Selection of Expanded Data Points in Immersive Analytics

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ABSTRACT

We propose a novel technique to facilitate the selection of data points, a type of data representation we often work with in immersive analytics. We designed and implemented this technique based on the expansion of data points following Fitt's law. A user study was conducted in an headset-based augmented reality environment. The results significantly highlight the performance of our technique in helping the user select data points and their subjective appreciation in working with the expendable data points.

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1 INTRODUCTION

Advances in Augmented Reality (AR) and Virtual Reality (VR) have recently brought forth the beginning of Immersive Analytics (IA). The overarching aim of IA is to "provide multi-sensory interfaces for analytics approaches that support collaboration and allow users to immerse themselves in their data" [1]. One of the primary tasks that take place during the data analysis process is the selection and manipulation of data. The effectiveness of selection depends not only on the pointing and selection confirmation technique but also the target size according to Fitt's law [2]. The pointing technique using ray-casting allows a user to indicate one or several objects to be selected for manipulation, and the confirmation selection technique (e.g., dwell, click, voice, and hand gesture) triggers the selection. The pointing methods depend on the ray's origin (head, hand, or eye) and direction. The Air-Tap and voice confirmation techniques combined with hand or head pointing have been largely used in Microsoft Hololens headsets. However, selecting distant and small objects is challenging, which can affect the user experience.

We propose a solution for this limitation by facilitating the selection via the expansion of a data point when the cursor hovers over it. Many existing research works [3, 5] focus on different factors affecting the selection of expanding targets. They conclude that the selection of isolated expanding items is faster and easier than non-expanding items. Our contribution is the design and evaluation of this new selection technique in an headset-based AR interface.

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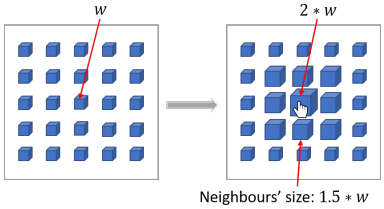


Figure 1: Design of expandable data points.

2 OUR PROPOSED SELECTION TECHNIQUE

Inspired by the study in [4], we designed a technique for data point selection in IA by expanding its size during the interaction. To select a data point, its representation is expanded as soon as the cursor intersects with it. From our preliminary study, we observed that for a data representation whose initial size is w, it is sufficient to automatically expanded its representation to $2 * w$ under the cursor. Moreover, to create a smooth transition when the cursor moves amongst different data representations, and to facilitate the user's correction of their selection, its neighbours (eight points on a 2D plane) are also expanded with the size of $1.5 * w$. This design can be dynamically modified to adapt to different size, density and regular/irregular arrangement of data representations in the scene. Fig. 1 illustrates our design of expanded data points.

3 EVALUATION

This experiment aimed to evaluate the benefits of the expanding technique of data points when the user selects 3D data points regularly tiled on 2D data board with a Microsoft HoloLens 2. We considered three factors: Pointing (*Head* or *Hand*), Selection Confirmation (*Voice* or *Air-Tap*), Point Design (*Expanded* or *NoExpanded*). The experiment was conducted following a within-subjects experimental design with eight conditions:

- C1: *Head-Voice-Expanded* (He-V-E)
- C2: *Head-AirTap-Expanded* (He-AT-E)
- C3: *Hand-Voice-Expanded* (Ha-V-E)
- C4: *Hand-AirTap-Expanded* (Ha-AT-E)
- C5: *Head-Voice-NoExpanded* (He-V-noE)
- C6: *Head-AirTap-NoExpanded* (He-AT-noE)
- C7: *Hand-Voice-NoExpanded* (Ha-V-noE)
- C8: *Hand-AirTap-NoExpanded* (Ha-AT-noE)

3.1 Hypothesis

We expected that the *Expanded* approach would help the user select more easily the data points within the scene. Therefore, we formulated **H**: *Expanded* point design will help the user finish their task faster compared to *NoExpanded* despite different Pointing and Selection Confirmation techniques.

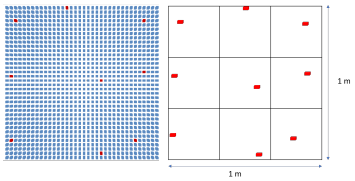


Figure 2: *Left*: Random distribution of red targets in nine zones of a data board which includes in total $36 * 36$ points regularly tiled. *Right*: Blue points are removed, targets are accentuated for visibility, and dividing lines are added.

3.2 Participants

There were nine males and seven females, whose age ranged from 22 to 30 ($\mu = 26.25 \pm 3.66$). Five of them (one male and four females) have never used a VR or AR system before.

3.3 Apparatus

The system used Unity3D on a computer with an Intel® Xeon® W-2135, 32 GB RAM, and Nvidia Quadro 4000. A Microsoft HoloLens 2 was used for rendering and interaction.

3.4 Experimental Task

In each condition (C1-C8), the participant selected nine red target points out of $36 * 36$ points in total regularly arranged on a $1m \times 1m$ data board (the remaining points were in blue). Each point is represented as a cube of 0.8 cm of each segment. This data board was placed directly $1.5m$ away in front of the participant at the beginning of the task. The target points were randomly distributed in nine zones of the data board (see Fig. 2 - right). When the participant selected a target, its colour turned white to indicate the successful selection. The task for each condition was completed when all the targets were selected. At the end of the experiment, we asked the participant to rank the eight conditions according to their preferences (1 is the best and 8 is the least preferred). For each trial, we collected the following measures: *Task Completion Time (TCT)* and *overall ranking*.

3.5 Results and Discussion

For the *Task Completion Time (TCT)*, the data were not normally distributed, and its distribution was positively asymmetric. Therefore, we applied a log transformation (log10(x) for positive asymmetric data). The average *TCT* for each technique and its 95% confidence intervals (CI) are showed in Fig. 3.

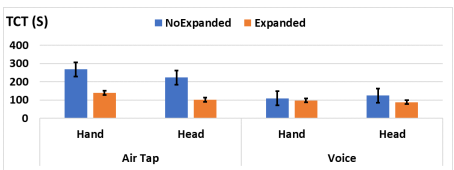


Figure 3: Task Completion Time (TCT). Error bars show 95% confidence intervals (CI).

Using multi-way repeated-measures ANOVA test for the three factors, we did not find any significant three-way interaction between them ($F_{1,120} = 0.01 * 10^{-3}$, p = 0.99). However, there was a significant interaction effect between Selection Confirmation and Point Design ($F_{1,120} = 7.85$, $p < 0.001$). Further analysis showed that the main effect of Point Design on *TCT* was statistically significant for the *Air-Tap* confirmation ($F_{1,124} = 27.60$, $p < 0.001$). We also investigated the main effect of each factor separately on *TCT*. The result showed a significantly independent effect of Point Design on *TCT* ($F_{1,120} = 21.57$, $p < 0.001$) and of Selection Confirmation on *TCT* ($F_{1,120} = 19.61$, $p < 0.001$). For *overall ranking*, the combined *Head-Voice-Expanded* condition was rated the best ($\mu = 2.44 \pm 1.88$), while the *Hand-Air-Tap-NoExpanded* was the least preferred ($\mu = 7.11 \pm 1.69$) (Fig. 4).

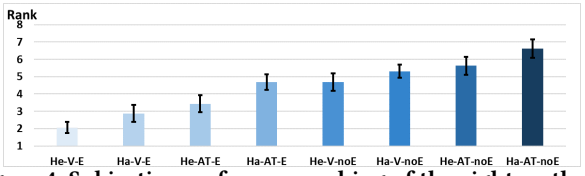


Figure 4: Subjective preference ranking of the eight methods. The 1st indicates the most preferred and the 8th the least.

Overall, if we consider only the Point Design mode, this experiment shows that selection using *Expanded* points is faster than *No-Expanded* ones. Expanding the data points significantly improves TCT using *Air-Tap* confirmation technique, but not in the case of *Voice* command. This result cannot confirm **H**. Moreover, using *Voice* to activate selection is faster than *Air-Tap* gesture. The participants preferred the condition with *Head* pointing and *Voice* confirmation command with *Expanded* points than the others.

4 CONCLUSION AND FUTURE WORK

In this study, we proposed an expandable data representation model inspired by the study in [4]. The experiment assessed our novel selection technique. The results show that the selection using *Expanded* points is faster than *No-Expanded* ones considering only the Point Design mode. Moreover, *Voice* confirmation was rated as the best selection technique from subjective feedback. Consequently, the expanded data point design received positive feedbacks despite pointing and confirmation technique.

There are many limitations to our experiments. In this study, the selection technique was considered only for visualising 3D data points regularly tiled on a 2D plane. Moreover, the multi-target selection was not evaluated. In future work, we will conduct a more in-depth study using Fitt's law experiment, which will allow us to confirm or deny whether the expanded target studies are still valid using augmented reality interfaces.

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