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課題番号　：P-7

Multimedia Interaction Interfaces for Table-Top Computers in Collaborative E-learning Environments

[1] Organization

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[2] Progress of the research

This cooperative research project continues to foster, expand upon, and further develop the work of an international research team that is investigating the design and development of innovative interfaces and environments for e-learning based on natural interaction paradigms that are adjustable to the needs of specific user groups. A large part of this work has examined interaction with tabletop computers (also known as surface computers and smart tables), where users position themselves around a horizontal computer screen in a manner similar to sitting around a "traditional" table and a combined audio/vision-based interface is employed for sound source and user tracking in real-time. Although tabletop computers have yet to be primarily designed as consumer models, with the growing popularity of multi-touch mobility devices (e.g., iPhone/iPads, smartphones), the move to multi-user touch screens and a horizontal surface is a likely trajectory of the technology. Moreover, these devices may well become a part of social entertainment, where families and friends can interact with each other around a table-like surface. Given that tabletop computers are intended to have multiple users seated around the computer display interacting with the display itself, they naturally promote interaction amongst users providing an engaging environment to promote a collaborative education.

Despite the potential benefits of tabletop computers, there are a number of open issues that must be addressed before they become more widely used, particularly for interactive e-learning educational applications. One critical question that must be addressed in order to fully operationalize tabletop displays is the user's ability to integrate multimodal display cues within the device. Of particular interest in this project has been the ability of the user to integrate spatialized visual and audio cues into a coherent perception of a spatialized event. The problem of spatial sound generation for such computing platforms is complicated by the fact that headphones (as used in "traditional" computing platforms to deliver spatial sound) are not an option as they will restrict and interfere with the ability of users to interact with each other. Therefore, spatial sound must be delivered via a number of loudspeakers positioned around the tabletop computer. To this end, our prior work within the scope of this project has investigated the generation of spatial sound via a series of loudspeakers surrounding the tabletop computer. We have developed various amplitude panning methods to allow for sound to be spatialized to some point on a horizontal surface and we have experimented with various loudspeaker configurations. We have also examined (through user-based experiments), the ability to localize a sound on a horizontal surface using our amplitude panning method although it is prone to error (see Lam et al, 2013).

Although we have made great progress, plenty of answers remained unanswered. More specifically, despite the fact that localizing a (virtual) sound on a horizontal surface is error-prone, we do not have any "ground truth" data to compare this to. In other words, just how accurately are we able to localize a sound on a horizontal surface when there is a physical sound at the corresponding sound location? Within the scope of this particular project, we developed a novel hardware setup to address this particular question. In addition to the basic research questions regarding multimodal interactions and sound localization on a horizontal surface (of a tabletop display), within the scope of this project, we have recently begun working on a novel application of a tabletop computer that involves its use in the interprofessional training of health professional teams (see (Dubrowski et al., 2013) for greater details). Although there are some interesting and perhaps difficult technical challenges to be addressed in order to accomplish this, the use of an interactive tabletop "simulator" for training of health professionals presents an interactive, engaging, platform making it an ideal environment for such training where multiple team members interact with the patient and with each other. Furthermore, such a platform is very cost-effective when compared to traditional simulation centers (that are costly to build and maintain), where most of this training takes place.

A number of research exchanges took place during the past year. More specifically, visits to Shizuoka University by several of the Canadian members of the research team took place in January and February 2013 (Professor Kapralos visited from January 31 to February 14, Professor Dubrowski from February 7 to 14, and Professor Jenkin from February 8 to 14). As will be outlined throughout the remainder of this report, during their visit, they devised experiments that will be conducted in Canada upon their arrival regarding sound localization on a tabletop (horizontal) display, and discussed, potential solutions and future plans for the tabletop computer "simulator" for interprofessional training of health practitioner teams. Professor Kanev undertook two trips to Ontario to visit the University of Ontario Institute of Technology (UOIT), University of Toronto, and York University in 2012. The first trip in early fall was to conduct groundwork and set up the basic parameters for a more extended work with a specialized experimental apparatus throughout the fall and winter. During his second visit and afterwards the experimental apparatus (see results, below) constructed at York University and installed at UOIT was used for further experiments.

3 Results

During the past year, work within the project has focused on table-top, touchscreen displays and two topics in particular: i) developing a greater understanding on how humans perceive spatialized audio cues in a tabletop environment, and more specifically, localization of a sound source emanating from a horizontal surface (relative to the listener), and ii) employing the tabletop, touchscreen display to support interprofessional education amongst teams of medical professionals. Greater detail regarding each of these two research topics is provided in the sections below.

3.1 Sound Localization on a Horizontal Surface ("Ground Truth" Experiments)

As previously described, our work has examined the localization of a virtual sound source (that was generated using several amplitude panning methods; see Lam et al. (2013)) on a horizontal surface, measured sound localization of virtual sound sources on a horizontal surface, and compared different panning methods or different loudspeaker configurations. However, "ground truth" data to compare these results with, was lacking. In other words, just how accurately can we localize a sound on a horizontal surface when the sound is emanating from an actual sound source at the corresponding location? This particular work addressed this question. A novel sound verification hardware setup and methodology was constructed (by Professors Jenkin, Kanev, Kapralos, and Hogue) and used to collect "ground truth" data in order to allow for meaningful comparisons with our previous results to be made. It allowed a single physical sound source to be moved to 36 pre-defined locations (positioned on a grid with x- and y-axis separations of 0.15 m) in a simple and efficient manner. This grid of 36 locations was identical to the grid we used in our previous experiments that saw a virtual sound spatialized to one of the 36 locations.

3.1.1 Experimental Procedure

The experiments took place in an Eckel audiometric room at the University of Ontario Institute of Technology (room dimensions of 2.3 m × 2.3 m × 2.0 m). The Eckel audiometric room provides (frequency dependent) noise reduction across a wide range of frequencies (e.g., 19 dB at 125 Hz and 60 dB at 4 kHz). Five volunteers participated in the experiment and their average age was 29. Participants were seated on a chair 0.51 m from the surface at a height of 1.36 m and instructed to look forward at the green marker located at the center of the box. In an effort to limit deviations from their intended positions, participants were asked to line up the tip of their nose with a thin piece of string (with a weight on its bottom) hanging from the ceiling of the audiometric room. For each trial, the loudspeaker was physically moved to one of the 36 sound source positions, the sound stimulus (white noise) was presented and the participant's task was to indicate which of the 36 positions they believed the sound was emanating from. Participants indicated their choice by stating the corresponding row and column to the experimenter who then recorded their choice. The sound was turned off and the next trial began. A total of 36 grid positions (spatial sound sources) were considered and each position was repeated two times leading to a total of 72 trials (i.e., 36 grid positions × 2 repetitions). Each of the 72 sound source positions was considered in random order. Prior to the start of the experiment, participants were presented with the auditory stimulus at each of the four corner positions of the surface (individually, one after the other) to provide them with a reference.

In addition to the collection of ground truth data with respect to a horizontal surface, the experiment was repeated with the box positioned vertically (i.e., flipped 90 degrees).

3.1.2 Experimental Results

The results of this experiment indicate that sound localization on a horizontal surface with actual sound sources is erroneous albeit to a lesser degree than sound localization of virtual sound sources. The average error Euclidean distance (the difference between the actual and perceived sound source positions, measured in meters) and standard deviation for each of the 36 virtual sound source positions (averaged across each of the five participants) for the horizontal configuration ranged from 0.02 m to 0.32 m with an average of 0.18m ±0.07 m. Given the grid spacing of 0.15 m × 0.15 m, participants were able to localize the sound source to within approximately two positions of the actual virtual sound source. The average error (Euclidean distance) and standard deviation for each of the 36 virtual sound source positions (averaged across each of the five participants) for the vertical configuration ranged from 0.02 m to 0.23 m with an average of 0.13m ± 0.05 m. Given the grid spacing of 0.15 m × 0.15 m, participants were able to localize the sound source to within approximately one position of the actual virtual sound source. A graphical summary of the results for the horizontal and vertical configurations are provided in Figures 1 and 2 respectively.

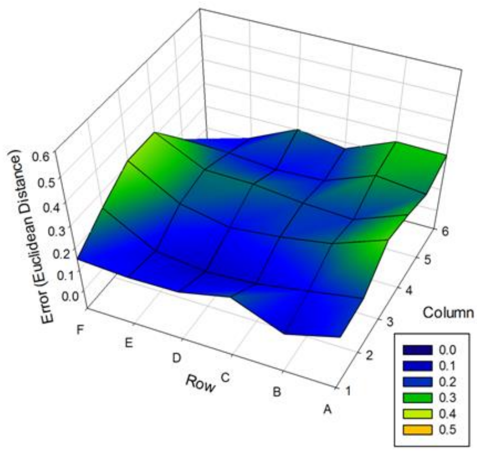

Figure 1. Sound localization results (average error) for the horizontal configuration.

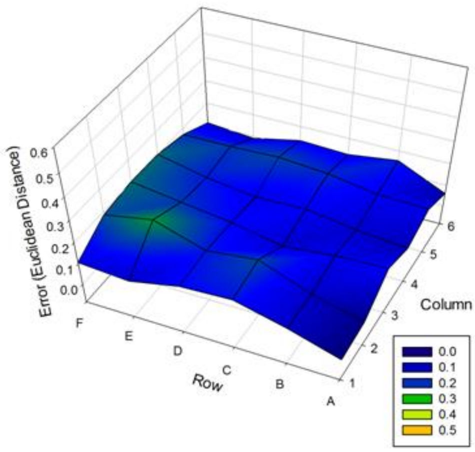

Figure 2. Sound localization results (average error) for the vertical configuration.

Although smaller than the errors arising from the amplitude panning methods, even in the presence of a physical sound source at the corresponding position, localizing the sound source is still prone to error hence, one should not expect to eliminate the errors when employing amplitude panning methods to spatialize a sound source to a position on a horizontal surface.

3.2 Tabletop Simulator for Interprofessional Education of Health Professional Teams

Simulation in health professions education (HPE) is defined as the replication of a task or an event for the purpose of training. The act itself demands reduction of a very complex and often overwhelming event, such as stabilizing a critically sick patient, to its basic elements. These elements are subsequently learned in less complex environments designed to optimize the learning process (Guadagnoli, Morin, Dubrowski, 2012; Matsuda et al 2012).

Although simulation strives for a learner-centric approach, where information is provided to the learner on an as-need basis, the current simulation technologies do not meet this goal. The first problem is the problem of the simulator. Typically, the simulators often referred to as models, have a limited number of learning objectives that they can deliver. For example, a synthetic bench-top simulator, such as a representation of an arm, may be well suited for teaching clinical technical skills of intra-venous (IV) catheter placement, but the same simulator is not well suited for teaching the underpinning anatomy. The second problem is that of the learner. Simulation is often used to train teams of health professionals not only to develop the clinical skills within their own domain, but also to understand what skills need to be performed by other members of the team, as well as develop skills that need to be performed together as a team. Because multi-professional teams consist of members with various backgrounds, as well as skills, knowledge and attitude (SKA) levels, learning styles and needs, the same-for-all mode of information delivery may not be adequate for optimal learning.

Tabletop computers where, as described above, users position themselves around a horizontal computer screen in a manner similar to sitting around a “traditional” table, promote collaboration amongst the users. Tabletop computers provide the opportunity for the development of innovative, engaging, interactive, and highly collaborative pedagogic applications, lending themselves nicely to interprofessional training of health professionals.

This particular joint Canada-Japan research project is examining the use of a multiuser interactive tabletop touch-screen computer in conjunction with novel image-based sensing and positioning technologies to allow for virtual simulators that promote embedding many learning objectives in a single simulation modality and tailor the learning experience to the needs of each of the learners involved while promoting interprofessional education amongst a team of health professionals and thus improve patient care. To allow for robust and accurate touch-sensing positioning on the surface with multiple users/participants as may be required within the scope of a virtual medical simulation, our approach will incorporate the Cluster Pattern Interface (CLUSPI) invented by Kanev and Kimura. CLUSPI-based technologies will be employed to permit the customization of the information presented to each of the users depending on their level (i.e., novice, intermediate, or advanced) and to their actions within the simulation. As described further in Section 4 (“Future Work”), this particular work presents some interesting technical challenges that must be solved including the ability to present individualized views to each of the users (ideally greater than two) which will require some form of user tracking and incorporating a display with a large refresh rate and may involve multiplexing of the rendering using shutter glasses and rendering the scene for each individual separately (work on solving these problems has recently begun). An overview of this work, including a detailed scenario, was presented at the 15th International Conference on Humans and Computers, (HC 2012) February 11-12, 2013, in Hamamatsu, Japan by Professor Dubrowski. Greater details regarding this work including an overview of the scenario and technical details are provided by Dubrowski et al. (2013).

4. Future Work

During the visit to Shizuoka University by Professors Jenkin, Kapralos, and Dubrowski in February 2013, together with Professor Kanev, they devised a plan to continue working on and move forward with both research topics. With respect to sound localization on a tabletop display, a research article outlining the results of the “ground truth experiment” is being prepared and will be submitted to the 2013 ACM International Conference on Interactive Tabletops and Surfaces (ITS’2012) to be held in St. Andrews Scotland, October 6-9, 2013 (the full paper submission deadline is June 14, 2013). In addition, a new experiment was devised. Rather than presenting participants with a virtual sound and then having them determine the location on the surface, in this new experiment, participants are told the location of the sound source on the surface and then they must adjust (via a graphical user interface) the gain applied to each of the four loudspeakers surrounding the tabletop computer display so that the virtual sound source is perceived to them as emanating from the given location. The UOIT student, Mr. Jonathan Lam, was hired to conduct the experiment. Currently, Mr. Lam has developed all the necessary software to support the experiment and is in the process of testing the software and hardware setup. It is anticipated that we will begin conducting the experiment in early April after approval from the UOIT Research Ethics Board has been granted. Although our work has focused primarily on spatial sound generation and sound localization, future work will also examine the interaction of audio visual cues and more specifically, we will examine whether visual cues can be used to reduce some of the inherent error associated with localization of a sound source on a horizontal surface. Kapralos, Collins, and Dubrowski have conducted various experiments that have examined audio-visual interaction within multi-modal environments (see Cowan et al., 2013; Cullen et al., 2012; Rojas et al., 2012) providing a good base to begin from.

With respect to the interprofessional health professional team training project, we are currently in the process of further developing the scenario that was originally described by Dubrowski et al. (2013) at the *HC 2012* conference in Hamamatsu, Japan. In addition, we are currently focusing on various technical issues and in the process of developing a method to allow multiple users (greater than two) situated around the table to view the scene from their perspective and be presented with individualized views. One approach we are exploring is to present individualized monoscopic views to the users (maximum of four users) by taking advantage of the high refresh rates available with current consumer televisions. Essentially, employing shutter glasses (as employed in active stereoscopic 3D viewing), during each refresh cycle, each of the four shutter glasses will be activated once and the other three will be closed thus allowing the displays refresh to be multiplexed across each of the four users (this will of course require a four-fold increase in rendering of the scene). We are aiming to have this setup completed this spring and planning to prepare a research article describing our solution to the 2013 ACM International Conference on Interactive Tabletops and Surfaces (ITS'2012). This work is taking place both at Shizuoka University in Japan and at York University and UOIT in Canada where separate tabletop touch-screen displays are available.

Further exchanges are planned in order to support the research. Professor Kanev plans extended visits to York University, UOIT, and the Learning Institute at the Hospital for Sick Children in the summer and fall of 2013. Initial planning is underway to prepare and submit a tutorial proposal for spatial sound generation for tabletop touchscreen displays at the 2013 ACM International Conference on Interactive Tabletops and Surfaces (ITS'2012) to be held by members of this research team. Finally, we are also seeking further funding from funding agencies in Canada to support this work.

[4] Publications

1. B. Cowan, D. Rojas, B. Kapralos, K. Collins, and A. Dubrowski. Spatial sound and its effect on visual quality perception and task performance within a virtual environment. *21st International Congress on Acoustics*, Montreal, Canada, June 2-7, 2013.
2. B. Cullen, D. Galperin, K. Collins, B. Kapralos, and A. Hogue. The effects of audio on depth perception in S3D games. *Audio Mostly 2012*, Corfu, Greece, September 26-28, 2012.
3. A. Dubrowski, B. Kapralos, M. Jenkin, and K. Kanev. Collaborative, interactive smart-table-based simulations for interprofessional education?, The 15th International Conference on Humans and Computers (HC-2012), Electronic Abstracts Collection (Hamamatsu sessions), Paper No ID10, pp. 17. [11-12 February 2013, Aizu-Wakamatsu & Hamamatsu, Japan; Düsseldorf, Germany].
4. M. Guadagnoli, M. P. Morin, and A. Dubrowski. The application of the challenge point framework in medical education. *Medical Education* 46(5):447-53, 2012.
5. Lam, J., Kapralos, B., Collins, K, Hogue, A., Kanev, K., Jenkin, M., Sound Localization on Table-top Computers: A Comparison of Two Amplitude Panning Methods. *ACM Computers in Entertainment* (to appear 2013).
6. D. Rojas, B. Kapralos, S. Cristancho, K. Collins, A. Hogue, C. Conati, and A. Dubrowski. Developing effective serious games: The effect of background sound on

visual fidelity perception with varying texture resolution. *Studies in Health Technology and Informatics*, 173:386-392, 2012.

7. N. Matsuda, H. Kano, H. Taki, L. Cui, K. Seta, and M. Ikeda. Reviewing Map to Represents Tutor's Intention for Nursing Report. The 15th International Conference on Humans and Computers (HC-2012), Electronic Abstracts Collection (Hamamatsu sessions), Paper No ID05, pp. 7. [11-12 February 2013, Aizu-Wakamatsu & Hamamatsu, Japan; Düsseldorf, Germany].

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Traveling Report

Name:	Noriyuki Matsuda
Affiliation:	Faculty of Systems Engineering, Wakayama University, Japan
Period of time:	February 10, 2013 – February 12, 2013
Destination:	Shizuoka University, Japan
Purpose:	To discuss the research and project organization, to schedule future work, and to participate at the *15th International Conference on Humans and Computers*, February 11-12, 2013.
Name of receiver:	Prof. Kamen Kanev

Name:	Michael Jenkin
Affiliation:	York University, Toronto, Ontario, Canada.
Period of time:	February 7, 2013 – February 14, 2013
Destination:	Shizuoka University, Japan
Purpose:	To discuss the research and project organization, to plan publications, and to participate and report obtained results at *15th International Conference on Humans and Computers*, February 11-12, 2013.
Name of receiver:	Prof. Kamen Kanev

Name:	Bill Kapralos
Affiliation:	University of Ontario Institute of Technology, Oshawa, Ontario, Canada.
Period of time:	January 31, 2013 – February 13, 2013
Destination:	Shizuoka University, Japan
Purpose:	To discuss the research and project organization, to plan publications, and to participate and report obtained results at the *15th International Conference on Humans and Computers*, February 11-12, 2013.
Name of receiver:	Prof. Kamen Kanev

Name:	Adam Dubrowski
Affiliation:	The Learning Institute, Hospital for Sick Children, University of Toronto, Toronto, Ontario, Canada.
Period of time:	February 6, 2013 – February 13, 2013
Destination:	Shizuoka University, Japan
Purpose:	To discuss the research and project organization, to plan publications, and to participate and report obtained results at the *15th International Conference on Humans and Computers*, February 11-12, 2013.
Name of receiver:	Prof. Kamen Kanev