Design an Interactive Visualization System for Core Drilling Expeditions Using Immersive Empathic Method

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Overview
In this paper, we propose an immersive empathic design method and used it to create an interactive high-resolution core visualization system for real-world geological core drilling expeditions. A high domain knowledge barrier makes it difficult for a person from outside this field to imagine the user experience simply through observation. The globally distributed nature of the core drilling community imposes further design constraints. We used this approach to embed a computer scientist trained as a junior core technician. This process allowed the developer to experience authentic user activities and enabled the design of an innovative system for solving real-world problems. This approach made the best use of precious co-located opportunities, overcame the initial domain knowledge barrier, and established a trust relationship between the developer and the domain scientists. The system designed through this approach formed a sustainable and adaptive foundation that the domain scientists can build on. Through in-situ deployment, observation and interview evaluations from on-going expeditions, we present the advantages of this process.

Keywords
HCI, Visualization, Empathic Design

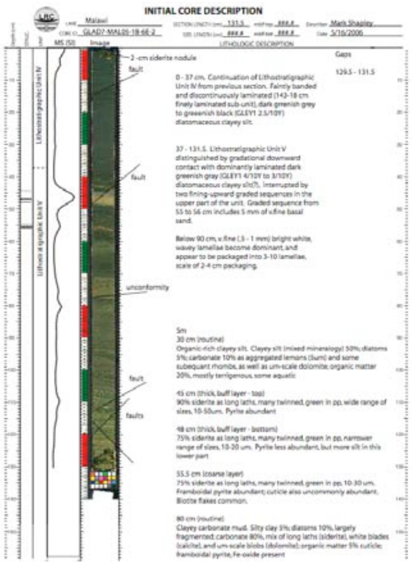

Figure 1. An example barrel sheet

Figure 2. Before having the CoreWall system, scientists use barrel sheets to look at collected data. This picture shows hand-drawn clast core description for 1,000 meters of cores recovered in Antarctica in 2006. Photo by Josh Reed

ACM Classification Keywords

H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces - Computer-supported cooperative work, Synchronous interaction, Collaborative computing

Objectives

It is difficult to design a useful system for people who work in a different knowledge domain. Prior literature and studies have proposed participatory design [2] and user-centered design [3]. However real-world users such as scientists may lack the motivation to take the first step. Empathic design [4] has been used in industry for commodity product design where designers use activities such as biographies, scenarios, simulations, role-playing and social probes to try to step into users' shoes. While these practices might be useful in designing commodity products, they may not be as applicable for scientific users.

Problem domain background

Geological cores are cylindrical bodies containing natural materials and sediments. They are recovered from the surface or the crust of the Earth. Just like tree rings, the composition and deposition layers of cores contain detailed records of the climatological and ecological changes on the Earth dating back millions of years [1].

Scientists have begun to acquire a large amount of core data including high-resolution numerical sensor logs and imagery. They would run core sections through sensor rings, split the cores in half, take photographs and they might not see the actual cores again. Even though scientists tried to utilize these digitized assets, they did not make the best use of the digital images' unique affordances, which include feature-preserving representation in high-resolution and easy remote access. Scientists used these digital assets simply to print out paper-based "barrel sheets" (Figure 1,2) through tedious steps as "workarounds". To generate barrel sheets, they have to combine outputs from photo editing, data plotting and desktop publishing software. There were no systems empowering them to visualize and navigate huge amount of data without interfering with their science workflow.

We set out to design a high-resolution visualization system for the geological core drilling. The objectives for this work were: 1. The system should make use of the unique affordances of high-resolution digital assets. 2. It should assist geologists to make detailed observation and interpretation. 3. It should minimally interfere with other scientific activities in the core laboratory. 4. It should attract scientists to buy into the concept and the proposed system.

Process

In order to overcome the initial high domain knowledge barrier to understand the working context of potential users, we proposed employing the "Experiential Learning" [6] theory and using the "immersive hands-on" method. Starting from summer 2004, one of the computer science developers joined expeditions. The developer received training as a junior core technician from an early stage of the design cycle. In 2006, he worked with geologists using piston tools to retrieve more than 10 meters of core samples from Lake Pepin, Minnesota. He went through the workflow including splitting the cores into "archive" and "working" halves, carefully smoothing the split core surface, and operating the high-resolution image scanning and

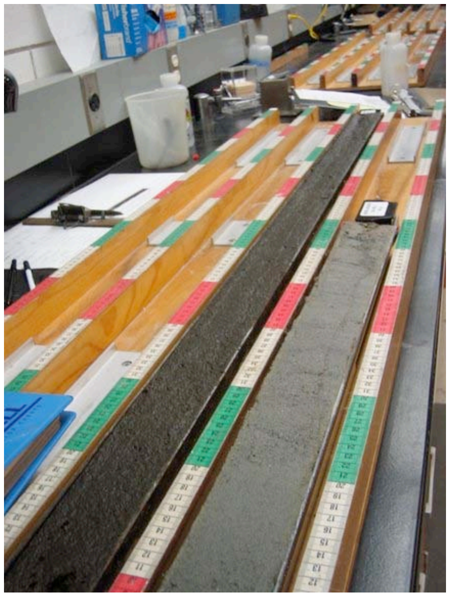

Figure 3. Split cores ready for initial core description on the core table

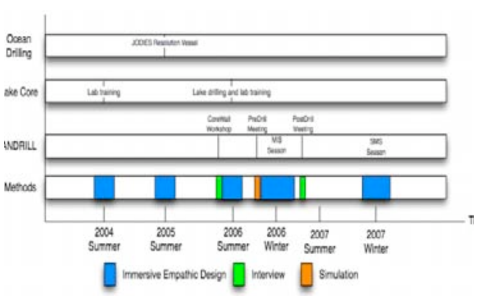

Figure 4. Overall timeline

multi-sensor core logging equipment to acquire digitized core data. He also attempted to do the initial visual core description as a real geologist on the core table (Figure 3).

During these activities, the developer not only recorded photos, audio and video clips as analysis material for the design context, the "self-reflection" step of "experiential learning" posed in-depth context-sensitive inquiries in later iterative prototyping, deployment and evaluation stages. The overall timeline is shown in Figure 4.

In the process we found more challenges. 1. Scientists want the freedom to choose what tools to use and have often found that systems designed by "outsiders" do not solve their problems. 2. Skeptical geologists have doubts about the authenticity of digital core imagery and would prefer to observe physical cores even though the digital image is perceptually better. 3. Different users might have different research goals and hence different interaction styles need to be supported. 4. Core drilling workflow is both spatially and temporally distributed. Take the Antarctica Geological Drilling project (ANDRILL) for example. ANDRILL consists of scientists, teachers and students scattered around the world, but only 70 people spent the season in the McMurdo station during the expedition season. And it might take one entire season to ship all the recovered cores back to the repository in the United States. In the past, scientists would have no way of accessing these core samples during this period to carry on their research.

Key Findings

The hands-on approach provided an efficient transformation to bring the developer into user's world especially focusing on the context of the involved activities. Besides, the developer's commitment and "get his hands dirty" established an invisible trusting bond between the developer and the users. This training experience was repeatedly referred to in later design cycles and in introducing the system to new communities.

As pointed out in [5] regarding remote collaborations, distance still matters. Another advantage of the "immersive hands-on" method is that it efficiently utilizes precious co-located space and time throughout the whole process. User feedbacks can result in immediate modifications to the prototype system instead of waiting for another designing cycle. Mostly importantly, the hands-on experience directly affected the design of the system described in the next section.

Results and Impact

We designed the CoreWall system. The CoreWall system includes a single workstation with tiled LCD displays as shown in Figure 5. This display arrangement was based on the experience gained in training: 1. Each section of core is roughly 1 meter long and 10 cm wide, and it is physically difficult to see all the details even with the help of the loupe. Multiple displays have enough resolution to display the cores in detail. 2. Room lighting conditions may affect observation and interpretation. LCD displays can be easily color calibrated to provide a unified representation. 3. The displays are arranged horizontally just like how the physical cores are laid out on the table. This visualization space provides a familiar experience, as if the scientists are examining actual physical cores. 4. The CoreWall reduces the extra mental load of

Figure 5. CoreWall Setups in National Lacustrine Core Repository (LacCore, above) and Antarctica Geological Drilling (below)

Figure 6. Dr. Franco Talarico switched from hand-drawn barrel sheets (**Figure 2.**) to the CoreWall setup in McMurdo station, Antarctica. Photo by Betty Trummel

swapping physical core sections on the core table. It also further stimulated geologists to generate more research ideas. The hardware design also affects the design of the software user interface. The software is implemented with a multi-level image texture paging system that provides scientists with highly interactive manipulation of thousands of meters of geological cores. The display borders are taken into account to reduce interpretation interference [7]. Scientists can easily interact with data from thousands meters overview down to micron scale details. Because the visualization area is large, user interface guidelines were also developed.

The system empowers scientists to juxtapose numerical sensor log plots, high-resolution images and user-generated annotations. The digital “mashup” can be distributed to colleagues to further support remote collaboration. Now scientists can access virtual core repositories remotely instead of having to travel to various physical locations. Scientists can get immediate feedback from data and make on-the-spot decisions during an expedition.

Starting from 2005, scientists in LacCore started using the CoreWall to assist initial core description. Two CoreWall systems were deployed to Antarctica for the ANDRILL expedition in 2006. In 2007, because of positive feedbacks, ANDRILL brought 6 CoreWall setups including one at the drill site to support on-the-spot drilling decisions. Currently the CoreWall is undergoing the International Ocean Drilling Program JOIDES Resolution vessel sea trial on the route to Honolulu.

Modern scientific research involves an increasing amount of distributed and interdisciplinary work. This paper has proposed an “immersive hands-on” design method and a real-world case study showing precious co-located opportunities were used to overcome initial barriers to development and acceptance in the community. The experience and reflection analysis built up sustainable knowledge and increased user adoption through the trust bond between the domain science users and the computer science developers. The method and lessons learned could be beneficial to future HCI practitioners when the potential users of the system are within domains sharing similar qualities such as the scale of the data involved, high levels of domain knowledge, geographically distributed users and the regularity of remote collaborations.

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