Advanced Interfaces to Stem the Data Deluge in Mixed Reality: Placing Human (un)Consciousness in the Loop

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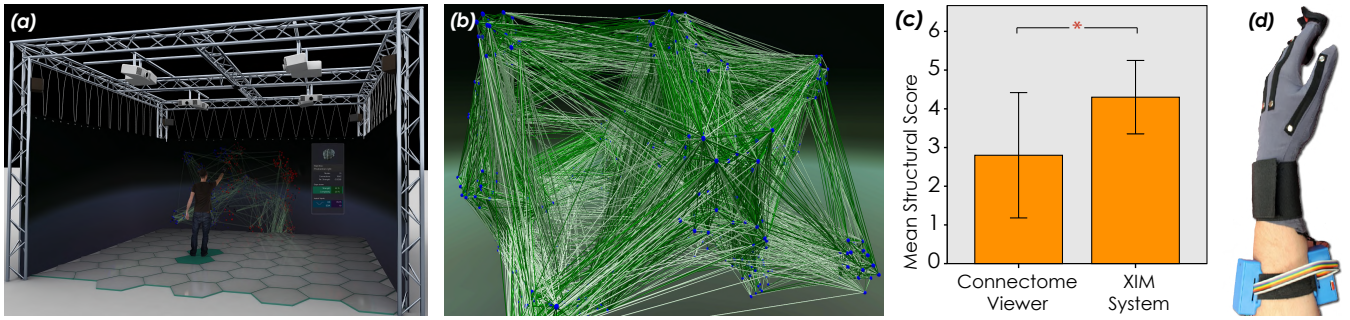

Figure 1: *(a) Exploration of a large dataset in the eXperience Induction Machine (XIM) using explicit and implicit interaction. (b) Visualization of a human connectome dataset composed of ~30k connections and ~1k nodes. (c) Mean structural score of the participants exposed to the Connectome Viewer and to the XIM: error bars represent the SD. (d) The glove prototype measures the user's physiological state.*

1 Introduction

We live in an era of data deluge and this requires novel tools to effectively extract, analyze and understand the massive amounts of data produced by the study of natural and artificial phenomena in many areas of research.

We built a mixed reality system that uses multi-modal input and output and permits embodied interaction with large datasets. One of the applications of our system is in the exploration of the human brain connectome (Fig. 1b): the network of nodes and connections that defines the key information flow in the brain. With our system the user can be fully immersed in this complex data seeking to understand their dynamics and to discover new patterns.

2 Methods

The novelty of our approach consists in the introduction of subconscious states of the user to boost the exploration process. For this, we use the mixed reality space eXperience Induction Machine (XIM) [Bernardet et al. 2010] along with wearable and unobtrusive sensor systems that assess the user's physiological state.

With our system the user can study the multi-dimensional organization of the brain and complex networks in general (Fig. 1a) by physically moving in the data space and by exploring different brain regions using natural hand gestures.

The function of the brain is closely coupled to its structure. For this reason we coupled the structural representation of the network with a real-time neuronal network simulator. This allows the user to stimulate specific areas and observe the resulting activation that is propagating through the network, leading to an appreciation of structural and functional interaction.

Additionally, we can operate through intuitive gestures on the parameters of the system and filter the number of visible connections by strength or complexity.

We provide an ecological form of interaction since the user can literally grab data clusters and manipulate them. The glove (Fig. 1d) transduces the user's explicit signals and measures electrodermal activity. In addition, we measure heart rate and respiration with wearable sensors.

These implicit responses are analyzed in real time to detect the user's interest and suggest relevant associations in the dataset. Our system can thus provide a discovery map of the user by highlighting areas where interest was peaked or rather diminished and by guiding the user to new relevant locations in the data space.

3 Results

We compared our system to the Connectome Viewer [Gerhard et al. 2011], a state of the art software for neuroimaging network visualization and analysis. 20 participants (mean age 27.3 $\pm$3.45) divided in two groups, were asked to explore a complex connectome structural dataset. The first group was exposed to the Connectome Viewer using a common PC, while the second group experienced the connectome data in the XIM.

We designed a questionnaire to measure the structural understanding of the network. Participants performed significantly better (in terms of structural score) using our system (mean = 4.30 $\pm$0.949) as opposed to the Connectome Viewer (mean = 2.80 $\pm$1.619) ($p < 0.05$, Fig. 1c).

4 Future Improvements

This active exploration process will be further guided by a synthetic Sentient Agent that will enhance our system with suggestions based on the collective experience of past users and a deep understanding of the physiological signatures of insight and discovery.

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References

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