Designing Cognitively Convivial Physics for Dynamic Visual Information Substrates

James D. Hollan
UC San Diego Design Lab
Department of Cognitive Science
Department of Computer Science and Engineering
UC San Diego, La Jolla, CA 92093 USA
hollan@ucsd.edu

Arvind Satyanarayan
Google Brain
Electrical Engineering and Computer Science
Computer Science and Artificial Intelligence Lab
MIT, Cambridge, MA 02139
arvindsatya@cs.stanford.edu

Abstract
The historical moment in time when people worked in front of a single computer has passed. Computers are now ubiquitous and are being embedded in virtually every new system, with the internet providing connection to ever-expanding information resources with previously unimaginable computational power. Yet with all the increases in capacity, speed, and connectivity, information-based activities too often remain difficult, awkward, and frustrating. Even after six decades of design evolution there is little of the naturalness and contextual sensitivity needed for convivial interaction with information in the myriad areas now intertwined with computers. We propose a dynamic visual information substrate designed to radically ease information-based tasks by operating in accordance with cognitively motivated physics sensitive to tasks, personal and group interaction histories, and context.

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Co-Adaptive Systems; Cognitively Convivial Physics; Dynamic Visual Information; Instrumental Interaction; Information Substrates.

ACM Classification Keywords
H.5.2 [User interfaces (Interaction styles).]

Introduction

For far too long we have conceived of thinking as something that happens exclusively in the head.Thinking happens in the world as well as the head. We think with things, with our bodies, with marks on paper, and with other people. Thinking is a distributed socially-situated activity that exploits the extraordinary facilities of language, representational media, and embodied interaction with the world. Today we increasingly think with computers. But the computers we think with are rapidly changing. The monolithic computer of the recent past is coming apart and being reassembled in myriad new forms. Computers are now ubiquitous and intertwined with every sphere of life. This evolution is accelerated by a radically changing cost structure in which the cost to use a thousand computers for a second is not appreciably more than to use one computer for a thousand seconds. Yet with all the changes and increases in capacity, speed, and connectivity, using computers too often remains difficult, awkward, and frustrating. Even after six decades of design evolution, there is little of the naturalness, spontaneity, and contextual sensitivity required for convivial interaction with information. In addition, the legacy conception of information as static and disconnected from processes, tasks, contexts, and personal histories persists.

Although the world of information is shifting residence from paper to the web and the screens, files, and databases of computers, information commonly remains as inactive as on paper. In most current systems information is fundamentally static. It has been characterized as pictures under glass [20, 21]. In addition, we typically need to search for information. Rarely does it come to us or change how it appears or behaves based on our context. We envision a future in which information *itself* is dynamic, interactive, and personalized to individuals, groups, contexts, tasks, and histories of interaction with it. In this radical alternative, information entities operate in accordance with cognitively inspired physics of behavior sensitive to current context and our perceptual and cognitive abilities. To help convey the future we envision, we sketch a brief example scenario.

A Scenario

Samantha leads a research group developing computational techniques to address questions about complex microbial ecosystems of the human body. She just returned from a conference and is resuming writing a paper involving analysis of data her group recently collected. She last worked on the paper a week before her trip and now can't remember what she was doing or where she left off. As she begins to examine the current version she launches an experimental system that provides interactive visual access to her personal information space. This zoomable multiscale space, accessible via a web browser on any of her devices, operates according to multiple behavioral physics so that entities act in ways attuned to and supportive of tasks and contexts. The space represents all the information (e.g., files, emails, messages, papers, web pages, notes, sketches, analyses, and visualizations) of her computer-mediated activities and the history of her interactions with it and with Jupyter computational notebooks that her group uses for data analysis. These representations are created automatically as a result of activity.

She zooms out to see the whole space and the active navigational physics of the space aids movement to an area associated with her previous activity. Recognizing movement along an often followed path, a simple gesture is all that is required to complete navigation. Visible are graphical depictions of the paper she was working on and histories of her interaction with whiteboard sketches from a group meeting she was using when last working on the paper as well as the visualization she was creating. A physics for interacting with history allows her to glide automatically along her earlier activity path and to use drawer-like push-pull gestures to jump between navigational landmarks automatically created during her previous interactions. At one landmark she initiates an activity replay and a movie-like sequence begins to play. She interrupts it and zooms into the visualization she had been creating. It has information scent widgets to indicate data quality issues (e.g., missing entries, mismatched data types, etc.) and a set of automatically constructed charts she typically uses at this analysis stage. Because the physics is built on a declarative representation of analysis semantics, there is also a warning of Simpson's paradox (a trend appearing in different groups of data but disappearing or reversing when the groups are combined). She dismisses it but notices an unusual trend and spike in the visualization. She circles it with a stylus on her linked iPad and connects it to a different part of the space to remind her to bring it up in a future group meeting. This interaction is interpreted as a query and results in retrieval of a visualization of a similar trend and spike noted by colleague. The visualization is dim to indicate that it will be deleted if not touched.

She zooms out to get an overall view of the analysis and resumes the guided navigation of what is now a higher-level summary of the lengthy analysis. This would be difficult, if not impossible, for anyone else to interpret but because it is her history it is evocative and she remembers exactly what she was doing. She now feels able to resume writing but first wants to discuss it with her group and hear about developments while she was away. She announces a video-conference and by encapsulating this portion of her information space makes it available to others and on a large wall display for those in her lab. Before the meeting starts, one student moves a collection of related technical papers into the shared space. Some resulted from automatic searches based on developing paper collections shared in the space. The student highlights a subset to discuss. This multiscale pile has a default behavior to show a montage of selected images from the papers as an iconic summary. As she awaits others joining, Samantha hovers over the pile and it dynamically shows more details as well as citation links. Many papers do look relevant and she connects the pile to an area of her personal space reserved for future reading. The fact they are already annotated will be useful. Similarly, sketches of possible figures to include in the paper, made jointly by two other students are shared into the space. The figures are dynamic interactive views of recent data. The shared information space facilities discussion in the meeting and by the end she feels caught up and prepared to resume work.

Of course, this idealized scenario glosses myriad complex issues. Designing a dynamic personalized sharable multiscale information space linked to existing information and capturing and representing histories of interaction confronts a host of challenging research questions. How are multiscale representations of information and activity created? How are they depicted and arrayed in the space? How are histories captured and contexts recognized? Our research plan begins to addresses these questions. These are certainly appropriate topics for a workshop on rethinking interaction but more fundamental for us is the notion of a “cognitively convivial physics” for information and the usefulness of a “physics” metaphor.

Cognitively Convivial Physics

By *physics* we simply mean a set of rules governing how representations behave and depict themselves. We caution not to take this too literally. We are not arguing for identifying a set of atoms from which information is built. We are attracted to the physics metaphor primarily because it captures the radical notion that the rules of behavior should be integral to the world of information itself rather than individual applications. The metaphor arose from early work on simulation-based training systems [9] designed to create interactive worlds to assist people in developing mental models similar to those used by experts to reason about complex physical systems. It also motivated design of zoomable multiscale interfaces (see [8] for a brief history and the first use of the "cognitively convivial physics" term). A deeper motivation is to shift the focus from creating specific applications to designing a general dynamic information environment. In our view this is fundamental to moving away from the silos of today's applications. The associated cognitive goal is to ensure a consistency, generality, and learnability that are too often missing from current application-based approaches. For a physics to be *cognitive* the rules must be designed so that informational entities present themselves, behave, and interact in ways that are responsive to context and that exploit people's cognitive and perceptual abilities. We add *convivial* to emphasize that instead of being static information should be lively, helpful, and enjoyable to interact with.

It is important to note that we are certainly not the first to view information as involving physics. Like many ideas in human-computer interaction, the intellectual roots can be traced to the seminal work of Ivan Sutherland on Sketchpad [18]. His revolutionary constraint-based interactive sketching environment was a first example of the type of cognitive physics we envision. In addition, the development of object-oriented programming environments like Smalltalk (see [12] for a history) and especially Borning's ThingLab system [5, 6] as well as work by Smith and colleagues on the Artificial Reality Kit [16] and the Self programming language [19, 17], and their related work on the implications of cartoon animation for interface design [7] are all significant influences. Kay's Dynabook [11] and associated conception of personal dynamic media [10] as well as early work on Steamer [9] and Pad++ [3] were also influential.

Our current objective is to develop a Webstrates [13] and Vega-Lite [15] based substrate for dynamic visual information linked to the existing world of information and applications but operating according to cognitively convivial physics. In doing this we join with others (e.g., Kay [10], Victor [20], and Berners-Lee [4]) in challenging the traditional and still prevailing view of information as being fundamentally passive. We also draw inspiration from recent work [1, 2] of Beaudouin-Lafon, on what he terms the *Instrumental Paradigm* in which interactions become first-class objects from the perspective of the user, designer, and developer; Klokmose on Webstrates[13, 14], a novel browser based approach for creating sharable dynamic media; and Satyanarayan on Vega-Lite [15], a high-level grammar of interactive graphics. A fundamental goal of these efforts is to move the design focus beyond application and document-centric views of information to a focus on designing dynamic information environments.

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