Sketching for Immersive Analytics with Situated Visualizations

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ABSTRACT

We explored sketching and ideation of situated visualizations at a local food bank with small displays as the hardware target platform. The design of situated and embedded data visualizations poses unique challenges because of the need to account for their situated nature like placement, size and level of detail of visualizations. Based on our observations and experiences at the food bank, we further envision a possible spatial augmented reality sketching tool and design activity for projected, embedded visualizations to provide a higher degree of immersion than with small displays.

KEYWORDS

Situated Visualization, Information Visualization, Design Workshops, Small Displays, Spatial Augmented Reality

INTRODUCTION

Recent trends in visualization research to move beyond traditional desktop visualizations [14] point to important opportunities to rethink existing visualization design approaches to better support the design of visualizations for *in-situ* data analysis. Examples of such trends include immersive analytics [1, 5] and situated and embedded visualizations [18, 19].

Requirements gathering, ideation and prototyping of embedded and situated visualizations [19] poses unique challenges due to the need to take into account the locations where the visualizations are deployed and the activities that they need to support. We explored these challenges through fieldwork

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in a project with a local food bank, a volunteer-based non-profit organization that combats food waste by distributing surplus food to social organizations. Our aim in this project was to explore how to make the organization's existing logistics and management data available inside the warehouse through situated visualizations in order to better support the work practices of volunteers and employees.

While research on immersive analytics often involves instrumented Augmented Reality (AR) and Virtual Reality (VR) with head-mounted displays (HMDs) [2, 15], Chandler et al. [5] note that 3D interfaces are "only one possible direction for research" into immersive analytics, and argue that it can also be enabled through other technology platforms such as touchscreens. Indeed, in the food bank case, we observed that HMDs would not be a practical hardware platform to enable immersive data analysis because HMDs would be disruptive to their existing work practices and might hinder social interaction. Instead, we decided to focus on small displays as the target hardware platform. We conducted a design workshop at the food bank to explore ideation and sketching, targeting such small displays. Our goal was both to elicit practical requirements regarding placement and desired form factors of the visualizations and to investigate the general information needs of workers.

In this position paper, we discuss our experiences and lessons learned with sketching and ideation activities for situated and embedded visualization at the food bank [4]. Drawing from our observations of the workshop that targeted small wireless displays as a technology platform, we further envision a possible design activity for situated visualizations enabled through Spatial Augmented Reality (SAR) [3]. A SAR sketching tool could allow annotating of the physical environment by sketching on a mobile tablet. The sketches that are drawn on the tablet would then be aligned with and projected on surfaces in the environment through a movable projector. Given that user instrumentation is not desirable at the food bank, SAR can provide a "spatially immersive" [13] experience using projectors, without user instrumentation with HMDs.

RELATED WORK

Relevance to Immersive Analytics

Our work can be situated within the areas of immersive analytics and situated and embedded visualization. Immersive Analytics [1, 5] is a vision that aims to leverage emerging interface technologies to provide immersive experiences and seamless workflows for real-world data analysis and data-driven decision making. White and Feiner introduced the concept of situated visualizations [18], which Willett et al. [19] expanded on with a conceptual framework for situated and embedded data representations, i.e. data visualizations that are displayed in proximity to physical referents to support in-situ data analysis. While we do not focus specifically on displaying data in 3D, we nevertheless see our work of providing data visualizations within an existing work environment as part of the vision of immersing people in (relevant and contextual) data [5].

Designing Situated and Embedded Visualizations

Conceptually, Bach et al. [1] introduced the AR canvas, detailing a design space for embedded visualization with AR. Prototyping tools and toolkits for embedded visualizations include MARVisT [6], a mobile AR visualization tool, that enables binding of visualizations to real-world objects, and DXR [16], a prototyping toolkit for immersive visualizations in AR and VR with HMDs. These tools enable in-situ prototyping of embedded visualizations, with a focus on later design-phases that would follow after initial ideation and sketching. Scientific Sketching [10], a methodology for collaborative visualization design for VR includes earlier design phases. Vermeulen et al. [9, 17] explored the design of situated glyphs at a care facility with a sketching workshop with caregivers, but removed from the locale where glyphs would be deployed. Bressa et al. [4] investigated sketching and ideation for situated visualization in several workshops, including the food bank workshop described in this paper.

Spatial Augmented Reality Systems

The aim of Spatial Augmented Reality [3] is to directly display and integrate content into the environment without instrumentation with HMDs, most commonly using projection. Raskar et al. explored SAR projection systems with iLamps [12] to provide object-augmentation with a hand-held projector. Building on that, RFIG Lamps [11] use a hand-held projector and wireless tags to to show information about the physical world with interactive projections. RoomAlive [8] is another projection-based SAR system that enables interaction with projections for immersive augmented gaming experiences and Lightform [7] is an example of a commercial design tool for projected AR.

THE SKETCHING WORKSHOP AT THE FOOD BANK

The Food Bank

The food bank is a non-profit organization that strives to reduce food waste by distributing surplus food to social organizations. Their workplace is set in a warehouse where goods are stored and packed for distribution routes. Volunteers deliver goods to receiving organizations several times a week with vans. Their work operates on a volunteer-basis, supported by a few permanent employees that are responsible for organization and management. To better understand existing work practices, the first author of this paper volunteered at the organization and joined a distribution run with the van.

Feasibility of Different Technology Platforms for the Food Bank Case

In our fieldwork, we observed that it was deemed important to minimize changes to existing work practices due to the volunteer-based nature of the organization. HMDs would be a disruptive modification to their practices. An important concern was to keep barriers to engaging in the volunteer work as low as possible. Training volunteers that often only work once a week to use HMDs would

Figure 1: Participants and sketching material at the food bank workshop.

prove to be challenging. Additionally, for many volunteers, part of the enjoyment of volunteering is about the social interaction and collaboration with other volunteers, which may be hindered through the use of HMDs. For these reasons, we did not consider HMDs as a practical hardware platform for the food bank case and chose small displays instead. Small displays have the advantage of being low-cost, flexible and easy to deploy and do not require extensive infrastructure.

Workshop Procedure

The workshop lasted two hours and took place at the warehouse of the food bank with four participants, two volunteers and two permanent employees. We provided sketching material in the form of whiteboard sheets in different form factors ranging from smartwatch sized sheets to A4 ($210 \times 297mm$) sheets that participants could chose from. Participants could attach the whiteboard sheets to surfaces in the warehouse with adhesive putty. We asked participants to sketch the information they would like to have available during their work routines at different places in the warehouse on the sheets. At each location, participants first came up with ideas individually for about 10 minutes and afterwards we discussed the sketches within the group for another 10 minutes. At the end of the workshop, we recapitulated and discussed all ideas for 30 minutes to pick the most promising ones.

Observations

Exploration of placements. The sketching material facilitated exploration of different placements of visualizations in the warehouse. The different display form factors could be integrated easily into the space by attaching them to walls and objects to associate data visualizations with the environment. The placement in the physical space enabled the participants of the workshop to see what the deployment of a display could look like and how it could be integrated into existing work activities.

Collaborative ideation. The workshop format and sketching material supported collaborative ideation of visualizations, including both volunteers and permanent employees in the sketching process. The whiteboard sheets were an effective communication tool to present ideas in the context of the warehouse and work procedures to the other participants to initiate discussion.

Robustness of displays. One issue of deploying visualizations on small displays in the warehouse of the food bank was that participants were hesitant to attach the displays to every possible surface, limiting possible placements. During the workshop, participants raised concerns about displays easily breaking when they were attached to movable objects like pallets or boxes.

Legibility of visualizations. In the food bank workshop we limited ideation to the sizes in which we provided the sketching material (Figure 1). Putting small displays up in high places can lead to poor visibility, which would be a problem for some of the large shelves and high ceilings at the warehouse.

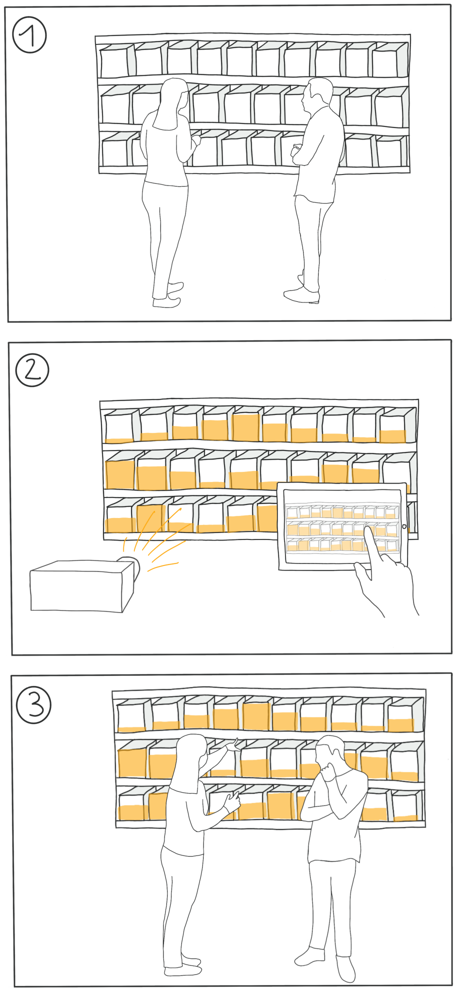

Figure 2: A possible sketching workshop procedure with the SAR sketching tool. (1) Brainstorming, (2) Sketching, (3) Discussion.

SPATIAL AUGMENTED REALITY SKETCHING TOOL FOR PROJECTED VISUALIZATIONS

Further reflecting on our workshop, we also see opportunities at the food bank for supporting embedded visualizations using SAR. SAR could further support visualizations in hard-to-reach places and could alleviate concerns with respect to readability and robustness of the technology. However, running a similar workshop for early-design sketching to explore the use of embedded data visualizations for SAR requires different materials, activities and tool support than the ones we used that targeted small displays. In this section, drawing from our experience with the first workshop at the food bank, we envision what a SAR sketching tool for projected visualizations could look like and how it could be integrated into a similar collaborative sketching workshop.

The SAR Sketching Tool

We envision a SAR sketching tool that consists of two main components: a movable projector and one or more mobile tablets. The tablets show their built-in camera feed so that participants can move the display to the object or surface they would like to sketch on. The sketches are then created by drawing directly on the tablet with either a stylus or one's finger. The projector subsequently projects the sketches drawn on the tablet into the actual environment, overlaying the sketches on top of actual surfaces or objects. The sketching tool with projector is placed on a mobile unit, for instance, a height adjustable desk with wheels, that can be moved to different locations to project at different heights, which is important for large spaces like the food bank warehouse.

Integration into a Sketching and Ideation Workshop

The collaborative workshop, that we envision the sketching tool to be used in, shares its basic structure with the food bank workshop. A small group of 4–5 participants would visit different locations during the workshop and generate visualization design ideas at each visited location. For each of these locations, the procedure is then divided into three phases: brainstorming, sketching and group discussion.

Brainstorming. At a location, the participants are asked to come up with as many ideas as possible for information that they would want to see at that specific location, i.e. during their work routines.

Sketching. Each participant has a tablet where they sketch their different ideas on individually. The sketches are overlaid onto the environment on the tablet's camera interface using mobile AR.

Discussion. The group discusses and examines the different sketches. All sketches are made available sequentially through the mobile tablet interface. When a particular sketch is selected, it is projected into the actual space through the projector. The group then discusses each idea, whether it is useful, how one would interact with the visualization and how it would integrate into existing work procedures.

The group can also explore possible adaptions to the sketch, by enabling each participant to further annotate the sketch with additional marks through the tablet interface.

OPEN QUESTIONS AND DISCUSSION TOPICS FOR THE WORKSHOP

SAR Sketching Tool Technical Realization. There are multiple possibilities of how to technically realize the SAR sketching tool. One option is to use an existing mobile AR platform (e.g. ARKit[1] or ARCore[2]) to sketch on the tablet. A calibration interface on the tablet could be used to mark the location and orientation of the projector in space. Assuming the 3D locations of the sketched annotations are known, they can then be transformed and projected from the projector's perspective. Alternatively, the projector can be combined with a (depth) camera as a calibrated projector-camera (pro-cam) unit. The tablet interface could show a live feed from the camera's viewpoint that the user can draw on. The projector can then display the sketches at the corresponding location in the environment.

[1] Apple Inc. 2019. ARKit. https://developer.apple.com/arkit/

[2] Google. 2019. ARCore. https://developers.google.com/ar/

Sketching Tool Input. We envision that participants would draw on the tablet rather than directly on the surfaces and objects in the environment. This facilitates sketching on large surfaces or objects that are not easily reachable. It may be, however, beneficial to provide complementary options for drawing directly on the projected surface [21] and drawing at a distance using a pointing device as, for instance, realized in RoomAlive with a pointing/gun controller [8]. Sketching directly onto the projection might be advantageous in situations where the sketched visualizations are smaller and restricted to reachable spaces and objects. Drawing with a pointing device might work well for medium-sized spaces where surfaces are reachable by pointing without requiring a lot of movement.

From Sketches to Visualization Authoring. The sketching tool could include extended functionality that goes beyond drawing sketches. It could enable the creation of visualizations by linking them to actual data, as common in most visualization tools. Sketches could also be combined and associated with data, which is a recent trend in visualization design like, for instance, in DataInk [20]. Binding of visualizations to objects like in MARVisT [6] would enable more fine-grained creation of visualizations connected to physical objects and surfaces. Creating a visualization tool that is less focused on sketching, might, on the other hand, be restrictive for ideation.

SAR to Sketch Visualizations for Small Displays. The SAR sketching tool could also be useful for the early-design of embedded visualizations with small displays as a hardware platform. Small displays with sketches could be projected in the environment instead of drawing them on physical sketching materials that get attached to different surfaces. Projection-based sketching might be beneficial for prototyping a large number of distributed, small displays.

Prototyping Interaction. Sketching interactive behaviour for situated and embedded visualizations is still a challenge. The sketching activities at the food bank as well as the current version of the SAR sketching tool are limited in that they assume mostly static visualizations. For the SAR sketching tool, one option could be to integrate animated steps with keyframes into the sketch to simulate interaction. For small displays, directly sketching on actual devices could facilitate similar behaviour.

Sketching for Immersive Analytics. Based on our experiences with the food bank, we found it beneficial for ideation to engage with the people we are designing for, in the particular place where the situated and embedded visualizations would be deployed. Sketching at a place can bring up new ideas that align with existing practices of people. The SAR tool we envisioned has the potential to demonstrate the possibilities to people of how an immersive analytics application could look like and it allows them to come up with their own ideas and applications.

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