**NSF Workshop on Synergies Between**
**Creativity and Information Technology, Science, Engineering, and Design:**
# Defining a Research Emphasis for CreativeIT

November 2 and 3, 2006
Hilton Arlington Towers Hotel, Virginia

**Chair**
Mary Lou Maher, Program Director, NSF mmaher@nsf.gov

**Steering Committee**
Bill Mitchell, Design Lab, MIT
Gerhard Fischer, Computer Science, University of Colorado
Larry Leifer, Hasso Plattner Institute of Design at Stanford (d.school)
Roger Dannenberg, Computer Science & College of Fine Arts, Carnegie Mellon

The Directorate for Computer and Information Science and Engineering (CISE) and the computing research community are exploring a programmatic concept designed to capitalize on the synergies between creativity and information technology, science, engineering, and design research. The purpose of this workshop is to bring together a broadly defined research and industry community to identify the research opportunities and recommendations for researchers interested in developing projects in this area.

Information technology is playing an increasing role in extending the capability of human creative thinking and problem solving. Design, and specifically creative design, is an underlying theme in bringing together research in creativity, information technology, science, and engineering. Design, as a reflective process, develops new products in the context of a perceived need or problem. In design, the reflection on problem finding becomes as important as problem solving, recognizing that designers often redefine the problem to be solved as they explore design solutions. The combination of creativity and design thinking in information technology, science, and engineering has the potential to define new areas and lead to increased successful innovation. Considering the synergy of creativity with research in design can have outcomes such as new models of creative cognitive and computational processes, innovative approaches to education that encourage creativity, innovative modes of research that include creative professionals, and new tools to support human creativity. Placing this emphasis in Computer and Information Science and Engineering (CISE) focuses research on generating simultaneous advances in computer science and information technologies with digital arts, design computing and cognition, and various areas of science and engineering.

The CreativeIT concept incorporates the following themes:

- Focused research on creativity in information technology, science, engineering, and design.
- Multi-disciplinary research involving computer science, physical and life sciences, cognitive science, engineering, design, architecture, and art during which the ideas from one discipline provide new research directions in another discipline.
- Funding partnerships that include organizations whose missions are science and engineering focused and those whose primary interests are in the creative arts and/or humanities.

The potential research outcomes include models of creativity, new models for research and education, and creativity enhancing tools:

- *New theoretical models*: Innovation through computational and cognitive models of creativity as ways of searching for problems and solutions in science and engineering.
- *New modes of research*: Research innovation by focusing on creative processes in research in science and information systems, for example, including resident artists in research groups.
- *Innovative educational approaches*: Creativity as a focus for learning environments in computer science and engineering using models such as studio learning and problem-based learning that reward creative thinking.
- *Creativity enhancing tools*: Innovation with information technology tools and infrastructure that support and enhance creativity in problem finding as well as problem solving.

The following research areas provide a focus for exploratory projects that are consistent with the objectives of CreativeIT. These areas are being developed further with feedback from the research community and the outcomes of exploratory research.

- *Understanding Creative Cognition and Computation*

This area has two major thrusts: research and education. Research in this area leads to cognitive models that serve as inspiration for computational models of creativity, support for human creativity, and approaches for educating people to be more creative. This research is typically done by adopting or adapting a model of cognition and evaluating its creative performance in different contexts, or developing a new model of creativity based on empirical or ethnographic studies. The emphasis in this area is the development of new models of cognition and computation that explain or simulate creativity. These models may then become the basis for new tools and new educational environments.

- *Creativity to Stimulate Breakthroughs in Science and Engineering*

This area considers the role and performance of artists in developing new technologies, discovering new patterns in information, and in finding new ways of seeing, knowing, and doing computer and information science and engineering. This is research that is done with groups of people from different backgrounds in which the creative synergy is focused on a specific context, problem, or perceived need. The result of this research is a new product, new model, or new area of research. The evaluation of the results of this kind of research does not follow directly from existing metrics or performance criteria and therefore needs to define its own performance criteria.

- *Supporting Creativity with Information Technology*

This area both develops new software and user interfaces to support users in being more creative and evaluates their performance through user studies either in controlled environments with empirical studies or in the context of a complex problem or situation with ethnographic studies. The emphasis in this area is the development of new support tools where the tool itself may be a creative product, and the tool is intended to support people in their creative activities.

## CreativeIT Workshop Program

November 2

| | |
|---|---|
| 8:30 | Opening and introductions<br>Debbie Crawford, Deputy Assistant Director of CISE<br>Mary Lou Maher, Program Director |
| 9:00-10.00 | **Communities of Creative Practice**<br>William J. Mitchell<br>**Surprise and Delight: Design-Thinking In Creative Practice And Theory**<br>Larry Leifer<br>**CELL - an interdisciplinary investigation into adult stem cell behaviour**<br>Mark d'Inverno |
| 10.00 | Break |
| 10.30-12:00 | **Discussion: Describing the big picture**<br>What areas of research will emphasize the synergies between creativity and computer science, information technology, engineering, and the physical and life scienes?<br>What kinds of education will support creative practice and interdisciplinary research?<br>What reform is needed to apply creative practice and interdisciplinary research more widely? |
| 12:00-1:30 | Lunch |
| 1:30-3:00 | **Mathematical Theory of Understandability**<br>Michael Leyton<br>**Music and Computer Science: Motivation, Analogies, and Experience**<br>Roger B. Dannenberg<br>**Beyond Binary Choices: Understanding and Exploiting Trade-Offs to Enhance Creativity**<br>Gerhard Fischer |
| 3:00-3:30 | Break |
| 3:30-5:00 | Role of SBIR in NSF: Errol Arkilic, Program Manager<br>**Discussion: Identifying the key ingredients**<br>What are the research methods in understanding new modes of creative practice and interdisciplinary research?<br>What models and tools are needed to support collaboration, innovation, design, etc.?<br>Are there theoretical contributions needed to improve creativity? |

November 3

| | |
|---|---|
| 8:30-9:00 | **Resources and Models for Creative Digital Media Research**<br>Pamela Jennings<br>**Collaboration Leads to Innovation**<br>Dana Plautz |
| 9:00-10:30 | **Small group development of workshop recommendations on research issues, areas, guidelines, methods, exploratory research** |
| 10:30 | Break |
| 11:00-12:00 | **Report to larger group and final recommendations to be placed on the wiki** |

## Workshop Presentations

**Communities of Creative Practice**
**William J. Mitchell**
Wherever creativity is, it isn't in the head. It is a function of communities of creative practice, supported by appropriate environments and tools. In this presentation I shall describe strategies for the development and management of creative design communities, at various scales, both in practice and in design education. I shall pay particular attention to mixed environments that simultaneously support both co-located and geographically distributed, and synchronous and asynchronous work. The discussion will be illustrated with examples of processes and outcomes of recent design projects.

**Surprise and Delight: Design-Thinking In Creative Practice And Theory**
**Larry Leifer**
Surprise and delight, how to take Information Technology, Science, Engineering, Design and Well-Being to the next level? Innovation is the engine. What is it? How does it work? Can we deliver precision innovation? We define innovation as the constellation of processes that discover ideas and transform them into successful services that create financial, intellectual, and social capital. The focus is on IT in organizational "triple-loop-learning." This presentation shares 3 short stories in which design thinking research and tool development have accelerated predictive product realization. Our work comes together in a bold new initiative, the Hasso Plattner Institute of Design at Stanford. You will learn where we come from, how we think, and where you can expect to see impact.

**Music and Computer Science: Motivation, Analogies, and Experience**
**Roger B. Dannenberg**
Music was once strongly connected to the study of science and mathematics. Just as Geometry represented the intersection of Mathematics and Space, Music represented the intersection of Mathematics and Time. In fact, musicians invented and defined the modern notion of time centuries before scientists made use of it. In modern times, we find that control constructs found in computer programs, such as sequences, loops, conditional execution, and subroutines, have analogues in music notation and performance. I would like to show how these analogies have been used to introduce young musicians to computer programming and to help them "visualize" program behavior. I will also share some experiences using music to teach computer science to undergraduates, for whom music and music processing is highly motivating.

**CELL - an interdisciplinary investigation into adult stem cell behaviour**
**Mark d'Inverno**
The CELL project was an interdisciplinary collaboration over 4 years that included an artist, a stem cell researcher, a curator, an ALife programmer and a mathematician. It employed a range of approaches to investigate stem cell behaviour. This included agent-based models; simulations and visualisations to model stem cell organisation in silico as well as art installations, which reflected on how different disciplines use representations and data visualisation. The impact on all members of the team was very significant and it motivated Mark d'Inverno along with the artist Jan Prophet to set up an interdisciplinary research cluster (funded jointly by both the science council and the arts council in the UK) to further investigate the potential of interdisciplinary collaborative research in general. (Please see interdisciplinary.co.uk) In this talk I will reflect on my experience of the process of interdisciplinary collaboration and attempt to lay down some ideas of the minimal conditions that need to be in place for it to flourish as well as enumerate some of the major obstacles.

**Mathematical Theory of Understandability**
**Michael Leyton**
Creative advances proceed by the generation of increased levels of understanding. Therefore, one cannot understand creativity, unless one understands understanding. In one of my books, A Generative Theory of Shape (Springer-Verlag, 550 pages), I elaborate a mathematical theory of understanding – what it is, and how it can be produced. The central problem handled in the book is what I call the conversion of complexity into understandability. This leads to an extensive reformulation of computer-aided design, human and machine vision, the structure of software, robotics, and the laws of physics. There is no more

important problem, for modern industry, than the conversion of complexity into understandability, as can be seen in all phases of the product life-cycle. The reason is that the modern world is dependent on large-scale engineering-systems integration. An example of one of the major obstacles to integration is the interoperability problem. Current studies estimate that the costs to industry of inadequate interoperability are enormous – in the billions of dollars. The interoperability problem, like all problems of integration, is, in fact, a crisis in understanding. Whether one deals with upgrading large legacy systems of software, or the transfer of a CAD model from one design program to another along the manufacturing supply chain, or the multi-disciplinary nature of engineering systems in an aerospace mission, one is dealing with the problem of understandability. And it is exactly the failure to handle this through the only solution possible – a rigorous theory of understandability – that is destroying industry's capacity to fulfill its goals. It is to solve this crisis, that I developed a mathematical theory of understandability. In this talk, I will give a very brief introduction to how this approach works, and is able to solve problems.

**Beyond Binary Choices: Understanding and Exploiting Trade-Offs to Enhance Creativity**
**Gerhard Fischer**

Many research approaches are conceptualized as binary choices, representing endpoints of a spectrum (each of them providing important perspectives within their own discourses). Design and creativity are often conceptualized as being focused on one of these binary choices, thereby overlooking other possibilities. My presentation will briefly discuss the following trade-offs:

- individual creativity and/versus social creativity;
- creativity in the head and/versus distributed intelligence; and
- rigor (psychometric and experimental methodologies) and/versus relevance (contextualized methodologies).

**Resources and Models for Creative Digital Media Research**
**Pamela Jennings**

Creative Digital Media research has been a subject of discussion in expert meetings, workshops and publications since the integration of creative practices and digital technologies, dating back at least forty years. Resurgence in discussions about interdisciplinary research policy and creative practices began in the late 1990's as the sophistication of creativity support tools increased and creative practitioners were trained to develop new technologies and applications that fulfilled a unique need for their practice. This convergence of research-in-practice is particularly visible in the exploration of the new design space of creative engagement (e.g. embodiment, intersubjectivity and affect), means of engagement (e.g. place and narrative), effects of engagement (e.g. creativity, sociability and sense-making), design approaches (e.g. metadesign, participatory design and user centered design), and participative systems (e.g. reflective communities and cultural knowledge networks). An overview of several publications and expert meetings that have had impact on global support policies for Creative Digital Media research since the late 1990's will be presented. These publications and expert meetings include; the *New Media Art | New Funding Models* report for the Rockefeller Foundation; the *Helsinki Agenda: strategy document on international development of new media culture policy* from the 2004 IFACCA (International Federation of Arts Councils and Culture Agencies) experts meeting in Finland; and the ACM CHI 2006 workshop *AboutFace Interface: creative engagement in New Media Arts and Human Computer Interaction*. Each document and/or event examined support issues for Creative Digital Media research, which in many forms is synonymous to information technology and creative practice (ITCP), that are synergistic to new research directions in Human Centered Computing, including; institutional resources, innovative funding models, curriculum development, research methodologies, evaluation, and shared epistemologies.

**Collaboration Leads to Innovation**
**Dana Plautz**

Why is it important to develop a common language and provide a new common ground between art, technology and science? This new common ground can catalyze the next generation of breakthroughs, and provide new pathways to innovation, if it is supported by a culture of collaboration. But what makes collaborations work? Why do corporations nurture art-sci collaborations, and why are these collaborations essential to the high-tech industry? This will be explored with key examples showing successful collaborations and guidelines that can help collaborators across multiple disciplines speak the same language.

**Discussion Summary: Opportunities, Issues, and Topics**

There is a significant opportunity to broaden the scope of research to include new approaches, new methods, and new ways of collaborating to encourage research and practice of creativity within information technology, science, and engineering. In order to achieve this, the workshop participants focused on the reform that is needed to encourage and recognize research excellence.

The workshop participants recognized that transformative research often came from the creative interaction of an interdisciplinary group. One recurring theme in the discussion and the presentations was this special kind of interdisciplinary collaboration. The people within the interdisciplinary group had a rapport, or empathy, for the others in the group. It is not sufficient for the individuals just to bring their expertise to a difficult problem, the individuals had to see the world from the others' perspective. While this is achieved in some collaborative research, it is often overlooked in favor of managing diverse individuals and maintaining their isolated expertise. Design studios provide a forum for this kind of collaboration, where people with different expertise come together to explore the problem space and the solution space when given a difficult problem specification. While interdisciplinary research is not a necessary ingredient for creativity, it is an approach that has the potential to change the participants and their knowledge of their own domain, and therefore, open up new areas of research.

A second recurring theme at the workshop is the idea of bringing artists into a research community as a contributing member of the group. This kind of collaboration brings a special view to the research that also has the potential to open up new areas of research as well as a mechanism to solve difficult research problems. A typical approach is to bring different individuals together, although there are examples of a single person that is both an artist and a scientist. This makes it possible to draw parallels between the underlying structures of art (paintings, music, sculpture, etc) and structures or models in information technology, science, and engineering. Identifying the common structure or language provides a way of understanding both fields from a different perspective.

In order for this opportunity to be realized, there are a number of reforms to defining and evaluating research projects that need to be considered:

- Encourage interdisciplinary research is a means to achieve a goal and not a goal in itself.
- Recognize that it takes almost as much creativity to recognize creativity.
- Recognize that it is difficult to publish interdisciplinary research.
- Consider multiple levels of funding similar to the way NSF funds Centers and SBIR grants: small seed-funding grants as a first round of funding followed by a second round of funding.
- Allow a grant to have different stages in which the goals can be re-evaluated in response to new ideas generated during the project.
- Consider design as a research methodology.
- Evaluate proposals in the way you evaluate design rather than the way you evaluate a research plan.
- Emphasize the evaluation of the person/group more than the research plan or methodology.
- Provide a matchmaking service for artists, designers, engineers and scientists.
- Encourage the investigators to suggest relevant reviewers.

Defining relevant topics for research in creative IT provides some guidance for people interested in this area. The topics should be open to include any research that improves our understanding and ability to be creative. Some topics suggested at the workshop are:

- social processes in creative design groups
- design guidelines for creativity support tools
- evaluation methods for creativity support tools
- cognitive processes in creativity
- evaluation methods for social creativity design tools
- creative explorations of advanced technologies
- creative exploration of new technology
- tools to support creativity
- situated technologies that enhance creativity
- creative approaches to computer mediated interaction
- geographically distributed interactions that encourage creativity
- creative coaching
- role of diversity in creativity
- computational modeling of the diffusion of ideas
- studying people in creative processes
- research in entertainment as a creative technology - economics, technology, psychology, sociology
- role of intuition in creativity
- understanding intuitive problem solving
- the role of creativity in innovation
- high speed learning in creative groups
- changing the reward structures to encourage creativity
- studying the experience of creativity in a person
- creative digital media
- computational models of creativity
- the relationship between individual and social creativity
- creative approaches to enhancing motivation for learning
- the critical mass and duration for creativity to occur
- mechanisms of improvisation
- computational agency as a metaphor for understanding collaboration and creativity
- formation of teams for creative problem solving
- understanding understanding, creativity as understanding
- roles of emotion and motivation in creativity
- the social/group conditions that optimize for promoting/nurturing individual creativity
- the effect of informal vs formal education in creative people
- early age (school and before) creativity
- studying creative designers

**Summary of Recommendations for CreativeIT**

The workshop made recommendations in four categories:

1. Exploratory research
2. Workshops
3. Outcomes and benefits
4. Guidelines for funding CreativeIT

**1. Exploratory Research**

**New theoretical models**: Computational and cognitive models of creativity as ways of designing innovative problems and solutions in science and engineering. For example:

- Models of human creativity in the context of IT, science, engineering, social systems.
- Computational models of automated or simulated creativity.
- Models of processes in which constraints enhance creativity.
- Models of the design space that address the problem that the creative process produces huge amounts of data.
- Principles that identify parallels between creative disciplines and IT, for example the structure of music and programming languages.
- Creative interpretations of complex systems.
- Extend the trajectory introduced by digital and electronic artists in their exhibitions by projects that bring together a researcher in IT with an artist.

**New educational approaches**: Creativity as a focus for new learning environments in computer science and engineering using models such as studio learning and problem-based learning that reward creative thinking.

**New tools**: Information technology tools and infrastructure that support and enhance creativity in problem finding as well as problem solving. For example:

- Design new tools that build on perceptual research and apply these findings to human-computer interfaces that connect digital models/data to physical/real life.
- Design tools that creatively use context data in determining how the tool interacts with others tools and other people.
- Machine learning tools that facilitate the identification of gaps in creativity research, that act as match makers for researcher, find potential common directions for different disciplines.
- Studies of immersive environments in terms of how they afford and prohibit/constrain creativity.
- Studies of how new IT affects the emergence of fundamental and radical ideas (and vice versa). For example study how Google (or similar technologies) has impacted various creative efforts (everyone has a hypothesis about how it impacts their work, but can we tease out which of these factors has broad significance and could be generalized).
- Development and study of mashups as a way of combining information and ideas that can lead to a creative synthesis of information.

**New modes of research**: Combining creative practice with science and information systems. For example:

- Take a new idea or product in computer science and allow artists to explore the space of new possibilities.
- Take an exhibition of digital/electronic arts and follow the trajectory to a new area of information technology.

- Fund a resident artist to work with a research group.
- Events as a way of doing research: exhibitions, interdisciplinary design studios and workshops that explore a specific need in a short period of time, match-making events in physical and online environments.

**2. Workshops**

There are different kinds of workshops that can be considered to promote the synergies between creativity and IT: community building workshops, defining the state of the art workshops, and "solving a problem" workshops.

**Community building workshops:** Bring together a collection of people with a common interest or set of goals. The focus of the workshop activities is on brief presentations and long periods of discussion. The outcome of the workshop is a report with ideas, tasks, recommendations for the future of that community. For example:

- Fostering transdisciplinary communities
- Workshop for people that cross disciplines in their own work
- Workshop for review panel participants to help them be able to better recognize the potential of innovative proposals

**Defining the state of the art workshops:** Bring together a group of people that have something to say about a research topic. The workshop activities focus on presentations and discussions about the presentations. The outcome is a publication that defines important contributions to the topic. For example:

- Research methods for studying creativity
- Design guidelines for creativity support tools
- Understanding social creativity

**"Solving a problem" workshop:** Brings together people from different backgrounds to solve a hard problem. The workshop activities focus on defining the problem, proposing possible solutions, redefining the problem, and developing solutions further. The outcome is a new idea, new theory, new language, etc. For example:

- Defining a common language
- Workshop to design production-based transdisciplinary workshops

**3. Outcomes and Benefits of CreativeIT:**

Outcomes

For the United States

1. Improve US global position
2. Make US an attractor for the world's best
3. Beyond manufacturing, beyond services – shift to the creative
4. New models in engineering, IT and design education
5. Attracting the best minds to technology and design

For Researchers

1. New areas of research
2. ew models of creativity and innovation
3. Ontologies for creative collaboration
4. New environments/ new spaces that encourage creativity

5. New digital tools that support creativity
6. New prototyping/fabrication tools
7. Graduate student support for creative arts graduate students

For Education

1. New educational theories, models, and programs that reward creativity
2. New kinds of graduates - effective participants in the creative economy

Benefits

For the United States

1. Economic: improve GNP
2. Adaptive labor force (rapid re-education and re-training), lower unemployment
3. Base economic engine on sustainable, renewable resources (IT and design)

For Researchers

1. Opens up new problem areas
2. New environments
3. New opportunities
4. Better theories
5. Personal efficacy

For Education

1. Transformation to more flexible and creative
2. Increase pool of talented graduates

**4. Guidelines for funding CreativeIT**

- Solicitation criteria should be inclusive of current creativity research across disciplines.
- Proposals can be descriptive rather than prescriptive, and should include reflection and evaluation.
- Guidelines should allow for interim reviews and/or support "seed funding". Initial funding should be large/long enough for researchers to build up sufficient resources to get to a first round prototype to see what directions are worth following.
- The goals for a project should be allowed to change and deliverables may need to be reviewed.
- Discovery in the process may be documented and presented as deliverable.
- Practice-based research: guidelines should be specific about supporting “makers”.
- Guidelines should be specific about supporting research as synthesis together with analysis.
- Consider a new kind of proposal called a “design proposal” as an alternative kind of funding to the traditional “research proposal”. A “design proposal” is focussed on a need area rather than a specific hypothesis or result. The proposal should combine different perspectives: multi-disciplinary in a way that is focused on ways to understand the need and should explicitly include “outsider” perspectives, e.g., if it is in art-centered project, include technologists, or, if it is a technical design project include artists.
- Educational activity is a key part of the project. Projects should be done with substantial student involvement to create an environment for giving design thinking experience to a wide range of students from different fields. The educational value is independent of the explicit results that emerge from the research.
- Create ties to other forms of student funding.

Reviewers and Selection Criteria

Reviewers should have some experience with creativity or research in creativity. "Creative" reviewers are more open to creative proposals. Applicants should be encouraged to suggest a list of recommended reviewers. NSF should select empathetic reviewers that are aware of research methods that form part of the proposal as well as reviewers that are familiar with the IT discipline.

Selection Criteria

- Will this research improve our understanding of creativity?
- Does this research help our understanding of the role of creativity in work?
- Does the research embrace technology and innovation?
- Does the research use creativity to broaden education in STEM disciplines?
- Does the research work at the interface of STEM and creativity?
- Does this research project encourage human/institutional capacities to learn by doing as the project evolves, rather than anticipating the results.

## Workshop Participants

**Ruzena Bajcsy** ("buy chee") was appointed Director of CITRIS at the University of California, Berkeley on November 1, 2001 and stepped down in August 2005. Prior to coming to Berkeley, she was Assistant Director of the Computer Information Science and Engineering Directorate (CISE) between December 1, 1998 and September 1, 2001. As head of National Science Foundation's CISE directorate, Dr. Bajcsy managed a $500 million annual budget. She came to the NSF from the University of Pennsylvania where she was a professor of computer science and engineering.

Dr. Bajcsy is a pioneering researcher in machine perception, robotics and artificial intelligence. She is a professor in the Electrical Engineering and Computer Science Department at Berkeley. She was also Director of the University of Pennsylvania's General Robotics and Active Sensory Perception Laboratory, which she founded in 1978. Dr. Bajcsy has done seminal research in the areas of human-centered computer control, cognitive science, robotics, computerized radiological/medical image processing and artificial vision. She is highly regarded, not only for her significant research contributions, but also for her leadership in the creation of a world-class robotics laboratory, recognized world wide as a premiere research center. She is a member of the National Academy of Engineering, as well as the Institute of Medicine. She is especially known for her wide-ranging, broad outlook in the field and her cross-disciplinary talent and leadership in successfully bridging such diverse areas as robotics and artificial intelligence, engineering and cognitive science.

Dr. Bajcsy received her master's and Ph.D. degrees in electrical engineering from Slovak Technical University in 1957 and 1967, respectively. She received a Ph.D. in computer science in 1972 from Stanford University, and since that time has been teaching and doing research at Penn's Department of Computer and Information Science. She began as an assistant professor and within 13 years became chair of the department. Prior to her work at the University of Pennsylvania, she taught during the 1950s and 1960s as an instructor and assistant professor in the Department of Mathematics and Department of Computer Science at Slovak Technical University in Bratislava. She has served as advisor to more than 50 Ph.D. recipients. In 2001 she received an honorary doctorate from University of Ljubljana in Slovenia. In 2001 she became a recipient of the ACM A. Newell award.

**Roger B. Dannenberg** is an Associate Research Professor in the School of Computer Science and School of Art at Carnegie Mellon University, where he received a Ph.D. in Computer Science in 1982. He is internationally known for his research in the field of computer music. His current work includes research on computer accompaniment of live musicians, content-based music retrieval, interactive media, and high-level languages for sound synthesis. Music students around the world use products based on his computer accompaniment research. Dr. Dannenberg is also an active trumpet player and composer, and he has performed in concert halls ranging from the historic Apollo Theater in Harlem to the modern Espace de Projection at IRCAM in Paris. His most recent musical efforts involve real-time computer graphics and computer music systems that interact with live musicians. Dannenberg also performs in Pittsburgh with the Roger Humphries Big Band and the Capgun Quartet.

**Mark d'Inverno** gained an MA in Mathematics in 1986 and an MSc in Computation in 1988 both from Oxford University. In 1998 he was awarded a PhD from University College London. He joined the University of Westminster in 1992 and was appointed professor of computer science in 2001. In 2006 he took up a Chair at Goldsmiths College, University of London, principally to continue his investigations into interdisciplinary work.

He has been interested in formal, principled approaches to modelling both natural and artificial systems in a computational setting. The main strand to this research focuses on the application of formal methods in providing models of intelligent agent and multi-agent systems. This work encompasses many aspects of agent cognition and agent society including action, perception, deliberation, communication, negotiation and social norms. In recent years, ideas from both formal modelling and agent-based design, have been applied in a more practical and interdisciplinary settings such as biological modelling, computer-generated music, art and design. He has published 2 books and over 80 papers in the last 10 years in these areas.

He is also a critically acclaimed musician and is Chairman of the charity Safe Ground which uses a range of different techniques (movement, drama, poetry, narration, improvisation and role-playing as well as the written word) to develop courses in family relationships with and for prisoners, which are now being run in over 50 UK prisons.

**Hal Eden** is a senior researcher in the Department of Computer Science and Associate Director of the Center for LifeLong Learning & Design (http://l3d.cs.colorado.edu) at the University of Colorado at Boulder. He has been the lead developer on the Envisionment and Discovery Collaboratory (EDC) (http://l3d.cs.colorado.edu/systems/EDC) since its inception and has worked closely with domain experts on embodying innovative design practices in the EDC. His research interests include participative design, tangible tabletop interfaces, interactive design and learning environments, embodied design, interaction support for face-to-face collaboration, and socio-technical environments in support of social creativity.

**Gerhard Fischer** (http://l3d.cs.colorado.edu/~gerhard/) is a Professor of Computer Science, a Fellow of the Institute of Cognitive Science, and the Director of the Center for Lifelong Learning and Design (L3D) at the University of Colorado at Boulder. His research is focused on new conceptual frameworks and new media for learning, working, and collaboration; human-computer interaction; cognitive science; distributed intelligence; social creativity; design; meta-design; domain-oriented design environments; and universal design (assistive technologies).. Over the last twenty years, he has directed research projects and has published extensively in these areas. More information about the L3D Center can be found at: http://l3d.cs.colorado.edu/.

**John Gero** is Professor of Design Science and Director of the Key Centre of Design Computing and Cognition at the University of Sydney. He is the editor/author of 43 books and has published over 550 research papers. He has been a Visiting Professor of Architecture, Civil Engineering, Computer Science, Cognitive Psychology, Design and Computation, and Mechanical Engineering in the USA, UK, France and Switzerland including at MIT, UC-Berkeley, Columbia, UCLA, and CMU in the USA, Strathclyde and Loughborough in the UK, INSA-Lyon and Provence in France and EPFL-Lausanne in Switzerland. His former doctoral students are professors in the USA, UK, Australia, India, Japan, Korea, Singapore and Taiwan.

He has been the recipient of many excellence awards including the Harkness Fellowship, two Fulbright Fellowships, and various named University Chairs including the Perloff Chair of Architecture at UCLA and the Springer Chair of Mechanical Engineering at UC-Berkeley. He is on the editorial boards of numerous journals related to computer-aided design, artificial intelligence, knowledge engineering and design and is the chair of the international conference series *Artificial Intelligence in Design*, the new conference series *Design Computing and Cognition* and co-chair of the international conference series *Computational and Cognitive Models of Creative Design*. His research spans computer-aided design, design optimization, design theory, artificial intelligence in design, design cognition and computational design creativity.

**Mark D Gross's** area of research is design methods and computational means. He has worked on constraint programming language for design, sketch recognition and analysis, tangible interaction, and architectural robotics. His current research, exploring the design space of next-generation computationally enhanced construction kit toys and craft for teaching and learning science, technology, engineering, and mathematics is supported by an Information Technology Research grant from NSF.

Gross received a Bachelor of Science in Architectural Design (1978) from the Massachusetts Institute of Technology, and a Ph.D. in Design Theory and Methods from the same institution in 1986. While an undergraduate student he worked in Negroponte's Architecture Machine Group on interactive models and tools for architectural design. After completing the undergraduate degree Gross worked at the MIT Logo Laboratory on personal computer implementations of the Logo programming language for children. His doctoral work, supervised by N. John Habraken, Aaron Fleisher, and Seymour Papert, developed a model of designing as exploring constraints and a software strategy to support this model. During this time Gross also worked at the Atari Cambridge Research Laboratory on educational computing.

From 1986-1988 Gross worked as a post-doctoral fellow at MIT with Habraken on "Concept Design Games," and with Fleisher, Donald Schön, and Larry Bucciarelli on "Designing and Designing Knowledge in Engineering and Architecture". From 1988-1990, with Habraken, he consulted for the Shimizu Construction Corporation on computer tools for spatial coordination in architectural design.

Gross taught at the University of Colorado from 1990-1999 in the College of Environmental Design, which became the College of Architecture and Planning, where he was also a fellow of the Institute of Cognitive Science. He also briefly held a joint position in the Department of Civil, Environmental, and Architectural Engineering. From 1999-2004 he taught at the University of Washington, Seattle in the Department of Architecture, where held joint appointments in the Departments of Landscape architecture and Computer Science and Engineering. He helped found a PhD program in Planning and Design at Colorado, and another in Built Environment at Washington. He joined Carnegie Mellon's School of Architecture faculty in 2004 where he teaches in the computational design graduate program.

**Tom Hewett** is Professor of Psychology and Computer Science at Drexel University where for 30 years he has taught courses on Cognitive Psychology, Psychology of Human Computer Interaction, and Problem Solving and Creativity. Tom has offered variants of this tutorial to hundreds of interaction designers at conferences and in-house training sessions. He has several times taught a weeklong course on Human Problem Solving for the User System Interaction program at the Technical University of Eindhoven, The Netherlands. In addition, he has been visiting fellow, visiting professor or visiting researcher at the University of Vienna, Vienna, Austria, Tampere University, Tampere, Finland, Twente University, Hengelo, The Netherlands, Loughborough University, Loughborough, UK, The University of the Aegean, Syros, Greece, and the University of Technology, Sydney, Australia. Tom is a published courseware author and has worked on the development and evaluation of several interactive computing projects, including a hypertext guidebook, instructional computing software and scientific problem solving environments. Some of the his recent research has involved collaborating with a team of researchers working on enabling and facilitating mathematical problem solving using mobile devices. As a consultant for over 2 years to NIST on the NIMD project Tom participated in multiple observations of intelligence analysts at work and advised on the development of Metrics and Measures for assessing the impact of novel software tools. Other recent projects have involved field trials evaluation of use and effectiveness of software tools designed to support Emergency Response Teams using mobile devices.

**Christopher Jaynes** is an Associate Professor in the Department of Computer Science and founding research director of the Center for Visualization and Virtual Environments (http://www.vis.uky.edu) at the University of Kentucky. He received his B.S. degree at the University of Utah in 1994 and his Doctoral degree at the University of Massachusetts, Amherst in 2000. He was awarded the NSF CAREER award in 2001 for work related to wide-area video surveillance and human-computer interaction technologies.

Christopher's research is related to visual information processing and its role in mixed reality and novel display technologies (http://www.metaverselab.org). He is the author of over 60 scientific articles, and is the editing author of the book Computer Vision for Interactive and Intelligent Environments (IEEE Press, 2003). He has been the keynote speaker at events ranging from the IEEE Conference on Virtual Reality and Cluster Computing to the Architectural Design conference ACADIA. His research related to multi-projector display systems lead to the formation of Mersive Technologies (http://www.mersive.com) in 2004 where he currently serves as Chief Technical Officer.

**Tristan Jehan** earned a Ph.D. in Media Arts and Sciences from MIT in 2005. Musician himself, his work combines machine listening and machine learning technologies to teach computers how to hear and make music on their own, even live. He first gained an MS in Electrical Engineering and Computer Science from the University of Rennes in France and applied it onto music signals at the Center for New Music and Audio Technologies at U.C. Berkeley. He now runs a startup company, The Echo Nest, that aims at solving digital music problems encountered in the world today, such as discovery, recommendation, and search, all automatically and without bias.

**Pamela Jennings** is an Assistant Professor at Carnegie Mellon University with a joint appointment in the School of Art and the Human Computer Interaction Institute. Jennings worked as a research interaction

designer and web producer at IBM Almaden Research Center for the Advanced Technology and Software Solutions Group and the User System Ergonomics Research Lab. She also worked as a research instructional designer for the Center for Technology in Learning at SRI international. She received her Ph.D. from the School of Computer Science, University of Plymouth, United Kingdom. in the Center for Advanced Inquiry in Integrative Arts program; M.F.A. from the School of Visual Arts; M.A. from the International Center of Photography and New York University; and B.A. from Oberlin College.

Jennings' digital media art works make visible personal narratives by revealing hidden realities while simultaneously encouraging public discourse. In particular, her research in *critical creative technologies* is informed by a convergence of critical theories of technology, human centered computing, and contemporary practices in interaction design and digital media art. Resulting in the development of new information technologies and collaborative applications for facilitating face-to-face discourse in public spaces with others in situations where communication may be stifled by societal norms.

Jennings' art work has been cited in Lisa Farrington's *Creating Their Own Image: The History of African-American Women Artists*, Oxford University Press and Phyllis Klotman and Janet Cutler's *Struggles for Representation: African American Film/Video/New Media Makers*, Indiana University Press. Her papers have been published and presented in the 2005 ACM Creativity and Cognition, 2005 Human Computer Interaction Consortium, several Inter-Society for Electronic Arts symposiums since 1997, several ACM Computer Human Interaction workshops, 2003 Interact Conference, and the 1999 European Union I3Net Symposium. Her journal articles have been published in the *Leonardo Journal for Art and Science*, *Convergence: the Journal of Research into New Media Technologies,* and the *CAA Art Journal*.

Jennings' internationally recognized digital media arts research advocacy work includes the *New Media Arts | New Funding Models* white paper commissioned by the Rockefeller Foundation, and co-writer of the *Helsinki Agenda* documentation of the 2004 Experts Meeting on International New Media Arts Policy sponsored by the International Federation of Arts Councils and Culture Agencies (IFACCA). She is chair for *Speculative Data and the Creative Imaginary: shared innovative visions between art and technology* and exhibition to be held at the National Academy of Sciences Gallery in Washington D.C. as part of the 2007 ACM Creativity and Cognition conference. She co-chaired the 2006 ACM CHI conference workshop titled *About Face: Interface – Creative Engagement in New Media Arts and Human Computer Interaction* and the first Interactive Art track for the 2004 ACM Multimedia Conference.

**Larry Leifer** is Professor of Mechanical Engineering Design and founding Director of the Center for Design Research (CDR) at Stanford University. A member of the Stanford faculty since 1976, he teaches a master's course in "Team-Based Product Design Innovation with Corporate Partners," a thesis seminar, "Design Theory and Methodology Forum," and a freshman seminar "Designing the Human Experience." Design thinking research projects include: 1) creating **collaborative design engineering** environments for **globally** distributed product innovation teams; 2) **instrumentation** of that environment for design knowledge capture, indexing, reuse and performance assessment; and 3), **design-for-wellbeing** as socially responsible design-thinking. Sustaining attention to the Stanford Design Institute (**d.school**) is his top priority this year.

**Michael Leyton's** mathematical work on shape has been used by scientists in over 40 disciplines from chemical engineering to meteorology. His scientific contributions have received major prizes, such as a presidential award and a medal for scientific achievement. His new foundations to geometry are elaborated in his books in Springer-Verlag and MIT Press. Besides his scientific and mathematical work, he is also a highly exhibited painter and sculptor, and his architecture designs have been published by Birkhauser-Architectural. Also he is the composer of published string quartets. He is president of the International Society for Mathematical and Computational Aesthetics, and is on the faculty of the Psychology Department and the DIMACS Center for Discrete Mathematics and Theoretical Computer Science at Rutgers.

**Mary Lou Maher** is a Program Office at the National Science Foundation in the Human Centered Computing Cluster in the Information and Intelligent Systems Division of CISE. She is developing the emphasis on research in creativity in CISE called CreativeIT. She is the Professor of Design Computing

and the Co-Director of the Key Centre of Design Computing and Cognition at the University of Sydney. She received her BS (1979) in Civil Engineering at Columbia University and her MS (1981) and PhD (1984) in Civil Engineering at Carnegie Mellon University. She was an Associate Professor at Carnegie Mellon University before joining the University of Sydney in 1990. She has held joint appointments in the Faculty of Architecture and the School of Information Technologies at the University of Sydney. She is a researcher in NICTA (National Information and Communication Technologies Australia) and a member of the Research Committee in the Collaborative Research Centre for Construction Innovation in Australia. Her current research interests include intelligent rooms, adaptive agents in design environments, motivated learning in physical and virtual worlds, tangible user interfaces for 3D design, empirical studies and new technologies for computer-supported collaborative design, and generative design systems in 3D virtual worlds.

**William J. Mitchell** is Alexander Dreyfoos Professor of Architecture and Media Arts and Sciences at MIT, and director of the MIT Design Laboratory. He previously served as dean of the School of Architecture and Planning at MIT and Architectural Advisor to the President of MIT. His most recent books are *Placing Words* (MIT Press, 2005) and *Imagining MIT: Designing a Campus for the 21st Century* (forthcoming, MIT Press, Spring 2007). In 2002-2003 he chaired the National Academies of Science and Engineering panel that produced the report *Beyond Productivity: Information Technology, Innovation, and Creativity*.

**Kumiyo Nakakoji** received the B.A. degree in computer science from Osaka University, Japan, in 1986, and the M.S. degree in 1990 and the Ph.D. degree in 1993, both in computer science from University of Colorado, Boulder, certified in Institute of Cognitive Science. She is currently Full Professor at Research Center for Advanced Science and Technology (RCAST), University of Tokyo, Japan, and directs the Knowledge Interaction Design Laboratory. She also works for SRA Key Technology Laboratory, Inc., Japan as senior research fellow. She has served as a chair, editor, and committee member for a number of research communities, journals, and conferences, both locally and internationally. She was a Board member of Human Interface Society, Japan, and is currently chairing IPSJ SIGHCI, Japan. She was awarded Distinguished Engineering Alumni Award from College of Engineering, University of Colorado, Boulder, in 2006. Her research interests include human-computer interaction design and collective creativity, specifically Knowledge Interaction Design, which is a framework for the design and development of computational tools for creative knowledge work. Her latest work addresses cognitive and social factors of software development as knowledge-intensive collective creative tasks.

**Ken Perlin** is a Professor in the Department of Computer Science at New York University, He was founding director of the Media Research Laboratory and also directed the NYU Center for Advanced Technology from 1994-2004. His research interests include graphics, animation, user interfaces, science education and multimedia. In January 2004 he was the featured artist at the Whitney Museum of American Art. In 2002 he received the NYC Mayor's award for excellence in Science and Technology and the Sokol award for outstanding Science faculty at NYU. In 1997 he won an Academy Award for Technical Achievement from the Academy of Motion Picture Arts and Sciences for his noise and turbulence procedural texturing techniques, which are widely used in feature films and television. In 1991 he received a Presidential Young Investigator Award from the National Science Foundation. Dr. Perlin received his Ph.D. in Computer Science from New York University in 1986, and a B.A. in theoretical mathematics from Harvard University in 1979. He was Head of Software Development at R/GREENBERG Associates in New York, NY from 1984 through 1987. Prior to that, from 1979 to 1984, he was the System Architect for computer generated animation at Mathematical Applications Group, Inc., Elmsford, NY, where the first feature film he worked on was TRON. He has served on the Board of Directors of the New York chapter of ACM/SIGGRAPH, and currently serves on the Board of Directors of the New York Software Industry Association.

**Dana Plautz** spent 10 years in the Entertainment field in Hollywood and 13 years in high tech specializing in the area of new media. She conceived and chaired the Intel Research Council grant program on Art and Entertainment. In her tenure at Intel she funded some of the most influential new media artist, such as Danny Rozin, Rebecca Allen, Bill Seaman and Ken Goldberg. She specialized in bringing about collaborations from various disciplines to bring new ideas to fruition. She is a frequent lecturer and conference speaker and an active member of the new media/creative community serving on numerous

boards. She is a founding board of directors of Eyebeam, a non-profit cultural and educational organization dedicated to digital art in N.Y. Plautz also serves on the Cal Arts Integrated Media Advisory Board, the advisory board of UC Berkeley's Art, Technology colloquium, The Design Studies/Design Management advisory board for the Portland Arts Institute, and is a member of the editorial board of the ACM Computer in Entertainment. She also held a government appointment for 6 years chairing the Oregon State Film and Video **office**. Her writing on the field of art and entertainment has been published in the Leonardo Journal and the ACM Computers in Entertainment Magazine to name a few. She is a graduate of Lewis and Clark College in Portland, OR.

**Rob Saunders** is a Lecturer in Design Computing at the Key Centre of Design Computing and Cognition in the University of Sydney. In 1995 he gained a BSc in Artificial Intelligence and Computer Science from the University of Edinburgh. In 2002 he was awarded a PhD from the University of Sydney for his work on Curious Design Agents and Artificial Creativity. He joined the University of Sydney as a Lecturer in Design Computing in 2006. From 2002 until his return to Sydney in 2006 Rob lived in London where he worked on a number of interdisciplinary projects with artists, designers, and scientists. During this time he developed biological simulations of stem cell systems as part of the CELL project, working closely with the mathematician Mark d'Inverno, the artist Jane Prophet and the liver pathologist Neil Theise. As a consultant, Rob worked with the designers at an international advertising agency to develop an intelligent logo design system. He has also worked with the artist James Coupe on two projects, 9PIN++ and Difference Engine, developing autonomous artworks that have been exhibited in galleries across the UK and more recently in the USA. With his return to Sydney Rob focussed his attention on his primary research interest, developing computational models of creativity, but continues to collaborate with people from a variety of disciplines around the world.

**Ben Shneiderman** (http://www.cs.umd.edu/~ben) is a Professor in the Department of Computer Science Founding Director (1983-2000) of the Human-Computer Interaction Laboratory (http://www.cs.umd.edu/hcil/), and Member of the Institute for Advanced Computer Studies at the University of Maryland at College Park. He was elected as a Fellow of the Association for Computing (ACM ) in 1997 and a Fellow of the American Association for the Advancement of Science (AAAS) in 2001. He received the ACM SIGCHI Lifetime Achievement Award in 2001.

Ben is the author of *Software Psychology: Human Factors in Computer and Information Systems* (1980) and *Designing the User Interface: Strategies for Effective Human-Computer Interaction* (4th ed. 2004) http://www.awl.com/DTUI/ . He pioneered the highlighted textual link in 1983, and it became part of Hyperties, a precursor to the web. His move into information visualization helped spawn the successful company Spotfire http://www.spotfire.com/ . He is a technical advisor for the HiveGroup and ILOG. With S Card and J. Mackinlay, he co-authored *Readings in Information Visualization: Using Vision to Think* (1999). His books include *Leonardo's Laptop: Human Needs and the New Computing Technologies* (MIT Press), which won the IEEE Distinguished Literary Contribution award in 2004.

**Dr. Steven M. Smith** is a Professor of Psychology at Texas A&M University, and he is a founding member of the Creative Cognition Research Group that was first established there in the 1980s. He is currently the Director of Research for the Institute for Applied Creativity, an interdisciplinary group at Texas A&M University. Dr. Smith has conducted many experimental studies examining aspects of creative thinking, focusing especially on the ways that mental impasses can be caused and how those impasses can be resolved. Dr. Smith and his colleagues have published numerous research articles on theoretical and applied aspects of creative thinking, and he has given invited addresses on the subject around the world, including England, Spain, and China. His books on creative cognition include *Creative Cognition: Theory, Research, and Applications* (1992), *The Creative Cognition Approach* (1995), *Creativity and the Mind: Discovering the Genius Within* (1995), and *Creative Thought: An Investigation of Conceptual Structures and Processes* (1997). Dr. Smith's applied research in creativity, funded by the National Science Foundation, has dealt with creative conceptual design in engineering, and with information discovery in computer science. His research on the creative design process has examined design fixation, incubation effects in ideation, and alignment of creativity research across levels of complexity and ecological validity. In the field of human-computer interaction, Dr. Smith has helped articulate the information discovery framework, and he has published experimental studies of combinFormation, a mixed-initiative system for

collaborative collection of information from the internet and digital libraries that represents discovered material in a navigable visual composition space.

**Terry Winograd** is Professor of Computer Science at Stanford University, where he co-directs the Human-Computer Interaction Group and the teaching and research program in Human-Computer Interaction Design http://hci.stanford.edu. He is also a founding faculty member of the new Stanford Institute of Design ( http://dschool.stanford.edu). He is a regular consultant to Google, a search engine company founded by Stanford students from his projects. His early research on natural language understanding by computers (SHRDLU) was the basis for two books and numerous articles. *Understanding Computers and Cognition: A New Foundation for Design* (Addison-Wesley, 1987, co-authored with Fernando Flores), took a critical look at work in artificial intelligence and suggested new directions for the integration of computer systems into human activity. He co-edited a volume on usability with Paul Adler, (*Usability: Turning Technologies into Tools* Oxford, 1992) and edited *Bringing Design to Software* (Addison-Wesley, 1996). Winograd was a founding member of Computer Professionals for Social Responsibility, of which he is a past national president. He is on the editorial board of several journals, including Human-Computer Interaction, ACM Transactions on Human-Computer Interaction, Personal Technologies, and Information Technology, and People. He was elected to the ACM CHI Academy in 2003.

**Professor Robert Woodbury** holds a Bachelor of Architecture from Carleton University where he was awarded the Lieutenant Governor's Silver Medal in Architecture in 1981. He earned his Master of Science and Ph.D. from Carnegie Mellon University. He was a faculty member in Architecture and the Engineering Design Research Center at Carnegie Mellon University from 1982 to 1993, at Adelaide University in South Australia from 1993 to 2001, at the Technical University of British Columbia from 2001 to 2002 and is now at Simon Fraser University. He was founding Chair of the Graduate Program in the School of Interactive Arts and Technology at SFU. Currently he is Scientific Director of the Canadian Design Research Network, the national association of design researchers in Canada.

Dr Woodbury's research is in computational design. From his research group have come many of the implementations of generative design systems, including the Genesis system, which was further developed and deployed at Boeing. His current work in generative systems is on subsumption-based design space explorers—an alternative to the long-standing and dominant rule mechanism. Since 1995, he has used the Internet as a means to enhance student learning. His particular emphases have been on peer-to-peer learning and the enhancement of competence and confidence through learning games. Recent projects include an online architecture gallery—A•VI•RE, the GeometryWare system for teaching the mathematics of computer graphics and Learning Object for Design, a collection of multimedia resources for design learning.

Dr Woodbury has won numerous national competitive and private foundation grants for both research and teaching, totaling over $4.7M. He has over 100 technical publications. In 1999 he was awarded a national citation for curriculum development from the Association of Australasian Schools of Architecture. In 2000 he won the Stephen Cole the Elder Prize as one of two top teachers at Adelaide University. In 1980 he was a member of the Canadian Olympic Sailing Team.