SkyHunter: A Multi-Surface Environment for Supporting Oil and Gas Exploration

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ABSTRACT
The process of oil and gas exploration and its result, the decision to drill for oil in a specific location, relies on a number of distinct but related domains. These domains require effective collaboration to come to a decision that is both cost effective and maintains the integrity of the environment. As we show in this paper, many of the existing technologies and practices that support the oil and gas exploration process overlook fundamental user issues such as collaboration, interaction and visualization. The work presented in this paper is based upon a design process that involved expert users from an oil and gas exploration firm in Calgary, Alberta, Canada. We briefly present knowledge of the domain and how it informed the design of *SkyHunter*, a prototype multi-surface environment to support oil and gas exploration. This paper highlights our current prototype and we conclude with a reflection on multi-surface interactions and environments in this domain.

Author Keywords
Oil and gas; multi-surface environments; tabletops; gestures; cross-device interaction; mobile devices

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User Interfaces. – Graphical user interfaces. J.2. [Physical Sciences and Engineering]: Earth and atmospheric sciences, Engineering.

INTRODUCTION
Multi-Surface Environments are systems where interaction is divided over several different displays, which includes digital tabletops, wall displays, tablets and mobile phones [1]. Because of the different sizes and capabilities of the displays in such an environment (e.g., resolution, mobility), they can support a wide range of different tasks and interactions. Key challenges for multi-surface environments still remain however. These challenges include finding what tasks can be accomplished in these environments and how collaboration can be made effective in these types of environments [1].

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Figure 1 - The *SkyHunter* multi-surface environment running with multiple iPads and a digital tabletop

Significant research has been done into different types of interactions, as well as collaboration for multi-display environments; however, very little work has gone into exploring multi-surface environments with real-world industrial partners. To move these potentially useful environments into the commercial space, as well as into the hands of industry, some benefits should first be displayed. As a result, we explored on the concepts of interaction and collaboration for multi-surface environments in the context of a specific domain, oil and gas exploration.

The oil and gas exploration process is both complex and multi-faceted. In a typical exploration project, several domains – geosciences, reservoir and production engineering, geophysics – must work together in a timely manner to achieve oil production goals as well as maintain the safety of the environment and personnel in the field. Multi- disciplinary teams are extremely common and their collaborative exchange is a necessity for the oil and gas exploration industry [2]. The importance of the collaborative activities of a multi-disciplinary team is shown by their effect on operating costs of an oil and gas company, as well as the resulting activities from their decisions. These decisions require a meticulous process, strong collaboration and communication, as well as a common understanding of the exploration process [3].

To address the research aspects and guide ourselves in the creation of a domain-specific interface for oil and gas exploration, we worked with Sky Hunter Exploration Ltd., who collect proprietary multi-disciplinary data, called *microseep* maps, which significantly increase the chances of finding oil and gas. We initially sought feedback about the domain and their current practices with the data, which included paper-mache mockups and paper maps and thus designed and developed a multi-surface environment (see Figure 1) to address not only this data but facilitate in the collaborative processes of oil and gas exploration. In this paper, we present our system designed with Sky Hunter Exploration Ltd. and share our reflections.

RELATED WORK

As a whole, the research space of multi-surface environments is very well explored. Significant research has been done in exploring the different ways in which the displays can be treated – continuously [4] [5] or discretely [6] [7] – as well as different interactions, such as flicking [8], or picking and dropping [9], among others. Furthermore, the individual components of multi-surface environments, such as digital tabletops, have been shown to increase collaboration significantly and effectively [10]. A unique advantage of multi-surface environments consequently, is the benefits they can provide as a collaborative workspace. Examples of collaborative workspaces in the research literature include Collab, which allowed groups of users to work together on desktop PCs and a large-scale wall display [11]. Dynamo, another example, allowed users to move information to a shared wall display [12].

The sharing and connection of information is also highlighted by Streitz et al. [7], who created an environment utilizing a digital tabletop, wall displays, and custom displays attached to chairs. This sort of interactive collaborative space is also shown in the iRoom project [4], allowing users to move content around different displays and devices.

Having different displays and devices in these collaborative multi-surface environments has been shown to lead to new discoveries or help support existing hypothesizes, particularly in the domain of astrophysics [13]. Furthermore, Tani et al. showed that displays in these environments can improve productivity significantly for spatial tasks [14]. These collaborative spaces have also been explored in supporting the learning of abstract knowledge through both collaboration and interaction [15] [16] .

For the oil and gas domain, the focus of this work, several different technologies have been explored to address collaboration. These include visualization rooms, haptic devices, as well as virtual reality [17] [18]. A significant challenge presented by many of these interactions and technologies however, is they are limited to single user interaction. For oil and gas exploration, which is multi-disciplinary, this is insufficient. In the context of multi-surface environments, there is very little research into oil and gas exploration. To our knowledge, this is one of the first

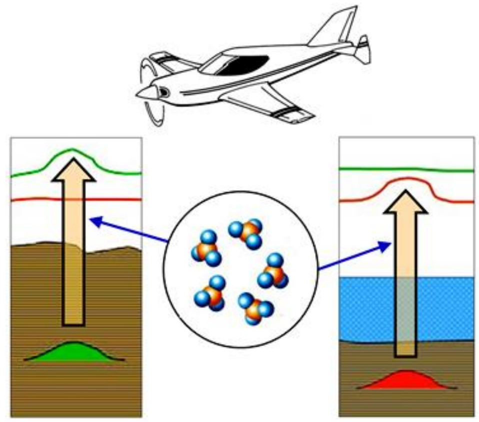

Figure 2 - Sky Hunter Exploration Ltd. uses an airplane to fly to survey an area while using an air sampling device to record the intensities of hydrocarbons that leak from the ground.

prototypes to attempt to map the oil and gas exploration process to a multi-surface environment.

OIL AND GAS EXPLORATION

The process of oil and gas exploration and production involves many complex tasks, with multi-phase workflows and depends on a number of different variables from different groups of inter-related disciplines, such as geophysics, geology and engineering [19].

In a new exploration project, field measurements are used to gather different types of information about a potential location for drilling an oil well. Much of this measurement information strictly belonged to the aforementioned disciplines, which bring with them different perspectives and sometimes conflicting solution strategies [20].

To support collaborative exchange in oil and gas exploration, a number of software tools are currently used. These tools interpret geological and geophysical data (among others) and result in typically 2D (and 3D) geospatial images and maps that are unique to the domains involved and often have different modalities and scales. This information is then used to facilitate in discussions to determine the best possible locations to drill for oil and gas.

However, these software tools and their output don't easily allow for collaboration. The processes are clumsy and there is a strong need for computational and visualization tools that properly integrate data from the numerous domains [21]. Furthermore, the data in its current form isn't interactive for exploratory analysis and direct manipulation. This problem is further enhanced with the newer data collection techniques that exist in the oil and gas domain that result in data that require multi-disciplinary visualizations and analysis.

Sky Hunter Exploration Ltd., an oil and gas exploration company located in Calgary, Alberta, Canada, uses a proprietary measurement technique that detects charged particles leaking from the ground with a customized airplane

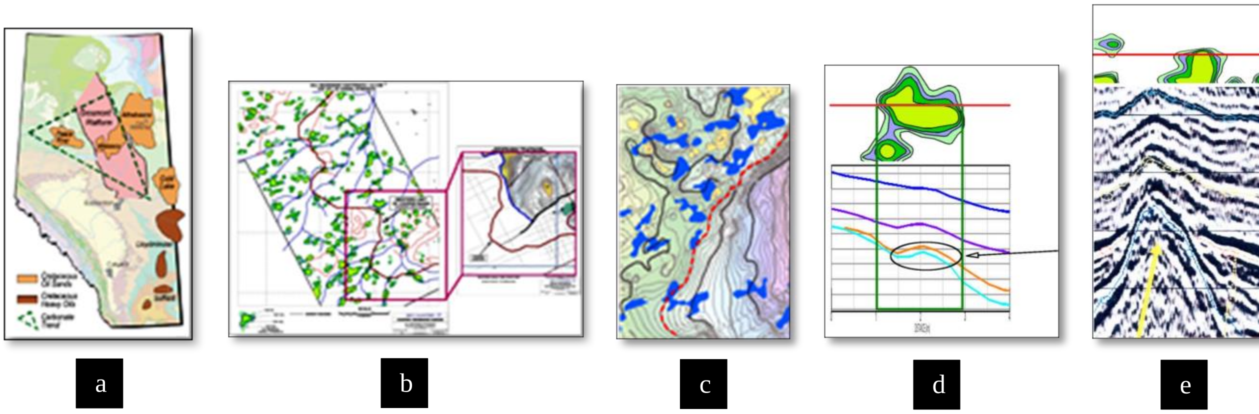

Figure 3 – The various modalities and scales of data for Sky Hunter Exploration Ltd. (a) 2D map representing the province of Alberta and oil fields, from a top-down view (b, c) A hydro-carbon map including microseep footprints combined with a secondary image (both in top-down view) representing subsurface information underneath (d, e) Zoomed hydro-carbon map with microseep footprints, from a top-down view, with appropriately scaled subsurface information underneath (seismic data), from a side-view.

(see Figure 2). The output of this measurement technique, after specialized interpolations, is a *hydro-carbon* map (see Figure 3b). This map, when combined with data from the other disciplines in the exploration process, results in a significantly more informed decision for a drilling location.

The unique challenges of the data that Sky Hunter Exploration Ltd. present to the oil and gas exploration processes are presented in Figure 3. While a majority of the maps are in 2D (e.g. Figure 3a, 3b, 3c), the image planes can be at different depths or mixed. For example, in Figure 3d and 3e, a hydrocarbon map is viewed in a top-down plane while the corresponding cross-slice is viewed from a side-plane, in a single mixed-plane image. For Sky Hunter Exploration Ltd., this data presents a conflict of modalities and is a significant barrier for its introduction into the decision making process for multi-disciplinary teams.

The workflow for a multi-disciplinary team using this unique data as described by Sky Hunter Exploration Ltd. is the following:

Step 1: The entire multi-disciplinary team surveys a prospective area for wells. Specifically, the *Land Man* – who has knowledge of the owners of any potential properties to drill oil upon – and the *Pilot* – who flies the customized airplane – are used to decide where to start an initial exploration.

Step 2: After the initial exploration by the *Pilot* has been completed, interpolation is performed on the measurements and the output, *hydro-carbon* paper maps are then used to highlight the results of the exploration. These maps are printed at different scales and different modalities for the various disciplines of the team and visually indicate zones of the highest concentration of charged particles when overlaid. Thus, this indicates the locations with the highest likelihood for successfully drilling a new oil well.

Step 3: The *Geophysicists* provide seismic information, while the *Geologists* provide subsurface information, such as subsurface formations, all of which is also paper based. Combined, these two disciplines provide visualizations and contextual knowledge for the entire multi- disciplinary team about the exploration environment; in addition, with the hydro-carbon maps, they provide a different visual perspective underneath the zones.

Step 4: The numerous engineering domains – reservoir, drilling and production – then use the static paper based data that has been combined thus far, to create "flow" models which may be used to determine the best location to drill an oil well, as well as strategies on how to drill a location.

Step 5: If a location has been determined, the production engineers then create an economically and environmentally viable production plan for drilling the location, which is then presented to a sponsoring company for the ultimate decision of whether to purchase the exploration area (if needed) and drill the location.

Overall, this workflow is highly collaborative and is tightly integrated with paper based processes and visualizations, which presents a number of unique challenges when building a multi-surface environment. This is described in the next section.

SKYHUNTER AND INFRASTUCTURE

To support the workflow as described by Sky Hunter Exploration Ltd., we designed the *SkyHunter* multi-surface environment. This environment supports different visualizations of data for the multi- disciplinary team and also provides integration for numerous types of data that are available in the workflow described earlier. The *SkyHunter* multi-surface environment was designed in collaboration with domain experts from Sky Hunter Exploration Ltd., and this section summarizes the design considerations and its features.

Design Considerations

While working with Sky Hunter Exploration Ltd., we continually discussed and iterated over three main elements in the design, which are as follows:

1. Simplification of the different modalities of data and interacting with it.
2. Providing different domains access to their own private data and a means to share it with the team.
3. Bringing together all the data.

The first design element is related to the simplification of the interactions with the data in the workflow. As described by an expert from Sky Hunter Exploration Ltd., "*if I want to view seismic information flat, or in another orientation at the same time, I can simply click a button or another means that allows me to do this.*" This means, accommodating the different modalities (mixed 2D planes and 3D) with the different devices in the environment, as well as providing more opportunities for seamlessly interacting with the data, instead of "*continually printing out different scales of map data on lots of paper*".

The second design element is of interest to Sky Hunter Exploration Ltd., as they described many of the disciplines to be *"somewhat sensitive of their own data in as they may have sensitive information they don't necessarily want to share (yet) or information they'd like to sell for profit later."* Along these lines, providing the means for the different disciplines to interact with their own unique data in both a private and public manner, while preserving ownership, is extremely important.

The last design element, was also of importance, as it was described as "*a unique challenge with our data is that it requires a lot of other data to be properly understood. Being able to integrate seismic or subsurface maps in a system easily would make our process significantly easier*". Integrating the different types of map information should be supported by the *SkyHunter* multi-surface environment, especially considering the number of domains and their data.

Infrastructure

As shown in Figure 4, *SkyHunter* is a multi-surface environment comprised of a number of components. To build this interactive environment, the MSE-API[1] framework was used. This framework, provides information such as device orientation and device location when utilized with the Microsoft Kinect[2] and easily allowed multi-surface interactions to be created for the *SkyHunter* multi-surface environment.

Specialized applications were also created for iPads[3] and the tabletop utilizing ESRI's ArcGIS API[4] , which provides mapping capabilities and gestures such as pinching and zooming, as well as the automatic scaling of map data. All of the proprietary information provided by Sky Hunter Exploration Ltd, is stored on a backend ArcGIS server, providing an integrated solution for the different types of data for the different disciplines.

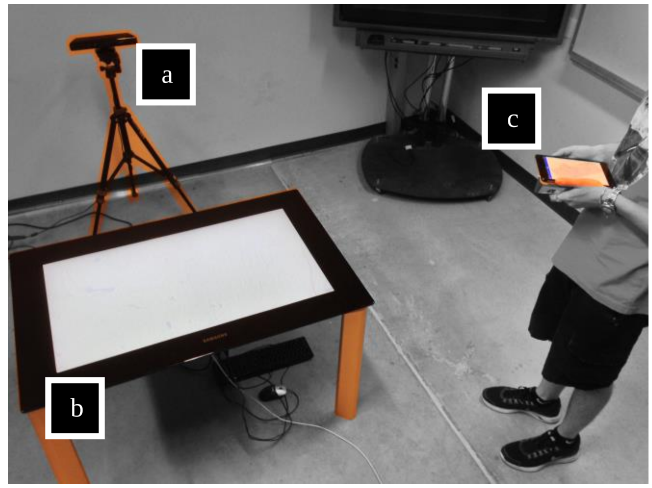

Figure 4 – Overview of *SkyHunter*. (a) Microsoft Kinect[2] used with MSE-API[1] for providing tracking and orientation information (b,c) Tabletop and iPad running custom applications.

Realizing the Design

An important component in the multi-surface environment for maintaining collaboration present in the oil and gas exploration process is the Samsung SUR40 digital tabletop[5]. In the environment, it is used as the main hub of collaboration in the *SkyHunter* multi-surface environment. The software designed for the digital tabletop replaces much of the paper based interactions that are described in the exploration process, particularly for cases where maps of different scales and types need to be viewed and overlaid simultaneously. The tabletop also serves as the primary location where data from different sources and disciplines can integrated in the exploration process (particularly in Steps 2-3).

Much like the exploration workflow described earlier, where a domain expert provides a paper-based map for discussion, the tabletop initially contains no data until a domain expert provides it to the tabletop to begin the collaborative process. Unlike the paper based workflow however, a number of multi-surface interactions are provided to simplify privacy, interaction and sharing of this data.

[1] MSE-API - https://github.com/ase-lab/MSEAPI-CS

[2] Microsoft Kinect - www.xbox.com/en-CA/Kinect

[3] Apple iPad - http://www.apple.com/ca/ipad/

[4] ESRI ArcGIS - http://www.esri.com/software/arcgis

[5] Samsung SUR40 - www.samsunglfd.com/solution/sur40

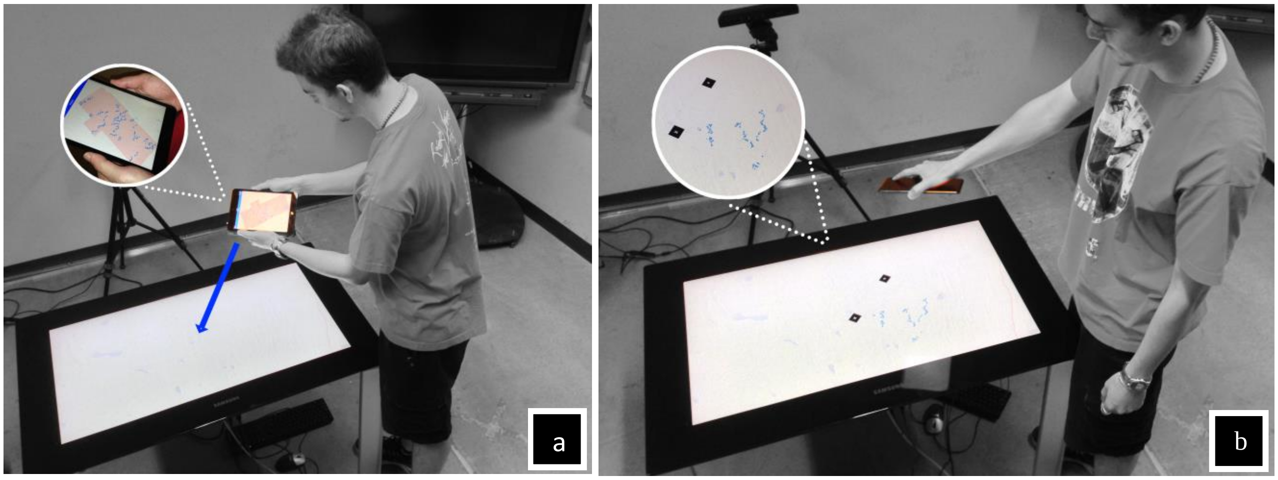

Figure 6 – *Pouring* data. (a) The user performs a *pouring* interaction onto the tabletop after selecting subsurface data on the iPad (b) The subsurface data appears on the digital tabletop after the *pouring* interaction is completed.

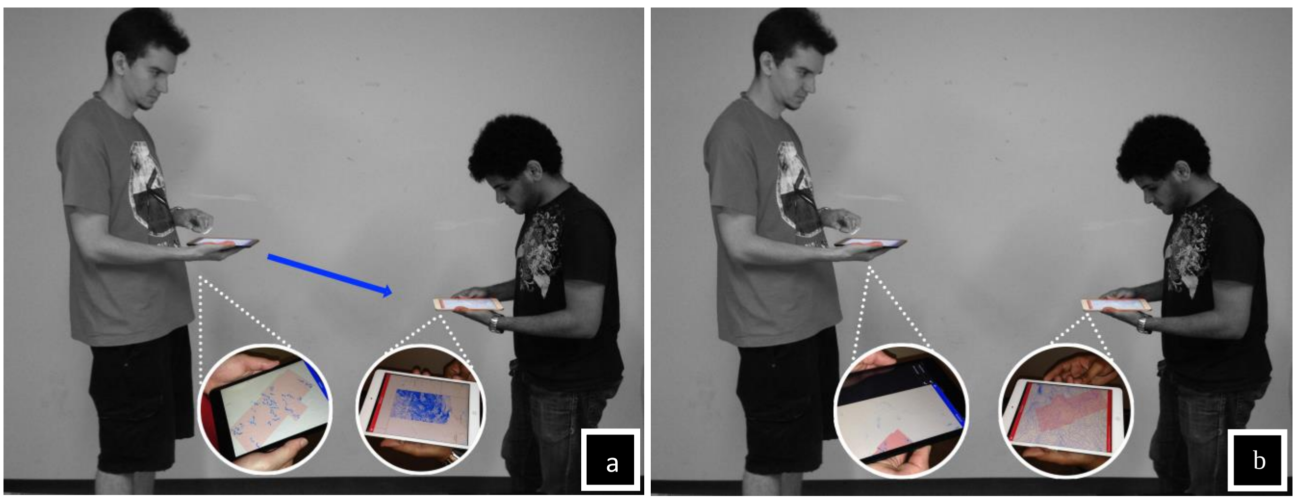

Figure 5 – *Flicking* data. (a) The user selects geological formation data to send and *flicks* towards the other user. (b) The geological formation data appears on the targeted user's device.

To establish private domain data, individual iPads are used as a means to distinguish the multi-disciplinary roles in the application, and selecting an appropriate role on the startup of the iPad application allows for appropriate data to be displayed and interacted with. For instance, a *Landman* in the application is only able to view and share well data while a *Geophysicist* similarly will only be able to view and share subsurface formation data. This allows for stricter control of data ownership and sharing, described as an important design consideration by Sky Hunter Exploration Ltd.

Interaction and sharing of data, as shown in the workflow, is critical to the collaborative process. Individually, both the tabletop and iPads provide pinching and zooming interactions for map data, which is useful for individual or group based interactions. However, to replace the paper-based interactions in the workflow, such as bringing a paper map to a central location or sharing a map with a specific domain expert, multi-surface interactions are available for users.

The *pour* interaction is used to send selected map data from an iPad to the tabletop, in close proximity (see Figure 6). Similarly, a *flick* gesture (see Figure 5) is also used to send selected map data to the tabletop, but is not restricted by distance to the tabletop, unlike the *pour* interaction. Both these interactions are useful for Steps 2-4 in the workflow, where users provide data to collaborate and make decisions based upon combined data from the different disciplines. Additionally, the *Camera* gesture (see Figure 7) is used to capture the shared visible data on the tabletop on a user's iPad at the conclusion of the workflow.

As mentioned earlier, one of the biggest challenges of the Sky Hunter Exploration Ltd.'s data in the workflow is its different modalities and interacting with it, highlighted

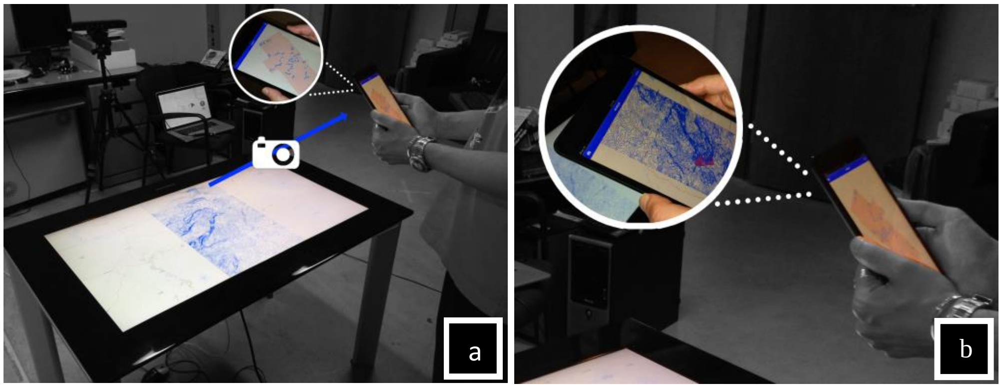

Figure 7 – *Camera* interaction. (a) The user points the iPad at the tabletop and selects a button to capture an image of the data available on the tabletop, in this case, geological formations (b) The geological formation data appears on the user's iPad after selecting the data on the iPad to capture.

earlier in Figure 2c. Due to the complicated nature of the data, its requirement of other data to be properly understood and unclear visualizations, there is a negative cascading effect on the workflow, particularly in Steps 2-3. To provide a better means of visualizing and interacting with seismic information (typically cross-slices) provided by *Geophysicists* and the *hydro-carbon* maps and other geographical information used in the workflow, a *slicing* interaction is used in *SkyHunter*. The *slicing* interaction allows the viewing of multi-modal information by combining information on the digital tabletop and the iPad. This is performed by placing the iPad down on the tabletop vertically (see Figure 8), resulting in seismic information being displayed on the iPad in the correct orientation, while a 2D map with various information is still visible on the tabletop. This specifically resolves the data representation issue presented in Figure 2c, where a top-down image can now be presented on the tabletop and the iPad can be used to display the side-view cross-slice.

EARLY DESIGN CRITIQUE AND DISCUSSION

Getting feedback from users, especially in the multi-disciplinary domain of oil and gas exploration is extremely critical. As we worked very closely with domain experts from Sky Hunter Exploration Ltd., we asked them to continually provide feedback through the various stages of our collaboration, including the prototype that is presented in this work. The goal of this extremely early feedback was to discuss the potential of multi-surface environments and applications to their domain as well as to brainstorm future development ideas. The feedback received is presented below in general themes.

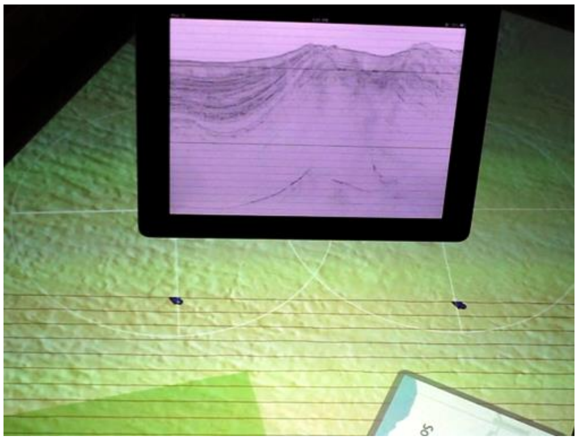

Figure 8 – *Slicing* interaction, allowing a user to see seismic information underneath a selected microseep when an iPad is placed on the tabletop.

Ease of Interaction: The feedback for being able to interact with all of the different data was extremely positive. Many comments were about how *"using pinch and zoom, exactly the same on the iPads and the large tabletop for the hydro-crap maps is useful. It's far better than printing out tons of maps for the same information."* It was also noted that the data was far easier to understand and manipulate now that it was easily accessible to the different disciplines across the different devices in the environment. It was also suggested in a future version, that the different displays be synchronized to ensure everyone was on the same page in the collaboration, especially if they were in a remote location.

Collaboration: A marked improvement noted by Sky Hunter Exploration Ltd, was the increased collaboration that resulted from the digital tabletop and wall display in the environment. A geologist noted "*it was far easier to collaborate with my data now that everyone is centered on a tabletop. I can match up my data with the hydro-carbon maps easily and I can then get more data later if I need it"*. The collaborative aspects of the tabletop for map based data was also highlighted, with the statement *"the tabletop is a great way to get everyone in the company together and on the same page. It's much better to have everyone gathered somewhere together, than sitting at their laptops and staring at a PowerPoint presentation."*

Visualization Enhancement: Given that the prior visualizations for Sky Hunter Exploration Ltd.'s data (and the decision workflow) was paper based or a paper-mache construct, placing it on different devices was an instant enhancement. The tabletop was also found to be useful for providing a big picture context of an area, as well as a means of sharing visual analysis of data or a specific area.

Multi-Surface Gestures and Interactions: The gestures implemented for *SkyHunter*, were based on previous work [1]. We initially assumed that there would be interactions that would be close to a central location or further away (i.e. using a flick gesture to tabletop as a geologist could be working privately, away from tabletop). The immediate reaction to these interactions for this domain wasn't positive. The geologist of Sky Hunter Exploration Ltd. noted that *"while the interactions are cool, they aren't useful for this domain, as they might require additional training, or an IT guy who can impede the whole process and make everyone uncomfortable*." Interestingly however, the camera gesture was well received and was found to be an easy way to take data away from a meeting, especially after everyone had agreed upon a drilling location.

Alternate Sources of Data: One of the most interesting aspects of the workflow of oil and gas exploration process, is the different types of data. A specific use case that Sky Hunter Exploration Ltd brainstormed was if different contractors entered the discussion with paper based maps, being able to overlay this data physically with the digital maps, would be extremely beneficial. This type of mixed-modality interaction although unique, provides the perspective that not everything should be considered "digital" in this domain.

CONCLUSION

In this paper, we explored the use of multi-surface environments and focused on issues such as *collaboration*, *interaction* and *visualization* specifically, in the context of the oil and gas exploration domain. We approached the design of the multi-surface application by working with Sky Hunter Exploration Ltd. from initial brainstorming discussions to a working prototype and present a preliminary design critique and discussion about their utility for the domain. In the future, we plan to extend the prototype further and continue with a more complete evaluation of its system and its impact on the workflow of oil and gas exploration processes. We hope this initial work will trigger greater interest in applying multi-surface environments and applications to this domain, as we believe they can benefit greatly from these technologies, especially from an HCI perspective.

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