

Final Report for Period: 10/2008 - 09/2009

Submitted on: 12/06/2009

Principal Investigator: Walker, Bruce .

Award ID: 0534332

Organization: GA Tech Res Corp - GIT

Submitted By:

Walker, Bruce - Principal Investigator

Title:
A System for Wearable Audio Navigation Integrating Advanced Localization and Auditory Display

Project Participants

Senior Personnel

Name: Walker, Bruce

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Dellaert, Frank

Worked for more than 160 Hours: Yes

Contribution to Project:

Post-doc

Name: Mariottini, Gian Luca

Worked for more than 160 Hours: Yes

Contribution to Project:

Gian Luca Mariottini is a postdoc in computer science, and has taken the lead on the computer vision and vision-based tracking components. His salary was paid for partly by this grant.

Graduate Student

Name: Lindsay, Jeffrey

Worked for more than 160 Hours: Yes

Contribution to Project:

Lindsay is a PhD student in Psychology and has been an active member of the SWAN team from the outset. He coordinates research using the system, both indoors and outdoors, and supervises undergrads. He also helps to liaise with the Center for the Visually Impaired (CVI). He has received some stipend support, and some funding has come from other funds.

Name: Patrao, Joseph

Worked for more than 160 Hours: Yes

Contribution to Project:

Joseph has graduated, and is no longer associated with the project.

Patrao was an MS student in Computer Science, and was the lead developer of the SWAN audio subsystem, and in charge of integrating the software and hardware. He was supported with a graduate stipend.

Name: Cambias, Craig

Worked for more than 160 Hours: Yes

Contribution to Project:

He has graduated, and is no longer associated with the project.

Cambias was an MS student in Computer Science, and was the lead developer of the tracking and localization subsystem, the sensor fusion subsystem (MERGE), and the computer vision

subsystem. He received a graduate stipend.

Name: Oh, Sangmin

Worked for more than 160 Hours: Yes

Contribution to Project:

Sangmin Oh is a graduate student, and has been the lead on the sensor fusion and location tracking components (MERGE). He has also worked on the computer vision subsystem. He has received part of his graduate stipend from the grant.

Undergraduate Student

Name: Lim, Ana

Worked for more than 160 Hours: No

Contribution to Project:

Ana has graduated and is no longer associated with the project.

Lim worked with Cambias on the computer vision and MERGE subsystems. She worked in part for credit and in part for pay under the REU supplement.

Name: Chauhan, Shakti

Worked for more than 160 Hours: No

Contribution to Project:

Shakti has graduated and is no longer associated with the project.

Chauhan worked on integrating additional sensors into the system. He worked in part for credit and in part for pay under the REU supplement.

Name: Holmes, Jennifer

Worked for more than 160 Hours: No

Contribution to Project:

Jennifer has graduated and is no longer associated with the project.

Holmes ran the outdoor evaluations as part of her senior thesis. She worked in part for credit and in part for pay under the REU supplement.

Technician, Programmer

Other Participant

Name: Wilson, Jeff

Worked for more than 160 Hours: Yes

Contribution to Project:

Wilson is a research scientist, in charge of the GIS databases and servers. Part of his salary was covered from this grant.

Research Experience for Undergraduates

Organizational Partners

Center for the Visually Impaired

The CVI provides a central and known location for blind and visually impaired individuals to come for focus groups, meetings, etc. The CVI also serves as a liaison to recruit participants. Finally, members of the CVI staff (sighted and blind) provide feedback on interim versions of the SWAN system.

Other Collaborators or Contacts

We worked with bone conduction headphone manufacturers (e.g., Temco) to begin to develop appropriate devices. As a result of some recent media attention, we have had contacts from around the world, interested in collaborating and trying out the SWAN system, whenever possible.

Activities and Findings

Research and Education Activities:

In the first year of the project, we had three major research projects. First, we evaluated the ability of users to navigate using the SWAN system in the presence of noise, using bone conduction headphones. Second, as part of Jeff Lindsay's Masters project, we evaluated users' ability to navigate while interrupted with a secondary listening task. Third, we have begun to use the system outdoors to compare outdoor use with indoor (virtual reality) use.

In the second year of the project, we focused on the SWAN hardware and software systems. We rewrote much of the audio generation code, to make it more manageable, bring it up to modern standards, and include the latest audio programming techniques. We rewrote the sensor fusion components, to include more robust communications with devices and sensors (e.g., GPS and thermometers). We made the particle filtering code more effective, fast, and reliable. We transitioned to new hardware, including a Sony Vaio ultramobile device, rather than a laptop. We focused on system integration, ranging from packaging and cabling, to pulling configuration data out of the application code and managing those settings in XLM files separate from the compiled application. We began work on evaluating the effectiveness of the location system, which involves ongoing efforts to obtain ground-truth measurements of locations. We are working on making our GIS database extremely well geo-referenced. We are working on the actual user interface sounds, now, with participation of the Center for the Visually Impaired.

In the third year, we have further developed the GIS database to include more accurate and detailed pedestrian-level data, and integrating it with our system. This has included collaborating with several other researchers on campus, most notably in our Center for GIS. We have also developed new ways of presenting the wayfinding audio to the user, and have been testing the effectiveness of the sounds. We had a student develop new sounds to represent the various environmental features (bench, tree, fire hydrant, stairs, etc.). The sounds were earcons, auditory icons, spearcons, and several hybrids. These were evaluated in VR-based studies, and presented at ICAD 2008. We collected more data outdoors on the astroturf fields. The location tracking had some issues, leading to a pause in data collection; we need to revisit that data collection effort, now that the tracking bugs are eliminated. We continue to develop new audio interface methods. For example, the original auditory interface always played a sound, and the user walked 'toward' that sound. In the new version, there is a 'quiet' mode, in which the system is quiet so long as the user is on track, and only makes sounds when the user is heading in the wrong direction. These methods are being assessed experimentally in the VR facility, and will soon be evaluated in the outdoor system.

In the non-cost extension period we have completed further tests of the auditory display system in the virtual environment, and refined the integrated outdoor SWAN system. We have archived and documented the project, and written up research papers about the work.

Findings:

1. Users are able to use the system with bonephones, both with and without noise. Noise degrades performance, but successful navigation continues nevertheless.
2. Secondary audio/listening tasks degrade performance, but users are still able to complete navigation tasks successfully.
3. Users are able to complete navigation tasks effectively outdoors (currently on the astroturf playing fields, for safety).
4. The system can determine user location very accurately, then connect to a GIS server to query for waypoints and obstacles in the vicinity. The system then can render the paths to a destination, along with salient environmental features, ranging from curb cuts to benches to buildings. All of this is done at the pedestrian level of detail, on the order of a foot or two, rather than vehicle- or street-size details.
5. We have developed and assessed a variety of audio interface approaches, and have determined some of the best ways to present navigation cues, as well as environment cues.
6. We have developed a complete, modular system for location tracking, and audio navigation cues.

Training and Development:

Many undergraduates have participated in the experiments, and as such have gained insight into the research process. Several undergraduates have gained valuable experience in running subjects and collecting data. Several undergrads have also gained deeper experience by conducting complete research projects as part of their undergraduate thesis. Graduate students have worked on complete projects as part of their Masters and PhD research. Post-doctoral students have tackled major systems integration projects, and supervised other student projects. Presenting the results of the work at conferences has been an important training activity for the students, as well.

Outreach Activities:

In addition to publication in academic journals and presentation at conferences, Georgia Tech released a press release about the project in the summer of 2006. This resulted in considerable media attention, which has resulted in a number of interviews and talks. In all of these we made efforts to educate the public about science and technology, and how they can provide benefits to all of society, in addition to those with particular disabilities. We are maintaining a list of potential beta testers, volunteers, and companies who may be interested in the project as we progress. The project has also been part of projects in classes in both Psychology and Computing. Our labs regularly participate in Demo Days through the GVV Center, the WirelessRERC, and other centers. The SWAN system is often demonstrated, and is very popular with general audiences.

Journal Publications

Walker, B. N., & Lindsay, J., "Using virtual reality to prototype auditory navigation displays.", *Assistive Technology Journal*, p. 72-81, vol. 17, (2005). Published,

Walker, B. N., & Lindsay, J., "Navigation performance with a virtual auditory display: Effects of beacon sound, capture radius, and practice", *Human Factors*, p. 265, vol. 48, (2006). Published,

Books or Other One-time Publications

Wilson, J., Walker, B. N., Lindsay, J., Cambias, C., & Dellaert, F., "SWAN: System for Wearable Audio Navigation", (2007). Refereed Conference Proceedings, Published
 Collection: Proceedings of the 11th International Symposium on Wearable Computers (ISWC 2007)
 Bibliography: Proceedings of the 11th International Symposium on Wearable Computers (ISWC 2007), Boston, MA (11-13 October).

Walker, B. N., & Lindsay, J., "Auditory navigation performance is affected by waypoint capture radius", (2004). Refereed conference proceedings, Published
 Collection: Proceedings of the Tenth International Conference on Auditory Display ICAD2004, Sydney
 Bibliography: Walker, B. N., & Lindsay, J. (2004). Auditory navigation performance is affected by waypoint capture radius. Proceedings of the Tenth International Conference on Auditory Displ

Walker, B. N., & Lindsay, J., "Navigation performance in a virtual environment with bonephones.", (2005). Refereed conference proceedings, Published
 Collection: Proceedings of the Eleventh International Conference on Auditory Display (ICAD2005)
 Bibliography: Walker, B. N., & Lindsay, J. (2005). Navigation performance in a virtual environment with bonephones. Proceedings of the 11th International Conference on Auditory Display (ICAD

Walker, B. N., & Lindsay, J., "Development and evaluation of a System for Wearable Audio Navigation.", (2005). Refereed conference proceedings, Published
 Collection: Proceedings of the Annual Meeting of the Human Factors and Ergonomics Society (HFES2005)
 Bibliography: Walker, B. N., & Lindsay, J. (2005). Development and evaluation of a System for Wearable Audio Navigation. Proceedings of the Annual Meeting of the Human Factors and Ergonomics

Walker, B. N., & Lindsay, J., "The effect of a speech discrimination task on navigation in a virtual environment.", (2006). Refereed conference proceedings, Published
 Collection: Proceedings of the Annual Meeting of the Human Factors and Ergonomics Society (HFES2006)
 Bibliography: Walker, B. N., & Lindsay, J. (2006). The effect of a speech discrimination task on navigation in a virtual environment. Proceedings of the Human Factors and Ergonomics Society

Oh, S. M., Schindler, G., Dellaert, F., Walker, B. N., & Lindsay, J., "Automatic Acquisition of 4D Urban Models and Proactive Auditory Service for Enhanced User Experience", (2006). Refereed conference proceedings, Published
 Collection: Extended Abstract in Young Investigators Forum In Culture Technology 2006,

Daejon, Republic of Korea

Bibliography: Oh, S. M., Schindler, G., Dellaert, F., Walker, B. N., & Lindsay, J. (2006). Automatic Acquisition of 4D Urban Models and Proactive Auditory Service for Enhanced User Experience

Dingler, T., Lindsay, J., & Walker, B. N., "Learnability of sound cues for environmental features: Auditory icons, earcons, spearcons, and speech.", (2008). Refereed conference proceedings, Published Collection: Proceedings of the International Conference on Auditory Display (ICAD 2008)

Bibliography: Dingler, T., Lindsay, J., & Walker, B. N. (2008). Learnability of sound cues for environmental features: Auditory icons, earcons, spearcons, and speech. Proceedings of ICAD 200

Web/Internet Site

URL(s):

<http://sonify.psych.gatech.edu/research/swan/index.html>

Description:

Provides an overview of the SWAN project.

Other Specific Products

Contributions

Contributions within Discipline:

The research has led to a better understanding of how non-speech auditory displays can be used as a navigation aid. Our research methods, including both virtual and real systems, has led to new techniques that can be applied in the field, such as the metrics of path and rate efficiency we use. We have added to the knowledge of how multiple listening tasks can be completed in the midst of a navigation task. In computing, we have developed novel ways to integrate data, and are showing how multiple sensors, including multiple GPS receivers, can improve accuracy of location estimates. We are beginning to develop taxonomies for sounds that represent environmental features, which could become de facto or actual standards for implementing audio cues about the environment.

Contributions to Other Disciplines:

Other fields that use auditory displays, such as in-vehicle audio displays, and other fields that use localization/tracking, such as robotics, may make use of our findings. Our approaches are being considered in a number of assistive technology areas, as well.

Contributions to Human Resource Development:

We are providing many undergraduates with the opportunity to experience research, both as participants and as researchers. We are also providing graduate training and experience. As for the actual results of the project, we are beginning to learn about how to improve wayfinding and navigation for people with vision loss, which will ultimately enable more individuals work, and in a broader range of fields. This should include science and technology, among other fields.

Contributions to Resources for Research and Education:

As indicated, we have provided research experience for undergrads and grads, as well as postdocs. The SWAN project also now serves as an example system that can be used for research in class projects.

This way, students in classes such as 'HCI' and 'Assistive Technology' can propose and carry out research using SWAN in ways that were not planned or proposed by the original project.

Contributions Beyond Science and Engineering:

The SWAN system has inspired a company (TRAClabs) from Houston to apply for funds to begin to commercialize a wayfinding system with an auditory interface based on SWAN.

Conference Proceedings

Categories for which nothing is reported:

Any Product

Any Conference