Advancing Collaborative Discovery through Reality-Based Interaction

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Abstract
In this paper we describe two projects that utilize reality-based interaction to advance collaborative scientific inquiry and discovery. We discuss the relation between reality-based and embodied interaction, and present findings from an experimental study that illustrate benefits of reality-based tabletop interaction for collaborative inquiry-based learning.

Keywords
Collaborative learning, multi-touch, tabletop interaction

ACM Classification Keywords
H5.2 Information Interfaces and Presentation: *User Interfaces*

General Terms
Design, Human factors

Introduction
Over the past two decades, research on Human-Computer Interaction (HCI) generated a broad range of interaction styles that move into new physical and social contexts. Examples include augmented-reality, tabletop and tangible interaction. These emerging interaction styles, leverage users' existing knowledge and skills about the non-digital world such as naive

physics, spatial, social and motor skills to a greater extent than traditional user interfaces [Jacob et al. 2008]. By basing interaction on pre-existing real-world knowledge and skills, this emerging generation of HCI offers the promise of a more intuitive, accessible and natural form of interaction.

From Embodied to Reality-Based Interaction

The notion of Embodiment has been influential in shaping emerging interaction styles. "Embodiment" refers to the fact that humans are incarnated, physical beings that live in a physical world rather than abstract cognitive entities. The human body and active bodily experiences inevitably shape how we perceive, feel and think [4]. Most directly, embodied interaction refers to the physical embodiment of data and its control through physical devices and body movement [3]. However, Dourish [1] extended this view of embodied interaction beyond physical manifestation. He suggested that embodied interaction is grounded (and situated) in everyday practice including social and cultural contexts. Thus, embodied interaction describes a direct and engaged participation in the world that we interact with.

Jacob et al. [2] proposed the notion of Reality-Based Interaction (RBI) as a unifying framework that ties together a large subset of emerging interaction styles as a new generation of HCI. The term reality-based interaction draws upon the notion of embodiment but focuses on the fact that many new interaction styles are designed to take advantage of users' well-entrenched skills and experience of interacting with the real non- digital world. Rather than emphasizing the situated nature of interaction, Jacob et al. [2] focus on four fundamental themes of interaction with the real-world that are typically leveraged by emerging interaction styles: 1) naïve physics; 2) body awareness and skills; 3) environment awareness and skills; and 4) social awareness and skills. These four themes play a prominent role in emerging interaction styles.

Jacob et al. further suggest that the trend towards reality-based interaction is a positive one, because basing interaction on pre-existing skills and knowledge from the non-digital world may reduce the mental effort required to operate a system. Thus, they encourage interaction designers to leverage reality-based skills and metaphors as much as possible and give up on reality only after explicit consideration, and in return for other desired qualities.

While RBI has been applied to a broad range of application domains, little HCI research has been devoted to investigating RBI in the context of scientific discovery. However, it is particularly important to study reality-based interaction in this context where reducing users' mental workload and supporting collaborative work could lead to new discoveries. Those RBIs that examined the possibilities of supporting scientific discovery, focus on the representation of information that has an inherent spatial structure (e.g. proteins, molecules, and maps). We are interested in investigating the application of RBI to areas where vast amount of *abstract* information is manipulated.

Following, we describe two projects that study the strengths and weaknesses of tabletop reality-based interaction in supporting collaborative scientific inquiry and discovery.

Enhancing Learning in Genomics through Tabletop Interaction

G-nome Surfer [5, 6] is a tabletop user interface for collaborative exploration of genomic information. G-nome Surfer was designed to lower the threshold of using bioinformatics tools and to foster collaborative inquiry based learning and discovery through fluid interaction with large amounts of genomic information.

The design of G-nome Surfer draws on users' existing knowledge and skills to provide a reality-based tabletop interface [5]. Specifically, G-nome Surfer uses naive physics metaphors such as inertia, transparency, and mass. The interface also leverages users' spatial skills, allowing them to organize information upon the surface to express relationships between multiple forms of evidence. Like tabletop interfaces in general, G-nome Surfer draws upon users' social skills and existing social protocols to afford collaborative interaction. Figure 1, shows G-nome Surfer in use.

Figure 1, Exploring genomic information with G-nome Surfer

To investigate G-nome Surfer's strengths and limitations in supporting collaborative inquiry-based learning, we conducted a between-subjects experiment with 48 undergraduate students comparing the system to both current state-of-the-art tools and to a collaborative multi-mouse GUI. We examined the similarities and differences in terms of quantitative performance and qualitative behavior in 24 dyads that worked on an inquiry-based task. We considered a range of measures including verbal and physical participation, performance, attitude, mental workload, and collaboration and problem solving styles. Sessions were video recorded and later analyzed. Findings from this study indicate that G-nome Surfer reduces users' stress levels and workload compared to current state-of-the-art tools as well as improves students' performance and attitude. These findings are described in detail in [6]. Here, we would like to highlight four benefits of tabletop interaction compared to a multi-mouse GUI:

1) *Increasing physical participation*: the tabletop condition exhibited significantly higher levels of physical participation. These were expressed by increased spatial manipulation of information. Several theories of embodied cognition suggest that spatial manipulations can help reasoning about abstract concepts.

2) *Encouraging reflection*: in the tabletop conditions participants spent significantly longer time on reflection activities and articulated a larger number of insights. Since research indicates that student's understanding of the nature of science is enhanced through

reflection [7] this is an important strength.

3) *Fostering effective collaboration*: on the tabletop condition participants exhibited turn-taking collaboration style (rather than driver-passenger style) with significantly higher number of coordination utterances, and significantly lower number of disengagement utterances. Thus, participants were engaged in more effective collaboration.

4) *Facilitating intuitive interaction*: in the tabletop conditions there was a significantly lower number of syntax related utterances. Also, users spent less time finding information.

These findings support our hypothesis that the tabletop condition facilitates a more *effective* collaborative learning process, and highlight some advantages for applying RBI to support collaborative discovery.

Supporting Large Research Teams

Following our experience with G-nome Surfer, supporting inquiry-based learning in small teams, we seek to investigate *how to apply tabletop reality-based interaction to support collaborative discovery in larger research teams*. To answer this question, we are currently developing, in collaboration with domain scientists, a large-scale reality-based tabletop interface that utilizes a 6’ x 9’ high-resolution multi-touch display. Our investigation focuses on supporting multi-user interaction in an area that require to access and manipulate vast amounts of abstract information – biological engineering. Specifically, we are developing a platform for designing and assembling synthetic biological systems. We expect the system to be used frequently by research teams of about 8 scientists. We intend to study how the system impact team dynamics, brainstorming and problem solving strategies, as well as insight development.

Summary

Reality-based interfaces offer the promise of a more intuitive and accessible form of interaction that reduces the mental workload requires for learning and operating a system. Our research agenda focuses on applying reality-based interaction to enhance scientific discovery in areas that explore vast amounts of data.

References

[1] Dourish, P. Where The Action Is: The Foundations of Embodied Interaction, MIT Press, Cambridge, Mass., (2001).

[2] Jacob, R. J., Girouard, A., Hirshfield, L. M., Horn, M. S., Shaer, O., Solovey, E. T., and Zigelbaum, J. Reality-based interaction: a framework for post-WIMP interfaces. *Proc. Human Factors in Computing Systems* (2008).

[3] Norman, D. The Next UI Breakthrough, Part 2: Physicality. Interactions, July + August. 46-47 (2007).

[4] Shaer, O. and Hornecker, E. Tangible User Interfaces: Past, Present, and Future Directions, Foundations and Trends in Human-Computer Interaction, Vol. 3, Issue 1-2, (2011).

[5] Shaer, O., Kol, G., Strait, M., Fan, C., Grevet, C., and Elfenbein, S. G-nome surfer: a tabletop interface for collaborative exploration of genomic data. *Proc. of ACM CHI.* ACM Press (2010).

[6] Shaer, O., Strait, M., Valdes, C., Feng, T., Lintz, M., and Wang, H. Enhancing Genomic Learning through Tabletop Interaction, Proc. of ACM CHI. ACM Press (2010).

[7] Singer, S.R., Hilton M.L., and Schweingruber, H.A. America’s lab report: investigations in high School science, National Research Council (2005).