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Tangible Visual Analysis: Brushing in a Mixed-Reality Environment

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Figure 1: *From 2D/3D tangible/virtual representations to tangible brushing in a mixed reality environment.*

Abstract

Exploratory visual analysis helps scientists and domain experts gain insight into complex data sets. Tangible visual analysis can be used to bring interactive data exploration to non-expert users, such as visitors in science museums (or similar settings). Collaborative possibilities make it attractive for experts users, as well. We present a preliminary work on tangible brushing for visual analysis in a mixed reality environment. Mixed reality devices, such as Microsoft HoloLens, are blurring the barriers between the real and virtual environments. We can take advantage of these new technologies to provide a mixed reality based system for tangible visual analysis. We describe the main idea, the design principles, and the prototype development.

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1. Introduction

Exploratory visual analysis is a well established methodology used to gain insight into large and complex data sets [TC05]. Coordinated multiple views (CMV) [Rob07] is a key technique for such analysis. The main idea is to use different views to depict data attributes and allow users to select some data items in one view (brushing) to be highlighted in all other (linked) views. Unfortunately, the CMV systems are usually tailored for expert users. Understanding complex interplay of various dimensions in multidimensional data is not trivial. We show how this interplay can be explored to help non-experts to comprehend various phenomena.

Mixed reality (MR) environments are well suited for tangible visual analysis because the user interface can enhance the real world environment with virtual constructs and leverage embodiment and context awareness [GES*14, Kir13, KHT06]. New MR technologies (e.g., Microsoft HoloLens) can augment the user experience and provide affordances for brushing by allowing the user to define the context using semantic representatives (virtual/tangible and 2D/3D). We introduce a concept of tangible brushing for exploratory analysis in a MR environment using tangible (semantic) representatives for data dimensions (Figure 1). Manipulation of representatives selects a subset of data providing to users immediate feedback and a powerful support in data comprehension. We use the cars data set [Qui93] to illustrate our approach.

Tangible user interfaces [Fis04, SH10] have been used on tabletops, in learning environments [BDG*04], in virtual environments and augmented reality (AR) applications, for example [KGS*06]. Virtual reality (VR) and AR/MR technologies [BR05] are becoming more affordable and thus more accessible to general users. Tabletop tangible objects can be used to interactively query a database [LAD14, JSK*15] or for interactive data visualization [JSTK*16] and information visualization [STSD10]. They have a great potential to improve accessibility and help people with special needs [ZI12] or to retrieve relevant information in a tourist spot [CDJG02]. We need to better understand challenges when it comes to developing MR applications. Tominski et al. [TGK*14] provide a survey of Interactive Lenses in visualization.

The Facet-Streams [JGZ*11] are the closest to our approach. The main difference is that they use generic tokens (disks) for a query and augment it on a tabletop surface. While they identify a small subset of items matching specific criterion we focus on insight into large data sets, We use self descriptive semantic tokens,

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2D/3D tangible or virtual representatives (Figure 1, first five images), that users can directly manipulate (e.g., to define range constraints). The novelty is the integration of a flexible tangible user interface and a visual analysis tool within a mixed reality environment. A 2D tangible representative (marker) has the associated 3D virtual representative. A 3D virtual representative can be used in connection or without the corresponding tangible representative.

2. Approach

Unlike traditional graphical user interfaces (WIMP paradigm), tangible user interfaces are not well integrated. There is a cognitive and contextual gap due to the space separation between the user input and display. Various modalities of tangible inputs (e.g., AR markers, smart objects) must be integrated with a display within the user interface space. Visually overlaying tangible input with visual analysis display within the same space must address issues such as occlusion, limited embodiment and limited user interface space. We have to move beyond the 2D displays and 2D representatives to leverage benefits of embodied interactions. MR devices with integrated cameras and environment mapping capabilities can provide support for flexible 3D tangible and 3D virtual representatives. The developed system combines tangible input space with visual analysis display space (CMV tool, Figure 2) into a coherent and consistent MR space. The information about position and relationship between attribute representatives is mapped to a logical query representing a brush. The brush description is sent to the CMV tool and displayed in the linked views.

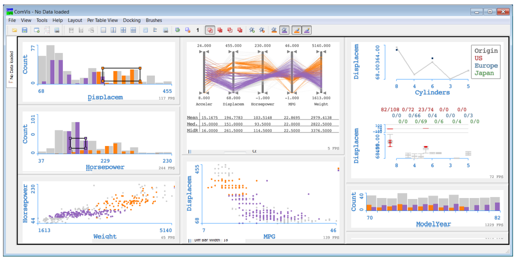

Figure 2: *ComVis CMV tool [MFGH08].*

We use Unity3D and Vuforia [PTC17] with attribute representatives to specify composite brushes. The requirement is that the representatives are semantically close to the dimensions they represent. The user can be offered a large set of identically sized representatives, a smaller set of representatives of different sizes, or a control representative to specify values. Specifying high horsepower is different in each case; a user either uses a number of identical horsepower representatives, one representative of particular size, or directly sets the value using the control representative.

Selection of one constraint, such as high horse power, is easy. However, in order to gain a full comprehension of data, composite brushing is needed. For example, we need to select cars with high horsepower and medium weight. We also need other Boolean operators, OR and DIFF. All these operators should be easily combined. Based on representatives position on the screen we have to clearly interpret what the user wants to specify.

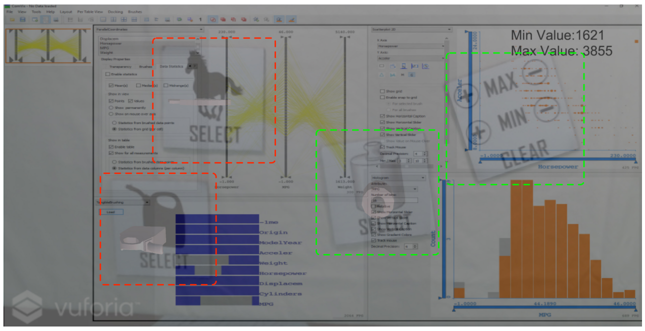

Figure 3: *Tangible composite brushing in MR: the CMV and 3D virtual representatives are superimposed over the real world view.*

We rely on proximity following the Gestalt laws of grouping [Roc97] and interpret representatives close to each other as combined using AND, and representatives far apart as intended to be interpreted as OR. The superimposed CMV tool linked views are displayed on a computer monitor or on a Microsoft HoloLens device (thus adding the context of the surrounding physical environment). The user can interactively modify the brush and observe the results without switching the context and view.

Figure 3 shows an example of tangible brushing using 2D representatives (annotated by the corresponding 3D virtual representatives) and the outcome of creating and modifying a tangible query — from simple to composite brushes. The CMV tool linked views include parallel coordinates (top left), scatter plot (top right), attribute range view (bottom left) and histogram (bottom right), We first select the horse power attribute (dashed red rectangle, top left) We then specify the range of values of horse power using the control representative (green dashed rectangle, top right). The selection appears in the CMV tool views (yellow and orange brushing). We repeat the process for miles per gallon (red dashed rectangle, bottom left) and weight representative (green dashed rectangle, center) resulting in a composite brush, logical OR, of three attributes. We then bring two tangible 2D representatives together (red dashed rectangles) resulting in a composite brush, logical AND of miles per gallon and horse power attributes. The AND brush (miles per gallon and horse power) is then combined in logical OR with the weight representative. The weight attribute representative (green dashed rectangle, center) is selected and the control representative (green dashed rectangle, top right) is used to set the range from 1621 to 3855. The CMV tool linked views are updated accordingly.

3. Conclusions

Exploratory visual analysis is a powerful tool. The complex user interfaces represent a main obstacle in making the exploitative visual analysis available in public installations. Tangible user interfaces, and their virtual counterparts, delivered using MR, could bringing visual analysis to a wider audience. The presented idea and the initial results show a great potential. We plan to evaluate the proposed approach in a case study that includes several data sets. It is important to investigate possible different preferences in virtual and tangible 2D/3D representatives.

References

[BDG*04] BINDER T., DE MICHELIS G., GERVAUTZ M., JACUCCI G., MATKOVIC K., PSIK T., WAGNER I.: Supporting configurability in a mixed-media environment for design students. *Personal Ubiquitous Computing 8*, 5 (Sept. 2004), 310–325. 1

[BR05] BIMBER O., RASKAR R.: *Spatial Augmented Reality: Merging Real and Virtual Worlds*. A K Peters, Wellesley, Massachusetts, 2005. 1

[CDJG02] CAMARATA K., DO E. Y.-L., JOHNSON B. R., GROSS M. D.: Navigational blocks: Navigating information space with tangible media. In *Proceedings of the IUI 2002* (13–16 Jan. 2002), pp. 31–38. 1

[Fis04] FISHKIN K. P.: A taxonomy for and analysis of tangible interfaces. *Personal Ubiquitous Computing 8*, 5 (Sept. 2004), 347–358. 1

[GES*14] GRAČANIN D., ECK II T., SILVERMAN R., HEIVILIN A., MEACHAM S.: An approach to embodied interactive visual steering: Bridging simulated and real worlds. In *Proceedings of the 2014 Winter Simulation Conference (WSC)* (Dec. 2014), pp. 4073–4074. 1

[JGZ*11] JETTER H.-C., GERKEN J., ZÖLLNER M., REITERER H., MILIC-FRAYLING N.: Materializing the query with facet-streams: A hybrid surface for collaborative search on tabletops. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (New York, 2011), ACM, pp. 3013–3022. 1

[JSK*15] JOFRE A., SZIGETI S., KELLER S. T., DONG L.-X., CZARNOWSKI D., TOMÉ F., DIAMOND S.: A tangible user interface for interactive data visualization. In *Proceedings of the 25th Annual International Conference on Computer Science and Software Engineering* (Riverton, NJ, 2015), IBM Corp., pp. 244–247. 1

[JSTK*16] JOFRE A., SZIGETI S., TIEFENBACH-KELLER S., DONG L.-X., DIAMOND S.: Manipulating tabletop objects to interactively query a database. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (New York, 2016), ACM, pp. 3695–3698. 1

[KGS*06] KIM J.-S., GRAČANIN D., SINGH H. L., MATKOVIĆ K., JURIĆ J.: A tangible user interface system for CAVE applications. In *Proceedings of the 2006 IEEE Virtual Reality Conference (VR '06)* (25–29 Mar. 2006), pp. 261–264. Application sketches paper. 1

[KHT06] KLEMMER S. R., HARTMANN B., TAKAYAMA L.: How bodies matter: Five themes for interaction design. In *Proceedings of the 6th ACM conference on Designing Interactive systems (DIS '06)* (New York, NY, USA, 2006), ACM Press, pp. 140–149. 1

[Kir13] KIRSH D.: Embodied cognition and the magical future of interaction design. *ACM Transactions on Computer-Human Interaction 20*, 1 (Apr. 2013), 3:1–3:30. 1

[LAD14] LANGNER R., AUGSBURG A., DACHSELT R.: CubeQuery: Tangible interface for creating and manipulating database queries. In *Proceedings of the Ninth ACM International Conference on Interactive Tabletops and Surfaces* (New York,, 2014), ACM, pp. 423–426. 1

[MFGH08] MATKOVIĆ K., FREILER W., GRAČANIN D., HAUSER H.: ComVis: A coordinated multiple views system for prototyping new visualization technology. In *Proceedings of the 12th International Conference on Information Visualisation (IV '08)* (9-11 July 2008), pp. 215–220. 2

[PTC17] PTC INC.: Vuforia. http://www.vuforia.com, 2017. [Last accessed 10 Feb. 2017]. 2

[Qui93] QUINLAN J. R.: Combining instance-based and model-based learning. In *Proceedings of the Machine Learning 1993*. Morgan Kaufmann, San Francisco, 1993, pp. 236–243. 1

[Rob07] ROBERTS J. C.: State of the art: Coordinated multiple views in exploratory visualization. In *Proceedings of the Fifth International Conference on Coordinated and Multiple Views in Exploratory Visualization (CMV '07)* (July 2007), pp. 61–71. 1

[Roc97] ROCK I.: *Indirect Perception*. The MIT Press, Cambridge, MA, 1997. 2

[SH10] SHAER O., HORNECKER E.: Tangible user interfaces: Past, present, and future directions. *Foundations and Trends® in Human–Computer Interaction 3*, 1–2 (2010), 4–137. 1

[STSD10] SPINDLER M., TOMINSKI C., SCHUMANN H., DACHSELT R.: Tangible views for information visualization. In *ACM International Conference on Interactive Tabletops and Surfaces* (New York, 2010), ACM, pp. 157–166. 1

[TC05] THOMAS J. J., COOK K. A. (Eds.): *Illuminating the path: The Research and Development Agenda for Visual Analytics*. IEEE Computer Society, 2005. 1

[TGK*14] TOMINSKI C., GLADISCH S., KISTER U., DACHSELT R., SCHUMANN H.: A Survey on Interactive Lenses in Visualization. In *EuroVis - STARs* (2014), Borgo R., Maciejewski R., Viola I., (Eds.), The Eurographics Association. 1

[ZI12] ZAJC M., ISTENIC STARCIC A.: Potentials of the tangible user interface (TUI) in enhancing inclusion of people with special needs in the ICT-assisted learning and e-accessibility. In *Agent and Multi-Agent Systems. Technologies and Applications*, Jezic G., Kusek M., Nguyen N.-T., Howlett R. J., Jain L. C., (Eds.), vol. 7327 of *Lecture Notes in Computer Science*. Springer, Berlin, 2012, pp. 261–270. 1