The Impact of Feedback Design in Haptic Volume Visualization

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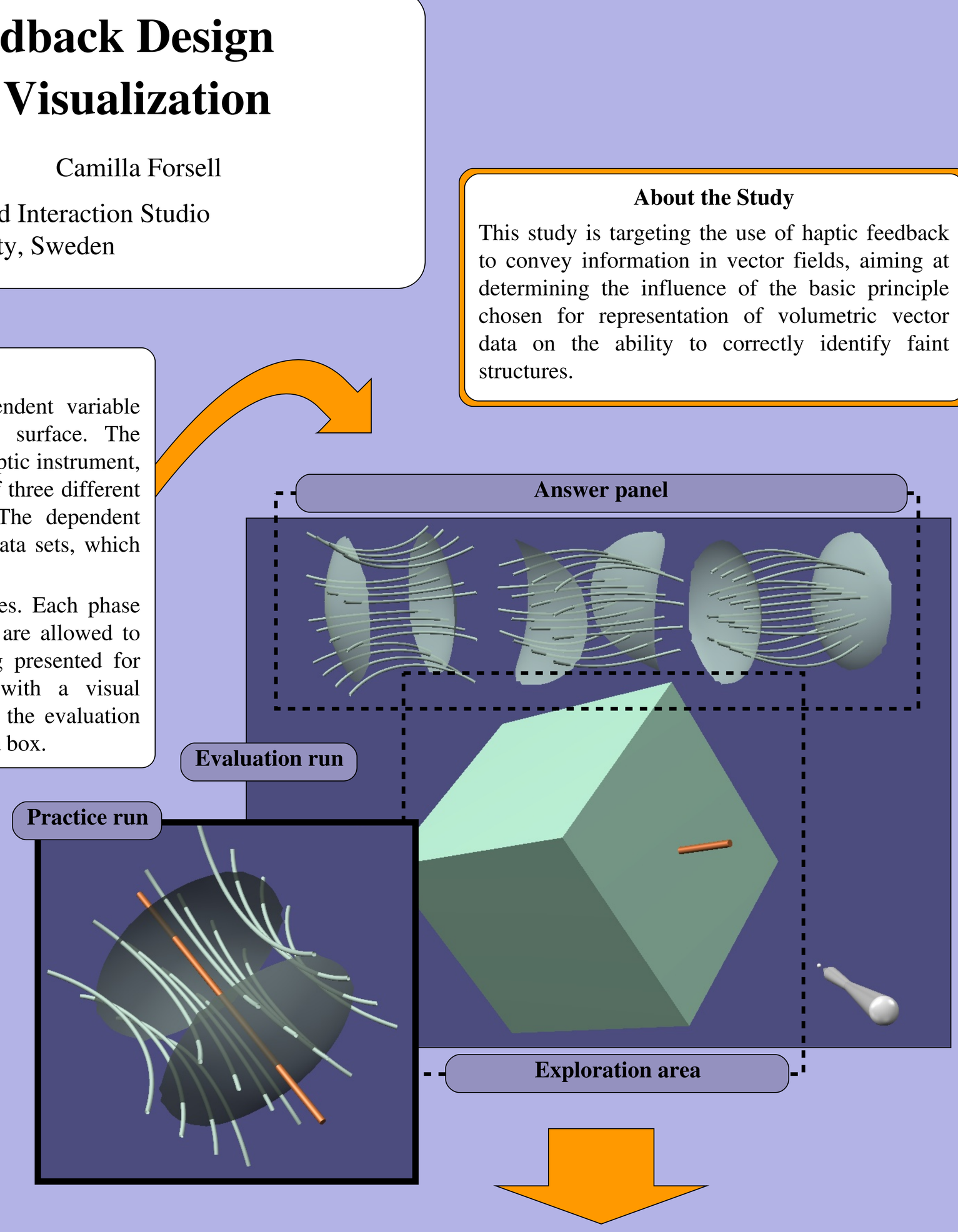
About the Study

This study is targeting the use of haptic feedback to convey information in vector fields, aiming at determining the influence of the basic principle chosen for representation of volumetric vector data on the ability to correctly identify faint structures.

Method

The study used a within-subject design with one independent variable (haptic metaphor) having three levels: force, line and surface. The participants were asked to reach into the data set with the haptic instrument, explore the data and identify, through touch alone, which of three different vector valued data sets was being presented to them. The dependent variable is the amount of curvature of the vectors in the data sets, which was specified through a staircase approach.

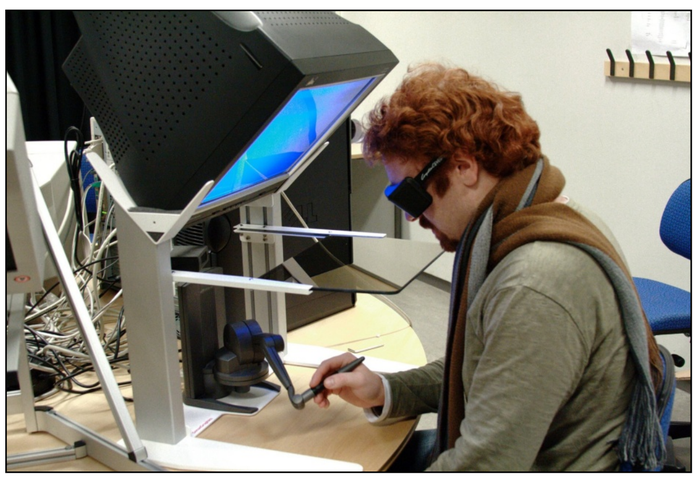
One metaphor was used at a time, resulting in three phases. Each phase opens with a practise run (6 trials) where the participants are allowed to familiarize with the current metaphor. The data set being presented for exploration was during the practise run also shown with a visual representation based on stream-tubes and surfaces. During the evaluation run of each phase (36 trials) the data set was represented by a box.



Implementation

The application was programmed in C++, Python and X3D using H3D API and Volume Haptics Toolkit.

Semi-immersive Environment



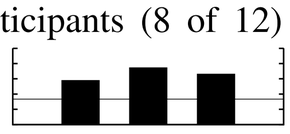
The application is running on a SenseGraphics IW presenting active stereo 3D graphics and co-located haptics through a Desktop PHANToM.

Participants

Twelve participants, all undergraduate or graduate students with technical background, took part in the evaluation, 3 women and 9 men aged between 24 and 32 years. The participants had no or little experience with volume visualization and haptic interaction and they had no prior knowledge of the purpose of the evaluation. All 12 participants completed the evaluation.

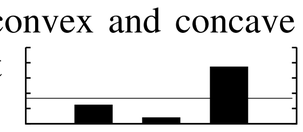
Qualitative Data Analysis

We identified three types of results. Most participants (8 of 12) performed correct exploration of the data, and interpreted the feedback correctly.



A failure can be when the participant does not perform correct exploration of the data and therefore has no or incorrect stimuli to interpret. The correct answer rate is then close to random regardless of the curvature level.

In a third alternativ the participant may perform correct exploration of the data but interpret the data incorrectly. This produces a worse than random result on the convex and concave data sets but better than random on the data set with mixed features.



Quantitative Data Analysis

An ANOVA analysis was performed on the data from the participants that made correct interpretation of the stimuli (8 of 12 participants). The result reveals a significant difference between the three metaphors ($F(2,14)=14.22$, $p=0.001$). Follow-up analysis using Bonferroni-corrected pairwise comparisons reveals a significant difference between force and line ($p=0.01$) and between force and plane ($p=0.02$). The line and plane metaphors both allow higher ability to identify faint structures than the force metaphor. No difference between line and surface was found.

Opinions of the Participants

Force:	easy to use, fast, comfortable, intuitive hard to understand/interpret, uncomfortable
Line:	easy to use, easy to understand, realistic, comfortable hard to use, hard to understand
Surface:	unnatural, hard to use/understand, “dodgy”

Poster Weblinks

Conclusions

The study shows that the design of the feedback has a significant impact and that using a shape metaphor instead of a force metaphor to convey information in volumetric data can increase the performance. It further shows that also counter-intuitive feedback can convey faint structures, in some cases even better than intuitive feedback, but that such feedback is in risk of being misinterpreted.