An Arts, Sciences and Engineering Education and Research Initiative for Experiential Media

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Abstract – **This paper presents a novel interdisciplinary approach for the training of media scientists and engineers. The approach is being implemented at the Arts, Media and Engineering program at Arizona State University. Our graduates will produce new paradigms for the integration of computation and media in the physical human experience. Their work will result in hybrid physical-digital environments that address significant challenges in key areas of the human condition. The training model has the following characteristics: it is driven by research problems rather than by disciplines; it is based on an extensive interdisciplinary network; it is organized under the dimensions of research and application and promotes work at their intersection; it provides multiple paths for combining different types of disciplinary training with interdisciplinary training; it also provides a transdisciplinary training path. This paper presents the reasoning and implementation structures of these key facets, discusses our evaluation approach and presents preliminary results.**

Index Terms: experiential media, interdisciplinary education, arts and engineering

DRIVING RESEARCH THEME

I. Experiential media - systems that integrate computation and digital media in the physical human experience

We are currently witnessing widespread efforts to integrate digital media and computation in the physical human experience (our physical interaction with the world), thus bridging the physical/digital divide. This integration requires a new complementary model of media computing. In the traditional multimedia computing model (e.g., the creation /consumption of a video), capture, analysis and media consumption are neither co-located nor synchronous or integrated. We are however witnessing a rapid decline in the cost of sensing, storage computing and display [1]. Thus sensors (audio, video, pressure, tangible), computing, ambient visual and sound displays and other feedback devices (vibration, light, heat) can now be co-located in the same physical environment creating a real-time feedback loop. This allows for development of a rich contextual understanding of human activity, at different scales of time and space, and offers the possibility to affect human activity in a radically new way. We are now able to work toward enhanced, user-oriented, unified physical-digital experiences. The resulting systems are referred to as experiential media systems [2]. Experiential media systems will give rise to a new set of digital media applications grounded in human activity in the physical world. Experiential media will engage three key current trends in computation:

- **Novel embedded interfaces** allowing interaction with computing and digital media through meaningful multimodal physical activity (gesture, movement, voice, sketches, diagrams, images, music, etc).
- **Human-Computing communication at the level of meaning** rather than the level of information.
- **Participational knowledge creation and content generation frameworks** where authors, users and audience are indistinguishable. Here the process is as important as the artifact.

II. The research model

The development of experiential media systems requires highly integrated research across five areas:

- **Sensing:** multiple types of electronic sensors must be used for sensing and recording the physical world and, most importantly, human activity.
- **Perception and Modeling:** The computational modeling of human functioning and sensing allows cognitive and perceptual principles to be incorporated into the design and analysis of control and feedback systems. The ecological coupling between users and systems is optimized.
- **Feedback:** Dynamic, multimodal feedback systems are developed for optimally connecting user(s) into the experiential media environment.
- **Experiential Construction:** Sensing, perception, modeling and feedback are integrally combined with the physical world to produce an enhanced, user-oriented, physical-digital experience.
- **Learning and Knowledge:** The knowledge produced by the resulting physical-digital experience is evaluated while avenues for further evolution of the system are identified and tested.

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III. What is the expertise needed for experiential media development?

The knowledge required to create experiential media systems is fragmented across disciplines. Technological sensing and modeling expertise traditionally lies primarily within engineering. Media communication and experiential construction expertise traditionally lies within the arts. Expertise on perception, cognition, and learning models traditionally lies within psychology and education. Therefore experts from these disciplines comprise the core of a large interconnected network of experts necessary for experiential media research (see Fig. 1). Other disciplinary experts are vital to the development of specific applications and thus the network needs to embrace a range of additional specialty members on those projects. For example, in creating a biofeedback system for rehabilitation medical doctors and physical therapists must be included as integral contributors. Finally the network must be completed by a class of experts who specialize in knowledge fusion for media development.

IV. Bringing together the network of necessary experts: the Arts, Media and Engineering Program

The ASU Arts, Media and Engineering Program (AME) is an interdisciplinary graduate education initiative that was created two years ago through active participation of fifteen academic units. It integrates all of the required expertise for research and education in experiential media (see Fig. 1). The core participating entities in AME are the Fulton School of Engineering (CSE, EE, and Bioengineering Departments), the Herberger College of Fine Arts (Music, Visual Arts, Theater Schools and Dance Department), the College of Education (Psychology in Education and Curriculum and Instruction Divisions), the Psychology and Kinesiology Departments and the School of Design. Faculty and students from these areas provide specialized knowledge in the five key areas of experiential media development: sensing, perception and modeling, feedback and interaction, experiential construction, and learning and knowledge. There is also supporting participation from the Sociology, Human Evolution and Social Change, Chicana-Chicano Studies Departments, and the School of Life Sciences. Thirty AME affiliated faculty from the above units are currently actively involved in AME research and education. The Arts, Media and Engineering program also has its own faculty who specialize in integrated media development. Their backgrounds allow them to connect transdisciplinary knowledge on media to the discipline-related specializations contributing to media development. We note that ASU has made a significant commitment to this program in terms of sustained seed funding, dedicated faculty positions, and space to co-locate all the AME faculty, scientists, artists, and graduate students.

V. Application areas

AME's work results in hybrid physical-digital environments that address significant challenges in four key areas of the human condition: health, education, societal communication and everyday living, and culture and arts.

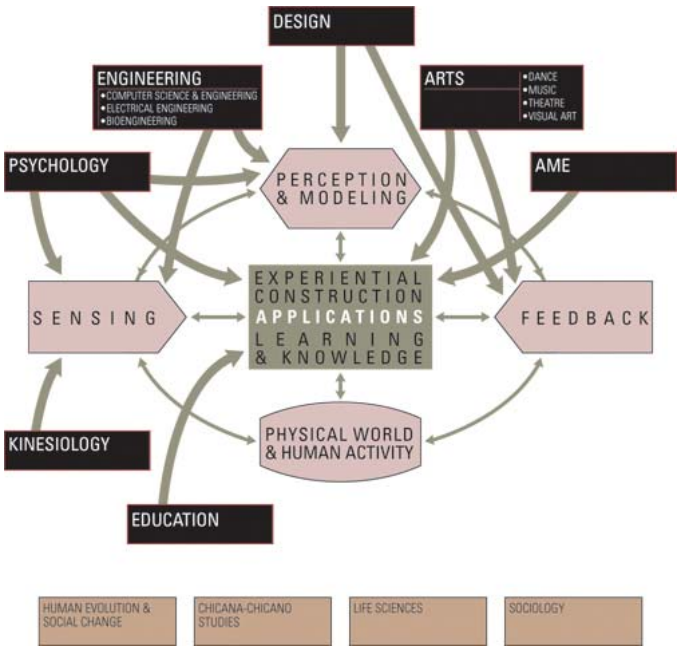

FIGURE 1: THE AME EXPERIENTIAL MEDIA RESEARCH MODEL AND NETWORK OF PARTICIPATING DISCIPLINES

More specifically, the current application areas of AME research and education are: Mediated Biosystems [3], Mediated K-12 Education [4], Everyday Systems [5], Culture and Arts [6, 7]

VI. Other interdisciplinary efforts for media development

Interdisciplinary efforts have played a significant role in media development. There have been a number of significant efforts in the past 30 years to bring engineering, arts and sciences together for the creation of new media tools and content. Among them are the MIT Media Lab, the CMU Entertainment Technologies Lab, IRCAM at Centre Pompidou and the CCRMA at Stanford. Projects produced there by a collaboration of traditional artists with traditional engineers many times resulted in re-working of existing knowledge. Importantly however, there are a number of researchers with interdisciplinary engineering-science-arts training, from these institutions, who spearheaded collaborations with a major impact. Miller Puckette, Associate Director of the Center for Research in Computing and the Arts (UCSD), is a scientist also trained in music who lead the development of the MAX [8] software tools for interactive audio/visual creation and manipulation while at IRCAM and UCSD. Psychologist Steven McAdams, Director of the Centre for Interdisciplinary Research in Music, Media & Technology at McGill University, and leader of many successful collaborative psychology-engineering-arts projects [9], has a PhD in psychology with specialization in music cognition and has working knowledge of digital signal processing and electronic music composition. The "Beyond Productivity" report [10] of the NRC committee on information technology and creativity suggests that hybrid training across engineering, science and

art can produce important innovations in information technology

VII. The innovations offered by our effort

We are proposing that the development of experiential media systems must be achieved through the training of a new generation of hybrid media engineers-scientists-artists who approach the issue of media development as an integrated multidisciplinary process. These new media scientists need to: (a) combine discipline specific training in one of the key contributing research areas (sensing, perception, modeling, feedback, experiential construction, learning), with broad understanding of the other research areas; (b) have working knowledge of the connections that exist between the constituting areas; and (c) be able to apply their knowledge to the collaborative creation of physical-digital media systems. The proposed training and system development requires a large interdisciplinary network of faculty and students covering all areas of necessary expertise as well as a common integrative research and education agenda for the network. This common agenda must be organized along two dimensions - research and application- and promote activity at the cross-section of those dimensions.

DETAILED PRESENTATION OF THE AME INTEGRATED RESEARCH AND EDUCATION MODEL

I. A system with two organizational axes: research and application

Careful study of previous efforts [10-12] and our own experience in setting up AME in the past 18 months have convinced us that successful integration of our interdisciplinary network starts with the organization of the research activities and research teams along two dimensions: (a) the *research area dimension* that is primarily discipline-related and lines up with one of the constituting research areas or sub areas and (b) an *application area dimension* consistent with our four areas of applications of societal significance. This is conceptualized as a two-dimensional table with the research area layers stacked horizontally and application areas cutting vertically across each research area (see Table 1). Research area/sub-area groups have a primary faculty leading the group from the discipline primarily related to this area and participating faculty from closely related research areas and/or closely related disciplines. For example, the movement sensing team has an EE vision faculty as primary supervisor and faculty from CSE, Psychology, Dance and Computation and Kinesiology as participating faculty. Application area groups have two co-coordinators – one with a computational background and one with an arts/experiential construction background. Participating faculty in an application area include all faculty that supervise the research work contributing to the application area.

Each faculty or student joining the AME network chooses to work at an intersection of a research area/sub area and an application area. They thus become a member of the research and application groups associated with their choice. Each cross section of Table 1 represents a possible faculty/student choice. For example, an Electrical Engineering student joining AME, depending on their interests and background might choose the intersection of the movement sensing group and the experiential education group (darkened cell in Table 1). This means that they will concentrate on movement sensing research with the primary application area being experiential education systems.

Research sub-area groups (e.g. every student and faculty involved in motion sensing) meet weekly and area teams (e.g. all faculty and students in the motion sensing, audio sensing, tangible sensing and sensor fusion sub areas) bi-weekly. Students present their research to the rest of the team that is then discussed. These meetings serve the integration of research within each research area and link participants from constituting sub-areas into one unified cluster. They furthermore allow interdisciplinary solutions and knowledge that result from application specific work to enrich discipline-centered research. Application groups also meet biweekly. Here the discussion centers on the integration of the work of the different research areas for the creation of an application-specific hybrid system. Because the driving point is the success of the application the conversation quickly leaves disciplinary boundaries and focuses on the application problem. The application area thus facilitates links not only to closely related research tasks (sensing with context) but also across significantly different disciplines such as CSE and the arts. The interdisciplinary supervision of each research area group further enhances this cross-disciplinary linking. Within this highly connected network, disciplinary knowledge in each research area is advanced in a context that encourages interdisciplinary holistic understanding of media.

TABLE 1: AME RESEARCH AREAS AND SUB-AREAS (HORIZONTAL) AND APPLICATION AREAS (VERTICAL)

	Mediated Biosystems			**Education**			**Everyday Systems**			**Arts**	
Knowledge											
Experiential Constructn.											
Feedback											
audio											
visual											
other											
Modeling											
interaction											
archiving											
context											
Perception											
Sensing											
tangible											
fusion											
audio											
movement											

II. Degree Concentrations that combine discipline-specific with transdisciplinary training in experiential media.

The cornerstones of our integrated research and education model are formally approved interdisciplinary concentrations. We have created hybrid arts, media and engineering concentrations within the graduate degree programs of six of the core disciplines of our effort. (CSE, EE, Music, Dance, Theater, Visual Art). Concentrations in the other five core disciplines (Bioengineering, Psychology, Education, Design, Kinesiology) are being formed. These concentrations require a unique plan of study (POS) that integrates courses and research across disciplines

- **Course work:** approximately half the credits come from course work

Discipline-specific: Two-thirds of the course credits are from discipline-specific courses offered by the home department of the student's concentration. They provide a solid foundation for the student' specialization. Most of these courses are taught by faculty affiliated with AME who can thus help students connect the disciplinary courses to the interdisciplinary research activities and courses of AME.

Transdisciplinary: One-third of the course credits are from hybrid media-arts-engineering courses. These courses are offered through AME and follow the structure of our research model with a course covering each of the research sub-areas and application areas. The courses are co-developed and co-taught by two AME faculty representing the primary specializations associated with the subject. The instructors are also lead participants in the related research or application areas and can thus connect the course work to the corresponding research and/or application activities. AME affiliated faculty from participating Departments that teach discipline specific courses that are related to the subject of each hybrid course have contributing instructor roles in the hybrid courses and facilitate the integration of disciplinary and interdisciplinary knowledge for the students.

- **Research and dissertation**

Approximately half the credits come from research and dissertation work within our research network, as a member of a research area and an application area group. This provides the necessary emphasis on the research structure and allows students the requisite time to fully participate.

Research: Each student joining an AME concentration selects two groups to work with simultaneously: a research sub-area group that relates to their specialization and an application area group that requires the contribution of that specialization. Research and Thesis credits relate to the work the student performs in the cross section of their research specialization and chosen application area. The different types of applications that inform each research area allow the students to generalize their research area knowledge beyond the confines of the applications they will be working on. At the same time the focus and network of collaborators provided by the application area allows them to show tangible contributions to complex working systems that have been embedded in the real world and tested and validated by extensive use. It also shows them as capable team players in the development of such complex systems which is a quality that both industry and academia are currently looking for.

Dissertation: When nearing completion of the course-work, the students form their dissertation committee and prepare their dissertation proposal. The proposal must show innovation and significant contribution to experiential media development, further the research activities of the student's groups, prove that the student has command of the discipline specific knowledge required for his/her specialization and is able to apply this knowledge to experiential media development and show possible paths for extensibility of his/her work beyond the scope of the dissertation. The approach to innovation of each proposal may vary; from exploring an improved research approach to an existing application task, to suggesting a new research approach to an existing task, to even suggesting a new application task. If a new task is suggested the proposal must show that the interdisciplinary group necessary for realizing this task is present within the program and committed to realizing the project. This range of possibilities allows students to suggest topics that fit their interest and idiosyncrasies. The most entrepreneurial ones can explore new tasks (shown by dotted lines in Table 1) and organize the groups that will realize them.

- **Degrees**

Degrees are granted by the participating departments and state the AME concentration. These concentrations have been designed to require no additional credit hours beyond what is normal for discipline-specific degrees. All concentrations resulted from rearrangement of the composition of discipline-specific and hybrid courses, and research in the students' specializations.

- **Advising**

All incoming AME students are assigned two co-advisors. One is a lead faculty in the students' research group and is from the student's home Department. The other is a lead in the student's application group and is an AME faculty. They mentor the student in integrating their research and application work, selecting the appropriate discipline specific and transdisciplinary courses and developing their dissertation.

- **An example training path**

Following is a specific example of the training path of a student that might enroll in the EE Ph.D. degree with a concentration in AME. The student selects the motion sensing and analysis group as her research area and the experiential education as her application area. The student's specific research work will be on extraction of movement patterns within groups of movers. The student will apply that to the development of a system for dynamic, customizable extraction of attraction, repulsion and correlation movement patterns amongst the groups of children that will be participating in our K-12 project [4]. The student will do an internship with an

industry partner connected to movement. Gang Qian (AME/EE faculty for motion analysis) and David Birchfield (AME music and computation faculty) will be co-advisors. Willie Savenye of the College of Education will be a committee member. Discipline specific courses through EE would include: digital signal processing, random signal theory, multidimensional signal processing, detection and estimation theory, adaptive signal processing, filtering of stochastic processes, information theory, modeling & performance analysis. Transdisciplinary AME courses would include: media theory, dynamic multimodal environments, motion capture and analysis, active learning. Future employment opportunities could include industry positions in design of interactive educational software or security applications or a position in academia.

III. A Media Arts and Sciences PhD for transdisciplinary, media-centric training

AME is developing a Media, Arts, and Sciences (MAS) Ph.D. that we expect to be ready for accepting students in the Fall 2007 semester. The proposed Ph.D. will complement the AME degree concentrations and strengthen the AME research and education network. It will provide a pathway for the training of transdisciplinary media experts who specialize in knowledge fusion for media development. The MAS Ph.D. is structured to provide students with:

- A broad understanding of each of the five constituting areas of experiential media.
- Working knowledge of the connections that exist between the areas.
- Ability to create and coordinate interdisciplinary teams for the development of experiential media systems.
- Ability to integrate knowledge across the five constituting areas of experiential media development for the creation of media systems of societal significance.
- Ability to generalize the knowledge resulting from the development of a system into broad theoretical principles for experiential media.

MAS Ph.D. students will get 2/3 of the required course credits through the hybrid AME courses and 1/3 through discipline specific courses offered by the participating Departments. Their research and dissertation credits will relate to a cross section of a research and application area of our common agenda (see Table 1). The majority of MAS students will work in the experiential construction research area; specializing on integrating constituting types of knowledge for the creation of an experiential media system. The application area of the student will relate to their interests and background. Degrees will be granted by AME.

The MAS Ph.D. students will have significant roles in the running and evolution of the AME application areas. During their first two years in the program, they will assist their application area advisor in identifying, establishing and optimizing the connections between the contributing research areas and in integrating the research area contributions within the framework of the application area. During the planning and realization of their dissertation MAS Ph.D. students will have the opportunity to create and manage their own team for the realization of an original application task or a subtask of an existing application activity. This will give the students extensive hands on experience with integration of different types of knowledge for the creation of a new mediated system and with team management. In the written part of their dissertation, MAS students will be expected to author a section that generalizes their knowledge, integration, and team management experience. It will also propose improved or novel knowledge fusion models for the creation of experiential media and/or new theoretical foundations for experiential media.

IV. Embeddedness

We aim to create a continuum between the education of the students within the university, the activities of related industry and societal needs and applications. Our plan for embeddedness is based on three evolving initiatives: creation of embedded labs for each application area, creation of a industry consortium, integration of industry and teaching experience in the curriculum.

- **Creation of embedded labs:**

Plans are under way for the creation of an embedding opportunity for each of the four application areas. Teams of students that have completed their qualifying exams will develop and run these spaces. This will give students the opportunity to develop and test their dissertation work and projects in real-life environments. The *everyday systems* application area will embed its work in the "mediated walk" at the Scottsdale Center for Innovation and Technology-Skysong [13]. The architecture and materials of the natural and built environment encountered on the walk will function as information and knowledge rendering devices. The *K-12 education* application area will embed its work in local schools through portable versions of the experiential education systems under development and in the education lab at Skysong. We plan to create a biofeedback lab in one of the area hospitals for embedding the work of the *biofeedback* group. Finally, working with a number of presenting and community organization partners, we are building an arts residency program that will bring artists to AME to work with the *interactive arts* groups in the creation of systems and works for international dissemination and installations for the many urban spaces under development in Phoenix.

- **Creation of industry consortium:**

AME, with the assistance of the ASU Center for Professional Development, the Corporate Leaders Program, and the Arizona Technology Enterprises, is forming a consortium of industry and community partners. Industry partners are mainly from the digital media and computing industries. Community partners relate to the application areas of our work. The consortium will bundle education and research and its charter will include: creating and supporting interdisciplinary research projects in experiential media,

developing structures for technology transfer, recruiting and placing students, developing a program for summer internships, and integrating AME technology in various outreach activities.

- **Internships and teaching experience**

All students will have an internship requirement of at least one semester or summer term with one of our industry or community partners. All students will be teaching assistants in their home Department for one year.

V. Evaluation:

The AME education and research activities will have three levels of assessment on a continuous and evolving basis: 1) self-evaluation every semester through formalized input by students and faculty; 2) university evaluation every two years by the experts specified by the ASU Evaluation Office; and 3) external bi-annual by external members of the Advisory Board composed of experts from academics, industrial and government agencies. Key performance indicators will be:

- Adoption of media systems created at AME by industry and community.
- Recruitment and retention of high-quality students from diverse backgrounds and prior training experiences.
- Program graduates producing high quality publications, presentations, inventions and products that have interdisciplinary use and appeal.
- Dissertations generate novel media-centric knowledge that cross disciplinary boundaries.
- Program graduates obtain positions in a variety of scientific, engineering, creative and community venues.
- Research and education agenda evolves in parallel with the field of media.

CURRENT STATUS AND PRELIMINARY RESULTS

AME has been in existence for only two and half years. During this time we have had a string of successes which show that the program is receiving the recognition of all its constituent communities. We have attracted significant grants from federal sources across the science and arts (NSF, NEA), including an NSF Integrative Research and Education Training grant (IGERT). We have a number of industry collaborations (Microsoft, NEC, Motion Analysis Corporation, Avaya, Ricoh) and community partnerships (Mayo Clinic, Barrett Medical Center, Scottsdale Cultural Council, Mesa Center for the Arts). Our faculty and students are presenting their work at the top, peer reviewed international conferences in the area of media [4,14,15] and in leading festivals and arts venues (i.e. Lincoln Center). Thirty-two students are currently enrolled in the concentrations. We expect that number to reach fifty by August 2006 and to keep expanding. Although no PhD level students have graduated yet, the majority of Masters students graduating from the collaborating Departments with an AME concentration have secured employment either in industry or academia.

CONCLUSION

We have presented the interdisciplinary training system for media scientists of the Arts, Media and Engineering Program at ASU. The program integrates research and education and exists at the cross-section of research and application. It brings together arts, sciences and engineering disciplines across campus for the development of experiential media – systems that integrate computation and digital media in the physical human experience. Graduates of the program have the necessary blend of discipline specific, interdisciplinary and transdisciplinary skills for the development of experiential media systems.

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REFERENCES

[1] Gray, J. , "What next?: A dozen information-technology research goals.", *Journal of the ACM* **50**(1), 2003, 41-57

[2] Sundaram, H., Rikakis, T., "Experiential Media Systems", *Encyclopedia of Multimedia*, B. FURTHT (eds), 2006, NY NY., Springer Verlag. XXVIII: 989p.

[3] Huang, H., Ingalls, T., Olsen, L., Ganley, K., Rikakis, T., He, J., "An Interactive, Multimodal Biofeedback System for Task-Oriented Neural Rehabilitation;; *IEEE-EMBC* 2005, Shanghai, China

[4] Birchfield D., Thornburg H., Savenye W., Minyard G., "SMALLab: a platform for mediated education", to appear in *Proceedings of ACM SIGGRAPH*, Boston 2006

[5] Kelkar, S., Kelliher, A., Sundaram, H., "Presence, Action and Memory: Understanding Extended Media Communities In Networked Hybrid Physical-Digital Environments". Arizona State University, *AME-TR*-2006-03, Jan. 2006.

[6] http://ame.asu.edu/motione

[7] Whiteley, D., Qian, G., Rikakis, T., James, J., Ingalls, T., Wang, S., Olson, L., "Real-Time Tracking of Multiple People from Unlabelled Markers and Its Application in Interactive Dance," *Proceedings of British Machine Vision Conference*, Oxford, UK, September 5-8, 2005

[8] www.cycling74.com/

[9] McAdams, S., Bigand, E., *"Thinking in Sound: The Cognitive Psychology of Human Audition",* Clarendon, 1997

[10] NRC Committee on Information Technology and Creativity, *"Beyond Productivity: Information, Technology, Innovation, and Creativity"* NRC, 2002

[11] NRC Committee on Facilitating Interdisciplinary Research, "*Facilitating Interdisciplinary Research*", NRC, 2004

[12] Born, G., "*Rationalizing Culture*", University of California Press, 1995

[13] http://www.skysongcenter.com/

[14] Appan, P., Sundaram, H.,. "Networked multimedia event exploration", *Proc. ACM Multimedia*, 2004, pp. 40-47, Oct. 2004., New York, New York.

[15] Chen, Y., Sundaram, H.,. "Basis Projection for Linear Transform Approximation in Real-Time Applications", to appear in *Proc. ICASSP 2006*, May 2006, Toulouse, France.