

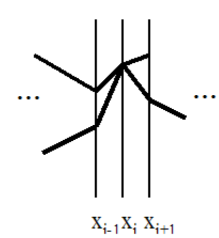

Figure 2: The problem of intersecting line segments.

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To avoid this problem, we used *extruded parallel coordinates* [4]. Here, each new line segment is translated one step further perpendicular to the coordinate plane (c.f. figure 3)

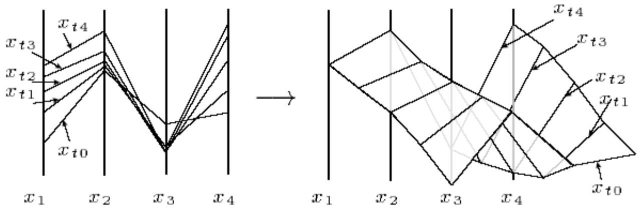

Figure 3: Extruded parallel coordinates (Wegenkittl).

leading to a threedimensional coordinate system.

3 Visualisation and Interaction

Visualisation of the data set was done on a stereoscopic projection wall . The size of the projection screen allows up to four persons to discuss and explore the medical data set. All collaborators can stand infront of the wall and see a stereoscopic image by the use of lightweight polarization glasses. One persons holds the interaction device and steers the application.

As mentioned, the extruded parallel coordinates form a threedimensional coordinate system. Figure 4 shows a view of our visualisation of these coordinates.

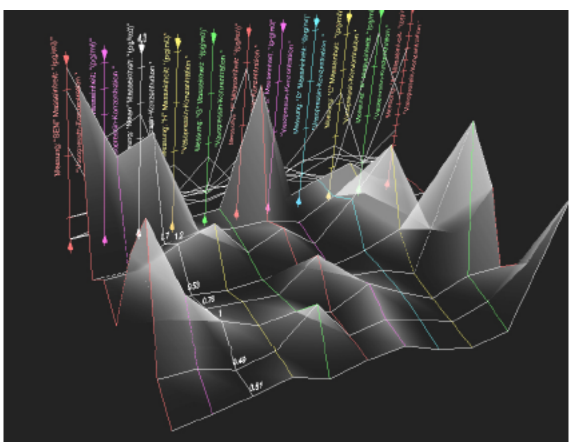

Figure 4: Threedimensional visualization of extruded parallel coordinates.

The different measured parameters of the bone metabolism can be seen from left to right (colored axis). Time is measured discretely along the depth axis. We connected parameter values and their time sequences by quadrangles. This allows to visualise the slope between two parameter values measured at the same time which is equivalent to the ratio of values. The front view and top view of the visualisation is shown in figure 5.

Interaction utilizes the CubicMouse [2] (c.f. figure 6). The following functionality can be steered intuitively by moving the CubicMouse or its rods or by pushing a button:

2D view Pressing a defined button of the CubicMouse toggles between the traditional twodimensional parallel coordinates and threedimensional extruded parallel coordinates.

Rotation and Translation Is done by moving the CubicMouse according to the desired transformation. A 6DOF sensor inside

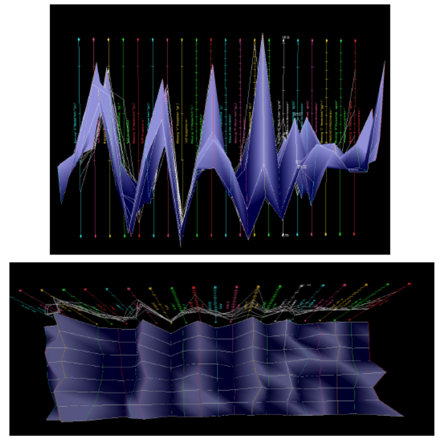

Figure 5: Front and top view of the visualisation.

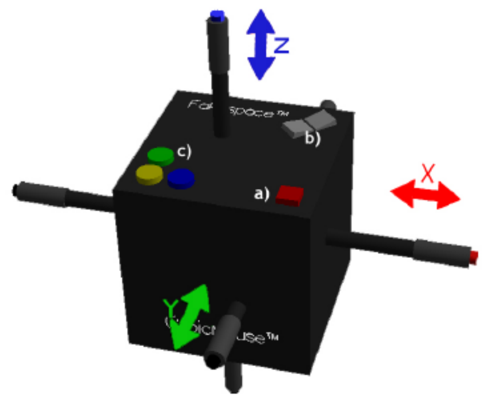

Figure 6: The CubicMouse (Fakespace Inc.)

the CubicMouse sends the corresponding transformation to the computer for camera update.

Axis highlighting . Highlighting can be achieved by moving the x-axis rod of the mouse. When an axis is highlighted the measured parameteres at each time step are shown as numbers. The highlighted axis is colored white. Highlighting is also the first action for some other actions.

Swaping parameter axis positions . One of the most important aspects of parallel coordinates is the control of axis positions by the user. To discover the relation of a certain parameter A with another parameter B visually, it helps to move their axis side by side. This can be done by highlighting one of the parameter axis, press the x-axis button of the CubicMouse and slide the x-axis back and forth. The highlighted axis can then be "dropped" at a proper position. This is easier and faster than marking two axis sequentially and then acknowledge the swapping.

Moving parameter values along the time axis . If there is a relation between one parameter value and another one, it might be delayed because of physiological effects. Figure 7 shows the shifting of parameter values in the direction of the camera. When the data value at t_0 is shifted to coordinate t_1 (in direction of camera) we decided to copy the old value at t_0 as the new value at t_0. We found this to be as favourable as inserting a 0-value at t_0.

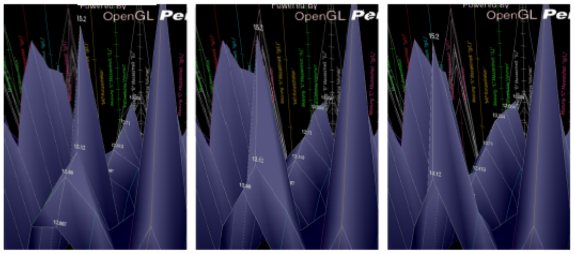

Figure 7: Shifting parameter values along the time axis (middle axis).

Scaling of parameter values . Sometimes it might be difficult to compare parameter value chaines because of the different scale of both chaines. If the developing of values is roughly the same but one curve is less elevated than the other, this correlation might be unnoticed by the user. For the purpose of scaling an axis the user highlights it and presses a button of the z-axis rod. The currently highlighted axis is scaled up and down by moving the rod up and down.

Brushing In order to highlight parts of the data set or to mask out data, the user is given virtual "‘brushes"’. For each measured parameter the user can set an upper and/or lower limit. Line segments beyound this bounds are faded out. Upper and lower limits are represented as small pyramids along the axis. To use this functionality the user highlightes the intersting axis first by moving the x-rod. If the upper button of the x-rod is pressed after this, any x-rod movement results in a change of the upper limit for the highlighted parameter value. If the lower button is pressed and the rod is moved, the lower limit is changed.

Undo Any change made can be undone by pressing a predefined button of the CubicMouse. We implemented a history buffer to allow undo of several changes.

Reset All changes can be undone by pressing a predefined button of the CubicMouse.

4 First Results

From a first demonstration of the system to some of the potential users we conclude that:

- There were no reservations to use the system.
- The time needed to comprehend the functionality of the system seems to be low.
- Due to the intuitiveness of the system, users seem to experiment more.
- Analyzing a data set invoked more discussions than before.

We think that these results allow us to continue the evaluation of the system (see below).

5 Conclusion and Future Work

We presented an application for the interactive exploration of medical study data. The system allows an intuitve usage through the use of a specialized interaction device. Relations between measured parameters are easy to see or to discover even if they are delayed.

Items of future work include:

- A (limited) user study. We plan to validate our approach with users of the "old" approach. Topics of interest are (besides validating the claims of the first results): Advantage of stereoscopic viewing (compared to mono view)? Advantage of cubic mouse interaction (compared e.g. to wand or 2D interacttion)?
- Angular brushing. In the current state of the system, brushing can be done by setting an upper and/or lower limit of a measured parameter. It makes sense to include brushing dependent on the angle of the line segment (in parallel coordinates) between neighboring parameters. This way we can emphasize certain parameter ratios.
- Different interaction devices. We would like to know if simpler (and thus cheaper) interaction devices can be used as intuitively as the CubicMouse for our application scenario.

6 Thanks

We thank Martina Heer from the Institute of Aerospace Medicine at the German Aerospace Center for the study data and many fruitful discussions.

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