Creativity Support Tools: A Grand Challenge for HCI Researchers

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Abstract Human-computer interaction researchers can play a key role in designing, implementing, and evaluating a new generation of creativity support tools. Understanding creative processes, especially when mediated by user interfaces will remain a continuing challenge, especially in dealing with novice and expert users, across a variety of disciplines. The expected outcomes include (1) refined theories of technology-supported creative processes, (2) active discussion of user-oriented empirical research methods, (3) new software architectures, database management strategies, and networking technologies, and (4) improved user interfaces to support discover and innovation, especially in collaborative environments.

1 Introduction

During the past 40 years, computing professionals have been enormously successful in developing productivity support tools for many users, so that they can perform their work more rapidly, effectively, and with fewer errors. Now, computing professionals are turning their attention to developing creativity support tools, which enable users to explore, discover, imagine, innovate, compose, and collaborate [8].

The grand challenge for creativity support tool designers is to enable more people to be more creative more of the time [7, 12]. Creativity takes many forms, such as paintings, sculpture, symphonies, songs, poems, plays, and prose. Creativity is also part of the design culture in consumer products, graphics, and architecture, as well as through the innovations from engineering, software development, and user interface design. Finally, creativity manifests itself in the scientific discoveries of physicists, biologists, chemists, mathematicians, or computer scientists.

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2 Theory of Creativity

My concepts of creativity were strongly influenced by the psychologist Mihaly Csikszentmihalyi, whose books include the widely cited *Creativity* [2]. He describes three key components for understanding creativity:

1. **Domain**: "consists of a set of symbols, rules and procedures" (creative work is within a domain), e.g. mathematics or biology,
2. **Field:** "the individuals who act as gatekeepers to the domain... decide whether a new idea, performance, or product should be included" (creative work is social and must be judged by others)
3. **Individual:** creativity is "when a person... has a new idea or sees a new pattern, and when this novelty is selected by the appropriate field for inclusion in the relevant domain"

Creativity's role in economic growth is well-documented by Richard Florida [4] in his book *The Rise of the Creative Class and How It's Transforming Work, Leisure, Community and Everyday Life.* He emphasizes the 3 T's: Technology, Talent and Tolerance. Further evidence of the economic impact of creativity comes from the U.S. National Academy of Sciences report *Beyond Productivity: Information Technology, Innovation and Creativity* [6], which argues that the challenge for the 21st century is to "work smarter, not harder."

As user interface designers we have a grand opportunity to improve and extend current software tools such as drawing programs, word processors, and information visualization tools to more effectively support creativity. The strategies may vary across disciplines, but there are enough common principles that we can learn from different tools and from different disciplines [5].

3 Creative Processes

Creative projects often begin by building on previous work, so methods for searching previous work are needed. Google is a good place to start in finding previous work, but exploratory search methods including stronger tools to organize and filter search results would be helpful additions. Visualization tools that enable users to see hundreds or thousands of alternatives help trigger creative associations or form meaningful groupings [11]. Information visualization tools enable users to find patterns, clusters, trends, gaps, and outliers. A small treemap of the gene ontology reveals some interesting outliers and subtrees with elevated levels of activity (Fig. 1).

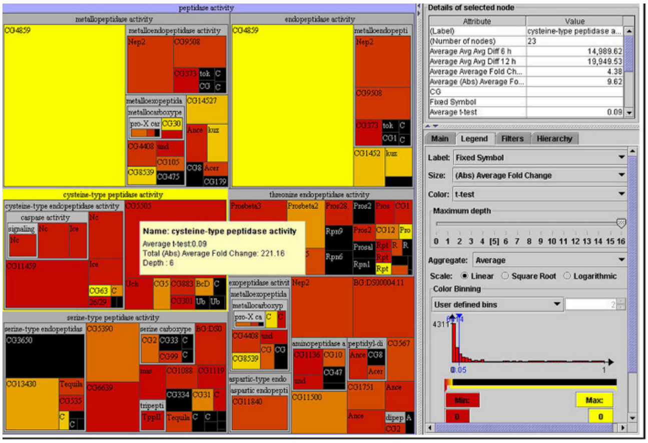

Fig. 1. Visualizations can help users make discoveries by presenting a large amount of information in a compact way that enables patterns and outliers to stand out. This small segment of the 14,000 genes represented in the gene ontology. Larger rectangles indicate increased activity, color shows significance by t-test.

For most creative projects users need to generate and review many alternatives. Large displays and software to organize many possibilities can be helpful to artists looking at hundreds of color schemes and biologists examining thousands of genes. Opportunistic discovery is appealing but systematic approaches to reviewing thousands or millions of alternatives are also valuable. The Hierarchical Clustering Explorer provides powerful methods to find features in high dimensional data sets such as found in genomics research (Fig. 2).

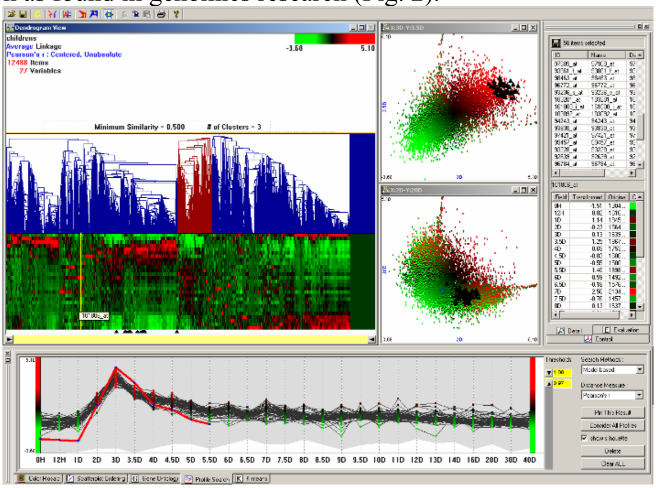

Fig. 2. The Hierarchical Clustering Explorer (http://www.cs.umd.edu/hcil/hce) enables users to find clusters, correlations, patterns, and outliers in high dimensional data sets, such as this example with gene expression data. This display shows a dendrogram in the upper left, parallel coordinates view on the bottom and two scattergrams towards the right hand side.

As part of the exploration process, users often have to backtrack to previous states, so effective tools provide history keeping and undo commands. Histories should also be convenient to save, send to colleagues, or replay in the form of macros.

A key part of most creative processes is the collaboration or consultation with other people. Well-designed software tools will enable sending of partial results, and help record the process of innovation during discussions. Finally, when work is completed innovators need better tools to disseminate their results. The balance of attention between individual and social creativity will ensure that both strategies get sufficient attention [3].

These descriptions can be summarized by eight creative activities that could be facilitated by improved interfaces [8]:

- searching and browsing digital libraries,
- visualizing data and processes,
- consulting with peers and mentors,
- thinking by free associations,
- exploring solutions, what-if tools,
- composing artifacts and performances,
- reviewing and replaying session histories, and
- disseminating results.

Researchers on creativity support tools will have to grapple with the methods for evaluating their products. Since quantitative metrics of creativity are difficult to obtain, observation and interaction with creative individuals and groups over weeks, months or years will be necessary [1, 10]. Case study research methods can provide feedback to refine creativity support tools and to develop a deeper understanding of what features were helpful to users.

4 Principles of Design for Creativity Support Tools

In June 2005, a workshop sponsored by the U.S. National Science Foundation met to discuss creativity support tools). The full report is available online (http://www.cs.umd.edu/hcil/CST), but the summary tells the story quite well [9]. The group came to support long term case studies as the preferred research method and proposed a set of user interface design principles that support rapid exploration and easy experimentation:

1. Support exploration
2. Low threshold, high ceiling, and wide walls
3. Support many paths and many styles
4. Support collaboration
5. Support open interchange
6. Make it as simple as possible - and maybe even simpler
7. Choose black boxes carefully

8. Invent things that you would want to use yourself
9. Balance user suggestions with observation and participatory processes
10. Iterate, iterate - then iterate again
11. Design for designers
12. Evaluate your tools

The participants also came to a consensus about these desirable future steps:

Accelerate research and education on creativity support tools by:
- Making the case for increased funding for creativity support tool research
- Encouraging investment in multi-dimensional indepth longitudinal case studies
- Proposing ways to create greater interest among researchers, educators, students, policymakers, and industrial developers.

Promote rigorous multidimensional evaluation methods by:
- Understanding the benefits and limits to controlled experimentation
- Developing observation strategies for indepth longitudinal case studies
- Collecting careful field study, survey, and deep ethnographical data

Rethink user interfaces to support creativity by offering principles for:
- Design tools for individuals and socio-technical environments for groups.
- Promote low floors, high ceilings, wide windows, and powerful history-keeping
- Support exploratory search, visualization, collaboration, and composition

5 Creativity and Cognition 2007 Conference

To help push this agenda forward, several of the organizers of the June 2005 workshop organized a major conference in June 2007 (http://www.cs.umd.edu/hcil/CC2007). We received 104 full-length paper submissions, from which the program committee chose 24 papers (23% acceptance rate) for presentation in the proceedings and at the conference. In addition to the papers, there were demonstrations and posters, plus two featured keynote speakers. Related events included 3 tutorials, 3 workshops, and a 3-month long art exhibit at the National Academies Building. An important event was our graduate student symposium that was funded by the U.S. National Science Foundation and the European EQUATOR project to bring 25 students from around the world. We believe that engaging students in these topics while they are still developing their research plans and performance projects could strongly influence the direction of their work.

More than 200 people participated in these activities producing comments such as:

> One of the best conferences I have attended. three days of intense inspiration.
> It was a fantastic experience for me… I've come away with renewed enthusiasm (though I am passionate about my work anyway), and filled with new ideas of how to progress.
> Very very extraordinary.
> I cannot begin to express my thanks and sincere appreciation to you and the organizing committee for the wonderful experience.
> It is a rare opportunity to be a part of a group of individuals that come together through a shared vision and that so passionately work to enhance the development of new knowledge in the arts and sciences.
> I benefited greatly from the student symposium, in particular from the diversity of project work and the inter-disciplinary dialogues established between people in the group, which have continued to develop since the event.
> Since I returned from Washington my feet have hardly touched the ground, thanks in no small part to the stimulation and encouragement I received from engaging with the other conference attendees.

These comments convey the enthusiasm from many participants. They expressed satisfaction with external confirmation of their research directions by the unique community of professionals and students who attended the conference. I have seen this sense of enthusiasm in the early days of the human-computer interaction field, when supportive feedback produced powerful confirmation of novel work. Creative researchers who cross domain boundaries with interdisciplinary work and those who boldly initiate new domains are understandably anxious, and therefore eager for confirmation of their efforts.

6 U. S. National Science Foundation Efforts

Further confirmation of the growing recognition of creativity research is the expansion of support from the U. S. National Science Foundation. Their program managers provided support for the 2005 workshop and the 2007 conference, plus they conducted several other workshops. During spring 2007, they announced the CreativeIT program (http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf07562) to provide larger funding for research:

> The goal of the CreativeIT Program is to fund research that focuses on creativity to produce simultaneous advances in both computer science and creative cognition, creativity support tools, engineering design or science… A better understanding of creativity and its role in computer science research, encouraging creativity in education, and supporting creativity with new information technology will improve American competitiveness and innovation.

An even more ambitious effort is proposed to start in 2008 under the Cyber-Enabled Discovery and Innovation program which may have up to $1B over a five-year period (http://www.nsf.gov/news/news_summ.jsp?cntn_id=108366). This program’s focus is on discovery and innovation in the sciences and engineering, which is appropriate considering the funding source. While the initial description focuses on technology aspects, we can hope that there will be sufficient attention to user requirements studies, early user prototype testing, observations of users, data logging of usage, empirical tests with users, and case study reporting.

7 Near-term Outcomes

Assuming that these and other funding efforts greatly expand research on discovery and innovation, what might we expect in the coming years? I believe that facing the challenges of creativity support tools could lead to at least these four near-term outcomes:

- **Refined theories of technology-supported creative processes**. The popular and scientific literature on creative processes in business, science, arts, etc. is huge, but the literature on how to design, manage, and use technology to accelerate discovery and innovation is modest. Cognitive theories of individuals make discoveries and the more challenging social psychology theories of small teams, larger groups, and broad communities will flourish. Researchers will study wikipedia.org to understand its remarkable success in bringing together hundreds of thousands of editors and writers to create a compelling resource. Similarly open source software communities, such as Linux, and information visualization communities, such as ManyEyes or Swivel, give an indication of much more ambitious collaborations that will emerge in the coming years. Understanding the determinants of success will be central. How important is lowering/raising barriers to entry, providing/limiting a hierarchy of administrators, or stability/change in content and interface? Other questions include the impact of rewarding active contributors, recognizing quality, and preventing malicious attacks?
- **Active discussion of user-oriented empirical research methods:** The traditional controlled experimental methods of perceptual or motor psychology are less effective for the complex cognitive, affective, and social processes involved in discovery and innovation that takes place over weeks and months. The shift to case study and ethnographic methods is well-underway, but many researchers still need convincing. Improved methods that ensure validity while promoting replicability and generalizability will be much sought after. Physicians and medical researchers have happily blended case study reports on small groups of individuals with carefully controlled clinical trials on thousands of patients over several years. Discovery and innovation researchers could follow this example, but major funding will be necessary for multi-year observation of large numbers of creativity support tool users.
- **New software architectures, database management strategies, and networking technologies:** The intense demands of discovery and innovation will cause designers of existing tools to revise their technology infrastructures to enable much improved search engines, larger and more di-

verse databases, and advanced networking to provide rapid synchronous and asynchronous collaboration. Google's impressive performance speed for their query responses sets a high standard for the more ambitious search requests that are desired for video, music, medical, and scientific databases.

– **Improved user interfaces to support discovery and innovation, especially in collaborative environments:** Many current user interfaces can be dramatically improved with better history keeping mechanisms that not only support undo, but allow capture of session histories as first-class objects. Histories should be constructed so that users can review, edit, send, and replay them. Moreover, histories should become the basis for programming-by-demonstration (sometimes called enduser programming), so that users can easily extend the functionality of their system to accommodate domain-specific needs and innovative applications. Science notebooks and document composition tools need improved versioning, annotation, and copying with linkbacks (so copied components point back to the source) will help promote collaboration while ensuring appropriate credit. Discovery and innovation tools that provide systematic yet flexible exploration, will guide users in their efforts over weeks and months. Such discovery management tools will also support partnerships by enabling large problems to be broken in to components that many people can work on simultaneously.

Of course, many other directions seem fruitful, but these four are a starting point for an expanded research agenda the focuses on discovery and innovation. These are high risk research directions with design, implementation, and evaluation challenges, but the payoffs could be remarkable.

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