Conferences

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Advances in Tangible Interaction and Ubiquitous Virtual Reality

EDITOR'S INTRO

This issue we have a special treat for readers, presenting reports on two different conferences instead of just one. The first summary reports on the 2007 International Symposium on Ubiquitous Virtual Reality, describing some of the latest results in developing useful, usable, and desirable augmented-reality systems. The second summary reports on the International Conference on Tangible and Embedded Interaction, highlighting some of the latest results in this first conference devoted to tangible user interfaces.

— Jason Hong

SUPPORTING AUGMENTED REALITY IN UBIQUITOUS COMPUTING ENVIRONMENTS

Dongpyo Hong, Tobias Höllerer, Michael Haller, Haruo Takemura, Adrian David Cheok, Gerard Jounghyun Kim, Mark Billinghurst, and Woontack Woo

Recent augmented-reality (AR) systems often use auxiliary sensory information to enhance the accuracy of context recognition and tracking and registration, especially in mobile settings, where computer vision alone is insufficient. As AR systems become increasingly commercialized, there have been many attempts to improve their design and usability. Here we report on context-sensitive AR research presented at the 2007 International Symposium on Ubiquitous Virtual Reality, held in Gwangju, Korea, on 15–16 July 2007. ISUVR 07 explored the use of contextual information, design principles, and effective user evaluation for developing AR applications for ubiquitous computing environments.

MOBILE AR: ANYWHERE AUGMENTATION

As mobile platforms have become sufficiently powerful, AR systems are shifting from desktop to mobile computers. In ubiquitous computing environments, mobile AR systems have several advantages over desktop-based platforms. On the symposium's first day, Tobias Höllerer (University of California, Santa Barbara) discussed the central goals and requirements of "anywhere augmentation"—making virtual content overlays readily and directly available in any situation and location. Current approaches rely on user-worn sensors and the availability of a 3D model of the environment or on active or passive markers in the environment. However, AR will become truly ubiquitous only if these requirements are relaxed.

For example, research on vision-based AR systems in unprepared environments is yielding initial results, but a general and robust automatic solution for this exceedingly hard problem is still out of reach. So, Höllerer also focused on exploiting various Geographic Information System data sources, such as aerial photographs, to aid outdoor tracking. He proposed to better empower the human in the loop by providing tools to easily set up initial registration frames, issue simple corrections to registration errors, and model scene geometry. Current real-time computer vision techniques and algorithms are far from being able to facilitate fully automatic scene understanding for general scenes. However, they're well suited to constrain and guide a user's informed input for scene analysis and augmentation, delivered in the form of a few simple point selections, stroke gestures, and common classifications.

DESIGNING AR SYSTEMS

Michael Haller (Upper Austria University of Applied Sciences) talked about particular challenges and solutions for designing interactive tabletops and walls. Such devices are becoming increasingly popular, and large augmented surfaces are already part of our physical environment. These newly emerging form factors require novel HCI techniques. A tabletop or wall provides a large interactive visual surface for groups to interact. It encourages collaboration, coordination, and simultaneous and parallel problem solving. Haller explained how to design a nontraditional user interface for large

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horizontal and vertical displays in combination with pen-based input. He introduced INTOI (Interchange of Ideas, www.intoi.net), a rear-projection setup combining accurate pen tracking with hand-gesture recognition. The hardware consists of an Anoto (www.anoto.com) pattern printed on a special rear-projection foil and an infrared tracking system. For example, users can collaborate with others or interact with physical objects by virtually picking up elements (for instance, images or text elements) from a real paper printout and dropping them on the digital flipchart.

SYSTEM APPLICATIONS

Adrian Cheok (National University of Singapore Mixed Reality Lab) talked about human media spaces that support embodied social and physical interaction between humans, animals, and computers, with the aim of novel interactive communication and entertainment. He's developing new types of human communications and entertainment environments that provide increased support for multiperson multimodal interaction and remote presence. He presented an alternative ubiquitous computing environment based on an integrated design of real and virtual worlds. After his presentation, we discussed different research prototype systems for human-to-human and human-to-animal interactive communication and play.

Haruo Takemura introduced research projects at Osaka University's Cybermedia Center. He first discussed collaborative work environments using virtual-reality (VR) and mixed-reality (MR) technology. These environments employ several techniques for seamless transitions between 2D and 3D operations. Such techniques are useful for colocated collaborative work. His second topic was remote operations using VR and MR technology. He discussed reconstructions of dangerous remote sites using range sensors and omnidirectional image sensors. The 3D model reconstructed from these sensor data will help remote-robot operators understand the environment where the robot is located. In addition, he also covered the educational application of ubiquitous VR.

SYSTEM USABILITY AND EVALUATION

Gerard Jounghyun Kim (Korea University) pointed out that, to make AR systems usable by the masses, researchers must pay more attention to usability. To make AR systems practical, we'll need to sacrifice many of the nominal system components, such as head-mounted displays, markers, and head-mounted cameras. Kim argued that we first must understand the difficulties of such practical constraints as using handheld displays instead of head-mounted displays or fixed cameras, and he suggested software solutions to minimize the expected usability problems. Possible solutions include using hands instead of markers or warping an image to correct for perspective when using a camera fixed in an odd position.

Context awareness can enhance augmented-reality techniques in the same ways that AR techniques can support visualization for ubiquitous computing.

AR technology has moved from the military, to research laboratories, and finally into the living room. Regarding that, Mark Billinghurst (University of Canterbury) discussed AR research directions. In particular, he talked about the trend of AR technology moving from desktop computers to mobile devices, and the research challenges we must overcome before AR becomes a widely used visualization technology. Providing a compelling user experience will be a key factor in AR systems' success.

This student-organized symposium produced several interesting findings. For example, many AR systems try to utilize hybrid tracking with various sensors such as GPS, accelerometers, and inertia sensors on mobile devices. The symposium also revealed a new direction: context awareness can enhance AR techniques in the same ways that AR techniques can support visualization for ubiquitous computing. For more information on ISUVR 07 and to read the papers and the invited talks, visit http://old.uvr.gist.ac.kr/isuvr07.

ISUVR 08 will take place from 10–13 July in Gwangju, South Korea. For more information, visit www.isuvr.org.

TEI GOES ON: TANGIBLE AND EMBEDDED INTERACTION

Eva Hornecker, Robert J.K. Jacob, Caroline Hummels, Brygg Ullmer, Albrecht Schmidt, Elise van den Hoven, and Ali Mazalek

The 2nd International Conference on Tangible and Embedded Interaction (TEI) took place in Bonn from 18–20 February 2008 (www.tei-conf.org). It followed on from the successful TEI conference in Baton Rouge, Louisiana, from 15 to 17 February 2007, shortly before Mardi Gras in New Orleans. TEI 07 was the first conference with "tangible" in its title, motivated by the field's growth over the past decade. One of this research area's most fascinating features is the range of perspectives and disciplines, including HCI, the arts, design, technology, and architecture. The TEI 07 call invited a multi- and interdisciplinary community to submit contributions from their specific viewpoints and approaches. TEI 07 thus brought together artists who employ tangible media with computer engineers developing toolkits, physical-appliance designers with researchers conducting user studies, and researchers exploring novel interface technologies with interaction designers who develop mixed-media systems.

Bringing these viewpoints together

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at an equal level created an inspiring atmosphere, often confronting researchers with surprising arguments and new perspectives. One participant described the conference as "refreshingly broad, but also refreshingly focused." Others saw it as a chance for crossing domains, with an atmosphere that let participants be open, inquisitive, and respectful and that fostered awareness of other perspectives and approaches.

TEI 07 clearly showed that this field is coming into maturity. As a key indicator of this, the presentations weren't dominated by novel systems and technical approaches. Rather, many dealt with conceptual and user-centered approaches toward understanding tangible interaction, along with critical questions pushing the field to reflect on itself and driving it forward. TEI 08 continued this, in particular with presentations of detailed user studies exploring the benefits of tangible interaction.

A SOMEWHAT DIFFERENT FORMAT

TEI 07 intentionally differed from the usual format. The conference organizers decided not to distinguish a priori between talks, demonstrations, and posters but to treat all submissions alike, reviewing and publishing them on the same grounds on the basis of their merits. Submissions could be eight, four, or two pages, and authors could indicate a preferred presentation form. The organizers asked the reviewers to evaluate content in relation to paper length and to look for thought-provoking and inspiring contributions. Final decisions on the presentation form lay with the program chairs, who assigned accepted contributions to presentation tracks. While this could have resulted in some initial disappointment about the assigned format, it provided the flexibility to accept many interesting papers and to create a mix of presentations across formats. This approach avoided treating demos and short papers as second-class contributions and raised the quality of all presentation types and paper lengths. All papers are archived in the ACM Digital Library (www.acm.org/dl).

While this unusual format placed pressure on the organizers to explain the procedure to authors, the feedback was positive. TEI 08 has therefore successfully followed similar procedures. The quality of TEI 07 submissions was high, and papers came from diverse topical and geographical areas. Part of the strategy was to bring different disciplines and perspectives into dialogue. Each TEI 07 session had an overarching abstract theme (such as "movement" or "connection") that was addressed from different perspectives, highlighting overlaps and differences in conception and approach. So, the same session could feature talks about prototyping toolkits, design case studies, ethnographic studies, and theory development.

The challenge today would be "how to reveal the invisible world of sensors, making it available as a resource for judgment."

Posters and demos were presented in 2007 and 2008 before the actual exhibition session in three-minute-madness sessions, a format that has been popular and useful in recent years at CHI and other conferences. The program design left ample time for interaction during demonstrations, poster presentations, and breaks.

FROM THE ARTS TO HARDWARE TO THEORY

In TEI 07's first call for participation, the core terms describing the conference's scope were "interaction," "design," "tools," "use," and "the arts." The actual scope far exceeded expectations. The 2007 presentations included

- artists exploring the expressiveness of physical materials such as felt and even raw meat in interactive and actuated sculpture,
- mobile-device developers investigating novel interaction mechanisms,
- creators of novel prototyping tools and toolkit architectures,
- designers and hardware specialists presenting actuated shape displays, and
- a shape-changing shoe that guides the wearer's steps.

Conceptual presentations

- discussed how movement is kinesthetically experienced,
- investigated movement's role in design methods,
- questioned tangibles' effectiveness for learning, on the basis of empirical evidence,
- investigated how to employ image schemas in tangible-interaction design, and
- addressed the contribution of "research through design" toward understanding expressive interaction.

As mentioned, posters and exhibits played a significant role. One of the many highlights was the ReacTable (see figure 1), a tabletop tangible interface for music improvisation and performance (since made famous by Björk's use of a high-end version in live concerts).

TOM RODDEN'S KEYNOTE

The TEI 07 keynote speaker, Tom Rodden (University of Nottingham), leader of the British Engineering and Physical Sciences Research Council project Equator, came with a birthday present for the first TEI. Equator (www.equator.ac.uk) provided generous sponsorship to support participation by students, artists, and other presenters with limited funding. In his keynote, Rodden discussed experiences from Equator, reflecting on implications and lessons for ubiquitous computing and particularly for tangible interaction. He stressed that what matters isn't technological possibilities but technology's actual relationship with

our everyday life. Might we someday be scared to touch things because it might result in an online purchase? Do we face a future where new technologies will educate us to be better consumers and supervise what we eat and drink?

Equator's core aim was to understand future interactions and how they could contribute to making life worth living. The research was situated in the real world, investing in deployment and working with users as research partners. Rodden illustrated his talk with video clips from various threads of the project. He critiqued the ideal of "seamlessness." Technology and sensors will always interfere and pose limitations. Instead of attempting to hide them, "exposing these 'hidden features' to designers and users could become a key to understanding the underlying links and seams." The physical-digital links of tangibles would almost certainly be "as uncertain and as dynamic, and as likely to shape key events in the interaction" as Wi-Fi, GPS, and other sensor technology explored in Equator. The material nature of technology (usually considered immaterial) "enters through the back door" and becomes evident only in real-world deployment.

For example, experiments with GPS coverage in London showed high variability in coverage, with GPS shadows moving and accuracy varying throughout the day. Participants using mobile devices to track down other players in city games exploited such phenomena, expanding the game's rules, once they understood the sensing infrastructure's properties—for example, by hiding in GPS shadows.

So, the seams become part of the experience, making it impossible to separate the interactive elements from the infrastructure. The challenge today would be "how to reveal the invisible world of sensors, making it available as a resource for judgment" instead of making sensors invisible (and too often inexplicably failing in the attempt). Rodden called on us to reverse the notion of seamlessness and to turn to approaches from media and art that exploit the differences of media and discontinuities as part of the experience, creating systems that are open to interpretation and appropriation. Understanding the relationship of new technologies with our life, as Equator has demonstrated, requires investment in real-world engagement but also results in new questions that can frame and drive research.

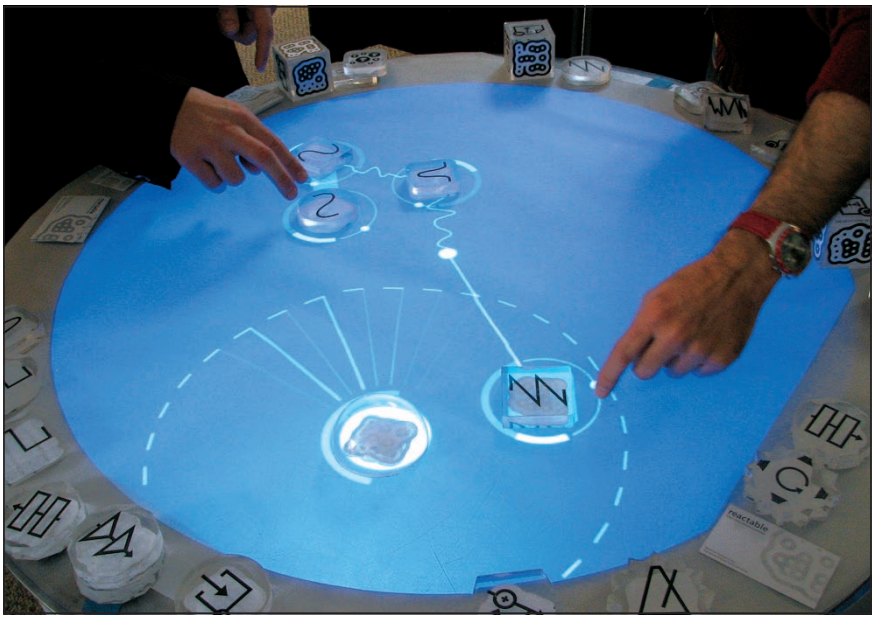

Figure 1. The ReacTable. This interactive digital tabletop, presented at the First International Conference on Tangible and Embedded Interaction (TEI 07), provides a tangible interface for music improvisation and performance.

THE TEI 07 PANEL DISCUSSION

The final panel distilled, highlighted, and discussed many of the topics that arose throughout the conference. This panel differed from typical conference panels in that the panelists were drawn from the audience. Throughout the conference, attendees dropped notes into a ballot box suggesting individuals they wanted to see in a panel. This resulted in a strong, balanced mix of panelists, spanning academia and industry, with diverse research areas, approaches, and career stages—not "the usual suspects."

The panel participants were Mike Kruzeniski (Nokia Research, Los Angeles), Trevor Pering (Intel Research, Santa Clara), Bruce Thomas (University of South Australia), Paul Marshall (Open University), Astrid T. Larssen (University of Technology Sydney), and Thecla Schiphorst (Simon Fraser University). The panel facilitators were Eva Hornecker (Open University), Caroline Hummels (Eindhoven University of Technology), and Robert Jacob (Tufts University). A full audio recording of the panel is available at http://tei-conf.org/07/program/TEI_panel.mp3.

The panel first discussed the conference's title—for example, what's the difference between embedded and tangible interaction, and what are the research area's boundaries? Some consensus emerged that tangible artifacts are "an unavoidable consequence of embedding interaction in things." Interaction by body movement, even without manipulating external objects, was considered a part of this research area. "We are embedding technologies in our bodies. We can embed things in our clothing. Obviously we can embed things in the world around us. And that's called 'embedded,' and in some way that's tangible." In that sense, you could consider a car to be a tangible interface, in light of thoroughly physical interaction with a

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multitude of underlying computers. Precisely delineating "what is tangible and what isn't" was viewed as potentially undesirable, particularly because this would exclude many possible physical and bodily mediums.

Panel participants from a problem-solution-oriented design viewpoint criticized that research projects often have tangibility as a design objective but that this "might not always be the right solution to the problem." Alternatively, several panelists from a research viewpoint argued that sometimes the aim isn't just to design a system to solve a specific problem—rather, there can be "value in exploring" what happens *if* …. The aim can be to learn from doing: "knowledge that you're trying to gain about the system, as opposed to just building it." Others argued that tangibility as a necessary solution puts us into a "question space" (instead of a problem space) that can act "almost like a container" for different approaches and frameworks. Participants also agreed that no sharp divide exists between physical and virtual things; users generally interact with graphical interfaces through physical artifacts in physical space.

As in other novel research fields, the tangible community still has to show the value of the field to the outside world. One way of doing that is by producing a killer application. On the other hand, one panelist noted that we haven't "articulated particularly well how tangibles improve user interfaces over just a normal standard GUI" but felt that this is a normal evolutionary process for a young research area. Another panelist suggested as a major research challenge that "everyone has this intuition that physicality is a really good thing, and that these kinds of physical interfaces are more fun to use. I don't think we've really worked out why that might be, and … that's something we should be focusing on." Also, too often the qualities of tangible interaction are only weakly developed; for example, too many systems only have the user moving objects on a flat surface. This sometimes leaves open what physicality actually buys us from an interaction standpoint. Understanding and describing the diversity of qualities in tangible interaction is a research topic needing more attention. Externally observing movement and actually feeling movement are completely different experiences, requiring different languages for description. This highlights the need to develop a more nuanced language for understanding and articulating these qualities.

Other big challenges in the eyes of the panelists include

- actuated interfaces,
- getting to where people can start building on others' work, thereby creating some momentum,
- conducting more evaluations,
- building "more rigorous hybrid methodologies,"
- developing metrics to compare tangibles,
- sustaining multigroup collaborations, and
- theoretically investigating physicality from diverse perspectives.

Panelists encouraged the research community to reach out to industrial designers and product groups in industry.

Some participants felt tangible interaction has now reached a tipping point, with a number of toolkits being available that ease creation of prototypes and therefore allow for more focus on these research tasks.

At the same time, panelists noted that the field should not just focus on evaluations but also continue with creative design work. "The evaluator should be running to catch up [with the design and development work], because that's what's driving the area." Participants criticized that there are too many "one-offs," with a likely outcome of more junk on your desk. "This is where the 'embedded' comes in: How do we embed this technology into our lives, and not have yet another plastic artifact sitting there doing one small little thing"? A major challenge is leveraging what works well in existing GUIs, in order not to lose the "value of the virtual." Several participants complained that many research systems are iterations of previous examples (such as Bishop's Marble Answering Machine); the big question might be, why aren't we seeing tangible interaction in marketed products? Panelists encouraged the research community to reach out to industrial designers and product groups in industry. They also discussed the need for hybrid methodologies that embrace both engineering questions as well as (for example) poetic approaches or approaches from physical practice in sports. These approaches can hold just as much rigor as the formal methods common in human-computer interaction—and often with very different results.

TEI 08

Besides preserving many successful elements of TEI 07's format and philosophy, TEI 08 maintained continuity in the organizing team. Albrecht Schmidt (University of Duisburg-Essen) and Hans Gellersen (Lancaster University) were the TEI 08 conference chairs; Elise van den Hoven (Eindhoven University of Technology) and Ali Mazalek (Georgia Institute of Technology) were the program chairs.

The final program consisted of 46 presentations, including exhibits and poster presentations. A major trend was mechanical actuation, including robotic devices, actuated fabrics, kinetic relief sculpture, and bounce sliders. Many new systems and user studies involved interaction with sound and music. There was a wide variety of application areas, including geoscience, business software, visualization, artistic installations, chemistry instruction, social networking, and language learning for disabled children.

Hiroshi Ishii's keynote

In his inspiring keynote, Hiroshi Ishii (MIT Media Laboratory) presented his well-known concept of "painted bits" (GUI) versus "tangible bits" (TUI). He was visibly moved to see the concept of tangible bits embraced and creatively reinterpreted by a broad, diverse, and growing community. Ishii discussed many central ideas and philosophies behind the MIT Tangible Media Group's work. For example, he spoke of the creative process as having three steps:

1. imagine and realize (including prototype demos),
2. critique and reflect (in academic, artistic, and commercial contexts), and
3. iterate (pushing ideas further).

Ishii emphasized the coincidence of input and output spaces in the design of tangibles. He stressed that having multidisciplinary teams of tangible-interaction researchers is important (and sometimes difficult) because the field draws from and builds on so many different fields. He also advised that we focus not on enabling technologies or applications, which might be obsolete in a handful of years, but on vision-driven design, which holds its conceptual value and impact far longer (perhaps a century or more).

The panel discussion

The format was similar to that of TEI 07, with conference participants selecting panelists through a vote. Brygg Ullmer chaired the panel, which had the theme "Where, When, What, Why, How, for Whom, and toward What Ends Tangibles Live in the World." The panelists were Mark Gross (Carnegie Mellon University), Ylva Fernaeus (Stockholm University), Jörn Hurtienne (Berlin Institute of Technology), Caroline Hummels (Eindhoven University of Technology), Eva Hornecker (Open University UK), Shahram Izadi (Microsoft Research Cambridge, UK), and Jill Coffin (Georgia Institute of Technology). While panelists wondered whether we really want computation to invade every aspect of our lives, there was also the sense that with this trajectory already well underway, it is important to participate in shaping its progression.

Arguments for tangibles' significance and potential included their

- support for group interaction;
- support for richer ways of interacting and appropriating technology;
- role as a natural extension of human life in a physical world;
- enablement of better cognitive processing, as users draw on all their experience (both conscious and unconscious) accumulated over a lifetime; and

Having multidisciplinary teams of tangible-interaction researchers is important (and sometimes difficult) because the field draws from and builds on so many different fields.

- exploitation of physical skills (both reducing demand on, and supporting reallocation of, cognitive skills).

Some participants argued for more tangibles in the office, where people spend most of their day. Others suggested kitchens, living rooms, hallways, sports facilities, and outdoor spaces as compelling loci for tangible interaction.

Participants proposed that tangibles could open new avenues for "bonding with products," allowing products to physically evolve over time, being "changed, appropriated, renewed, and repaired." They also noted that tangibles could actually slow down interaction (in a productive and fulfilling fashion), whereas current mainstream technology tends to be tailored toward perpetual acceleration. Other participants argued that research is still needed to understand tangible interaction's benefits. Participants noted these benefits might be difficult to measure, especially because in many domains we are experiencing a trend away from physicality (with machines using graphical interfaces). For software companies, whose business is deeply rooted in the design and sale of GUIs, this added dimension of identifying the foundation, trajectory, and optimal mode of engagement with TEI research and development could be a challenge, even when such companies have the will to engage in tangibles research.

Panelists also critiqued tangible-interaction research's predominant focus on short-duration applications. In contrast (but also complementarily), several participants argued for interactions that take place over long periods of the user's life, not just while he or she is using the device. In this context, participants also discussed the conceptual and perceptual linkage between tangible interfaces and ambient displays. In addition, some participants suggested that more complex computation should be occurring behind the tangible interface, instead of only one-to-one input-output. Designer participants also questioned why, as one participant complained, there are "so many multitouch tables with so many generic things on them—what about expressivity [of the artifacts]?"

End-user programming was proposed as an upcoming research area for tangibles ("I want to program my T-shirt"), creating new opportunities for collaboration with software engineers. The panelists also discussed the consequences of the community's interdisciplinary nature, with diverse paradigms of practice accompanied by different ways of thinking and doing. For example, from an art perspective, when evaluating user interaction with art installations, you would "not want to disrupt the aesthetic experience, and you do not know when it is finished." So, artists often prefer not to interview exhibition visitors or use other standard HCI methods; this, in turn, should

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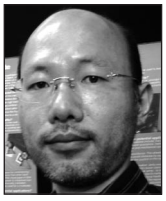

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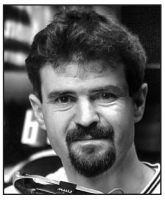

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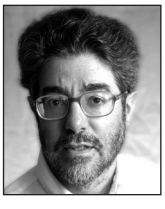

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influence what we expect to see in papers written from this perspective.

These examples illustrate that diverse disciplines in the community are indeed communicating, sharing, and hybridizing their views and perspectives. We find this synergy highly rewarding, promising many new prospects, ideas, and avenues for further research. We are hopeful that TEI 09 will continue this trend. Given that Microsoft Research Cambridge (UK) is hosting TEI 09, the event might also highlight commercial interests in tangible and embedded interaction.

For 2010 there's an open call: proposals to host TEI 10 are invited at the same due date as paper submissions for 2009 (check www.tei-conf.org for the latest information).

ACKNOWLEDGMENTS

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