Aero: a tangible interface for a critical healthcare context

Martina Eriksson
Umea Institute of Design
martinaninaeriksson@gmail.com

Shibashankar Sahoo
Umea Institute of Design
sahooshib1@gmail.com

Carolyn Wegner
Umea Institute of Design
carolynmwegner@gmail.com

Abstract

UPDATED—27 November 2017. Our current understanding of the translation of subjective data into numbers in user interfaces has limited our capacity to perceive the intrinsic meaning associated with data and its source. Here, we envision Aero, a tangible interaction framework that connects the user and data source by combining data physicalization and tangible manipulation. We illustrate the application of this framework through a case study on a critical context of an anesthesia ventilator machine, where the connection between data source, i.e patient, and user, i.e nurse, is vital. This interface enables the users to monitor, communicate, and manipulate the tangible data in real time. This thereby establishes a deeper connection between the data source and the user. Lastly, we analyze the challenges, limitations and future opportunities of this approach in this professional context through two prototypes - fabric, jellyfish.

Author Keywords

Data physicalization; visualization; tangible; shape-changing interfaces; medical; system; complexity;

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous;

Figure 1: Current GUIs used in operations

Introduction

In all the recent developments in the tangible interactions, the research community has focused on the theoretical definition, concept exploration, education, and art installations. But a study of tangible user interfaces [1] in a complex context has always been a challenge. In this article, we apply the tangible user interfaces in a professional context where safety is critical. By implementing TUIs in such a context, we learned more about challenges in data communication, manipulation, usability, and system complexity. This helped us to open possibilities for the research on the existing domain of tangible interfaces.

The development of tangible interaction has paved the path towards the sensory richness and action-potential of physical objects as carriers of meaning in interaction[3]. Data physicalization enables the user to interpret data with an artifact whose geometry or material properties encodes data and supports cognition, communication, learning, problem-solving, and decision making [2]. We bring in the inspiration from these studies and attempt to design an interface for a critical context.

In the first half, we explore the challenges and limitation tangibility through various prototypes. In the second half, we propose a tangible interface framework that combines the data physicalization and manipulation into one cohesive and dynamic system that connects data, data-source and the user. We have designed this interface by embracing the human-machine interaction in a critical context of the hospital.

Case Study

We began our case study by looking at the interface for a ventilator machine used in the hospital. We developed a series of prototypes that addressed the challenges and potential opportunities.

Currently used GUIs in Hospital

During the critical process of ventilation, the breathing data is translated into various parameters on the graphical user interface(GUI) (figure1). This takes years of training for the nurses to interpret the values. This affects decision making in a context where meaning matters the most.

We believe that when something as subjective as the breathing of human body is translated into numbers like breathing frequency and pattern, it loses its rich quality.

Data Physicalization

Figure 2: natural breathing frequency simulation of lungs using tangible cubes

Figure 3: Jellyfish artifact offers a natural resistance and a pressure mapped from the lungs

Figure 4: Concept aero hybrid supports tangible manipulation and data physicalization

We explored various ways to communicate the breathing data through prototype fabric (figure 2) and then focused on the motion of natural breathing by translating the movement into a tangible form.

Data Manipulation

Today's manual ventilation provides lots of hidden and qualitative information about the patient condition that can only be read by professional nurse. For an example, a slight change in the muscle relaxation can readily be felt through the manual ventilation pump, whereas it takes a longer time to display on the GUI screen. Thus, we designed an artifact jellyfish(figure2) that translate breathing information into real-time physical variables like resistance, stiffness, and pressure. It further enhances the emotional input through rich haptic feedback.

Challenges

The challenges that we faced in this critical context were the amount of data that need to be layered and timed appropriately communicated precisely to its user in this physical medium. The diverse category of data used in the medical context poised a major challenge for us in physicalization. Therefore, we divided the data into three categories- qualitative, quantitative and hybrid data. Some values, such as partial pressure of gases requires precise number to be displayed quantitively. Some values are qualitative such as alveolar pressures, tidal volumes, and gas flow inside the lungs are more visual, subjective. Other data, such as the partial collapse of the lungs, require multiple parameters in terms of quality and quantity to be fully understand the phenomena.

Concept Aero

We explored the ways in which we could take diverse data, with a range of expressive needs, and translate them into a coherent hybrid (figure 4). We explored the intersections of tangible manipulation and data physicalization with data derived from ventilation machines

Towards a system complexity in tangible interaction

During the research on ventilation for anesthesia, we observed that the nurse(user) and patient(data-source) mutually interacted and manipulated values through a

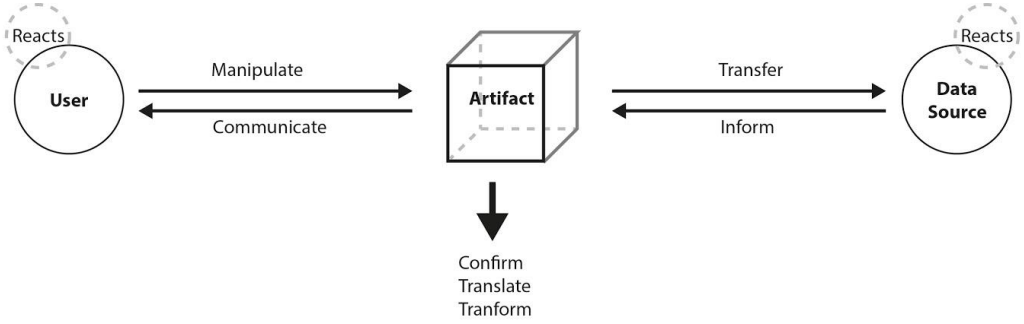

Figure 5: A tangible interaction system consisting of multiple actors and artifact in a context

machine(artifact). The nurse's action on the machine influenced the patient, and the patient, in turn, influenced the data displayed on the machine.

This, however, created a complex system involving multiple intelligent users interacting with data. See (Figure 4). Current use of graphical user interfaces veils this system complexity of interaction, reducing it into mere numbers and dials on the screen. This makes it harder for the user in visualization, interpretation, decision making, and manipulation.

Discussion

Through the application of tangible interaction in a critical context, we encountered many design problems that helped us identify various research opportunities. These opportunities included *the emotional meaning of data, communication, manipulation, dynamic affordance, and systemic complexity in tangible interaction*. Among the research issues that we explored, we realized that when we look at tangible interfaces as a bridge between digital and physical world, it leads to issues in communication, manipulation, usability, scalability, and application. To solve this, we propose two approaches. First, we solve each of these issues by zooming into each of them on a micro level. Second, we zoom out and understand the bigger picture in a user context. The method however is an open question to the research community.

Conclusion

We reflect on the nurse, patient, and ventilator machine in hospital ecosystem in the case study and realize that instead of treating TUIs as a bridge between digital and physical world, we should treat them as a part of an ecosystem in a context where multiple intelligent actors and artefacts mutually influence the outcome. In the future, we imagine the seamless connection and collaboration between intelligent actors like Artificial intelligence(AI), environment and human in a cohesive system, where tangibles become the medium of communication. With the advancement of smart materials, we envision more of these smart interfaces, used in the professional user context.

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