A Framework for Electronic Travel Aids

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Abstract: Electronic Travel Aids (ETA) help visually impaired people to avoid obstacles. In the ETA area new user interfaces and interaction modes are investigated. Due to increasing hardware and software complexity used in modern ETA there is an increasing demand for simulation tool to facilitate development processes. Such tools enable testing of larger varieties of user experiences in shorter time. In the field of acoustic virtual displays capabilities of different sounds and psychoacoustic phenomena to display three-dimensional sound have to be evaluated. Different simulators make it difficult to compare research results. To facilitate comparability between different approaches an ETA framework is introduced in this work. The framework includes a simulator which allows research groups to perform experiments with their specific interfaces. Due to the same underlying simulation environment results of various groups are comparable. Using a framework would make algorithms or devices from different research groups be directly usable for others. In this position paper the development of such a framework is reasoned and the basic requirements on such a framework are proposed.

1 INTRODUCTION

In the context of electronic travel aids (ETAs) for visual impaired many research projects exist and products are developed to support user orientation, finding a target or recognizing an obstacle. Those projects use sensors like a compass, an accelerometer or a gyroscope to gain environmental information for navigation purposes. Information is then presented by a device that serves an information channel different from vision. Typically this is the haptic or acoustic channel.

In this position paper a framework is proposed to support research and development of ETAs for visual impaired. In ETAs devices and software fulfill two tasks (1) acquisition of environmental information and (2) displaying them. For the display process the chosen information channel has to be tailored precisely. It should not disturb the function of the channel e.g. perception of the environment via sound in case of an acoustical display. On the other hand gathered information should be displayed to a great extent. Preferably research on information acquisition and displaying should be performed independently. The approach introduced here aims on an decoupling of these two tasks: The presentation subsystem can be developed using our environment-simulation as part of the framework decoupled from the data acquisition systems. Such an environment-simulation is implemented in current research projects by virtual environments, where the user can walk by mouse or keyboard input. These simulation-games provide sensor data gathered by virtual sensors in a virtual environment. Thus the tested presentation subsystem will display the virtually measured data. No direct dependency of the presentation subsystem to the sensor subsystem exists, allowing parallelized research. For the final integration-step the modular approach provided by the framework helps replacing the simulation subsystem by a real acquisition system. The modular architecture facilitates overall system optimization by selecting the best combination of a variety of different subsystem-implementations.

Environmental simulation may also be used to perform user studies. The simulator enables monitoring of (1) movement and (2) collisions with obstacles as quality metrics. Other advantages of simulations in complete virtual environments are: (3) repeatable environmental influences and (4) avoidance of real user interaction in dangerous situations. Serious disadvantages are: (1) simulations cannot cover the full range of possible situations and (2) simulating user behavior may be close to reality, but will never be exactly realistic. E.g. a head movement would optimize the

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perception of the position of a sound source placed in a three dimensional space compared to a fixed head (Wu et al., 1997). But in simulations with a keyboard as an input device, head movements are not as intuitive as they are in the real world. Providing a single open source simulation system for research groups working in that area removes duplicated work, helping development being focused on the key aspects of a project. Also an accumulated effort of a community driven project will lead to a far more advanced simulation compared to the scope of work a single research team can gain. An example of such a widely used framework in the domain of mobile robotics is the Robot Operating System (ROS)[1]. It combines a communication middleware as well as simulation environment and many modules implementing common algorithms as well as hardware drivers used in mobile robotics. It is an open source project supported by a wide community. Thus the decision to develop a framework for ETAs is justified. Section 2 outlines a few ETAs, the GIVE-ME framework and ROS. Section 3 lists requirements for an ETA framework, followed by a discussion of disadvantages and advantages of such a framework.

2 RELATED WORK

Dakopouls and Bourbakis divided ETAs into three categories based on their feedback interfaces. The categories for classification are “Audio feedback” , “Tactile feedback” and “w/o interface”. (Dakopoulos and Bourbakis, 2010) Given below three projects are described and categorized. After that the GIVE-ME framework and ROS are introduced as a basis for the intended framework. The Tyflos project assists visual impaired in navigation tasks and the environment recognition.

> “In particular, the Tyflos prototype integrates a wireless portable computer, cameras, range and GPS sensors, microphones, natural language processor, text-to-speech device, an ear speaker, a speech synthesizer, a 2D vibration vest and a digital audio recorder.” (Bourbakis et al., 2008)

Tyflos is a multi-modal assistance system which interacts via different input and output channels to gather or present information from the user. A tactile device to serve an output channel is the vibration vest. Like setting a pixel on a two dimensional monitor the vest vibrates on a two dimensional position. To gather information of the environment or get instructions from the user the project uses a camera or a microphone. This project is categorized as “Tactile feedback”.

Gomez Valencia developed a few systems to assist visual impaired and described them in his PhD Thesis. He developed a system to recognize street signs and read them to the user. This assists the user in case of self localization in a city. Additionally he developed an acoustic display to present different colors by different instruments. He developed an obstacle detection and a tactile input device, too. (Gomez Valencia, 2014) Because of the acoustic display for information presentation this project is categorized as “Audio feedback”.

The sound of vision project[2] did much research on three dimensional sound for acoustic displays. Therefor they developed glasses as a device to capture the environmental and present information to the user via sound. To provide their results to a community they plan a reusable sonification library and a reusable training serious game as part of their “additional outputs”. This project comes close to the intended open community. But it only provides the results with a library but not a whole framework with the possibility to exchange a device to test algorithms with other hardware. This project is also classified as “Audio feedback” even if it has a few elements of “Tactile feedback” by providing a haptic west.

Khoo describes a real framework. The GIVE-ME framework was developed under the key points of maintaining a simulation environment for devices with the intention to use gamification aspects in user tests to make the tests more interesting. He describes the framework with the simulator and the workflow of keeping this framework alive. (Khoo, 2016) But the last changes to his website were in March of 2016.

ROS is a framework for distributed systems driven by a large and vital community. The active community is a big benefit in contrast to the GIVE-ME framework. ROS provides the ability for modules to communicate or interact in different ways. E.g. a module encapsulates an algorithm or a device driver. The modules could be distributed over a network. ROS also implements different tools to analyze live data or replay recorded data. A mass of modules for typical problems in mobile robotics such as self localization or navigation are implemented and provided by ROS. ROS will be used as the basis for the intended framework because of its scope and the similarities between problems in mobile robotics and ETAs for visual impaired.

[1] http://www.ros.org/

[2] http://www.soundofvision.net/

3 REQUIREMENTS

ETAs are mobile systems a user have to rely on. Therefor there are several requirements which have to be fulfilled. The requirements presented in this section are derived from Dakopoulos's und Bourbakis's work in which they compared several ETAs developed in research projects (Dakopoulos and Bourbakis, 2010). This comparison is based on a list of features described in table 1.

Fast Data Communication. Communication between different devices like a haptic belt, an acoustic display, a 3D camera, etc. is time critical hence the framework has to supply a fast infrastructure. A slow communication would result in a delayed perception of the environment which could result in a collision or other dangerous scenarios.

Reliable Data Communication. Message exchange between modules has to be reliable. A message has to reach the destination without fail and must be accepted only once if an repeated message occurs. If the modules would communicate in an unreliable way the detection of an object possibly would not be reported to the user or it could be repeated at a time where the object is out of the way.

Platform Independence of the Framework. The platform a device is running on has to be transparent for the framework. T It could be reasonable to deploy one part of the system to a Linux platform and another part to e.g. an Android platform.

Close-to-Hardware Programming Abilities. ETAs can use user interfaces that have to be programmed directly (setting an output pin to start a vibration engine). But it could be an advantage to program the system with higher languages in case of rapid prototyping. Therefore a framework should be programmable on a higher level of abstraction (Python) and on a low level of abstraction, too.

Distributed Nodes for Different Tasks. The framework should follow a distributed system architecture for ETAs. This way the control of acoustic or haptic interfaces and their drivers can all be implemented as distributed modules which communicate with each other. An explicit description of module interfaces allows their exchange. The interface consists of data and services provided by a module. In case a navigation functionality should be implemented one can use a module for self localization and another for path planning and additional modules for engine drivers. The communication of modules should not be limited to one platform therefor a network communication should be provided.

Physical Layer Independent Communication. Especially in the context of a distributed system the communication should be independent of the used communication medium (WiFi, Bluetooth, CAN, ...).

Open Source. The framework should be open source. This way the development could be driven by a community.

Security. If the system would implement a face recognition based on a phone book then private data would be communicated. To ensure privacy of such data secure communication is essential. Data manipulation must be prevented. So security means also authenticity and integrity.

4 DISADVANTAGES OF AN OPEN FRAMEWORK

On ETAs resources are constrained due to mobility and small size. If a framework is used to develop ETAs developers may lose the focus to optimize the code for a constrained device. The complexity of a framework can be much higher than needed for a task. A device which is developed without a framework could reduce the power consumption to provide a higher battery life. There are also risks in the advantage of a community. If there will be no community formed, there is no advantage in this point. The acceptance of manufacturers would also improve the framework but is not necessarily predictable.

5 ADVANTAGES OF AN OPEN FRAMEWORK

The implementation of an open and distributed framework for the development of ETAs offers opportunities if the risks of a community and the acceptance of manufacturers eventuates.

Contribute and Exchange Basic Code

In the sound of vision project an audio game for sound localization was developed. With this game different auditive representations on navigational hints were tested and a suggestion to reduce front / back confusion in sound localization was proposed (Bălan et al.,

Table 1: Structural and operational features. The upper half for the user's needs, the lower half for the developer's and engineer's needs. (Dakopoulos and Bourbakis, 2010).

Feature	**Description**
Realtime	The system operates fast enough such that information exchange with the user is useful e.g. if an obstacle detection system needs 10 seconds to detect an obstacle that is 6 feet in front of the walking-user, then the device is not working in appropriate "real" time.
Wearable	The device is worn on the user's body or as a piece of his clothing. Wearable devices are useful for applications that require computational support while the user's hands, voice, eyes, ears or attention are actively engaged with the physical environment. The interaction between the user and the device is constant. Another feature is the ability of multi-tasking: users can continue their current tasks while using the device; it has to be integrable into all other actions.
Portable	The device has to be lightweight and small in size with an ergonomic shape so that the user can carry it without effort for long distances and time.
Reliable	The system functions correctly in routine but also in different hostile or/and unexpected circumstances.
Low-Cost	The device is (or it will be, when it comes to the mass production) affordable for most users.
Friendly	The device is easy to learn, easy to use and encourages the user to regard the system as a positive help in getting the job done.
Functionalities	The number and importance of the system's functionalities.
Simple	The complexity of both hardware and software is small. The hardware parts are few and simple to use (from the user's point of view) and simple to build (from the designer's aspect)
Robustness	The device is well constructed so it withstands difficult environmental conditions or hard use. Its functionality varies minimally despite of disturbing factor influences. It can still function in the presence of partial failures.
Wireless connectivity	The device is connected wireless to a computer (server/database) in order to continuously exchange information. Additionally, part of the processing needed for its operation can be done on the remote computer.
Performance	Overall performance
Originality	The idea and the methodology are original promoting scientific and technological knowledge.
Availability	The system is implemented. A device that is ready to use and real-time experiments can be performed e.g. a system that is only in the software stage is not available.
Future	Future improvements or enhancements

2015b). This way they developed a simulation to find the best auditive representation to use them in their device. A similar concept of a virtual labyrinth was introduced in the RaVis3d[3] project which began recently. If a realistic simulation environment would exist and other projects would propose their results and implementations with the same simulation environment, research projects could complement each other in a more effective way. This can be enabled by a common framework and a platform to exchange results and implementations.

Modular Architecture and Uniform Messages

In a framework based on ROS the architecture of ETAs would be modular. If the development is realized in a strictly modular way the advantage of exchanging modules with the same interface would be given. Even the maintainability would profit of this architecture. The interoperability between different devices would also profit by uniform message and service interfaces.

[3]http://ravis-3d.de/

Multimodal User Interfaces

The amount of information delivered by an device to a user's senses is restricted. E.g. an auditive display could display many information. But at some point the user would be distracted by the auditive information and natural signals like environmental sounds (cars, bells, ...) would be discarded. Thus there have to be more than one interface if the amount of data is to big. In parallel a tactile interface could be used to arrange the information between these devices. Another use case of using different devices is user training with feedback. This way Bălan et. al. trained users to optimize three dimensional audio localization with haptic feedback. (Bălan et al., 2015a) A framework enables changing and bind interfaces if the message and service interfaces are defined for different interface types.

Exchange User Interfaces

In every project it is possible to reach a point where a change of direction would be appropriate. In the sound of vision project they changed their presentation device from a stereo headphone to a self made headphone.

> "The conclusions from the spatial audio tests led us away from HRTF-based solutions towards the idea of the custom multi-speaker headphones." (Bujacz et al., 2016)

Such an change would be much simpler if interfaces are standardized. This way device drivers in operating systems are implemented for different classes of devices e.g. sound cards. With the same concept the interface of a device driver could be implemented for a 3D audio device by defining standard messages and services. This way a 3D audio device will be exchangeable. Appropriate presentation strategies (e.g. which frequencies should be used to display a position) are an important issue, too. As an example Coo and Cha developed a strategy to reduce front / back confusion to optimize sound localization (Koo and Cha, 2008). Exchangeability of strategies are worthwhile as well. In case of an existing framework such strategies could even be distributed between different research groups if they implement the same interfaces (messages and services). By this means a research group that wants to develop strategies to present data does not have to develop the device, and vice versa. Every group could concentrate on their main topic.

Distributed Computation

Gomez Valencia realized different projects during his PhD like an detection of letters, colors, objects and their presentation (Gomez Valencia, 2014). One point of his conclusion deals with the computational power. Parallel execution of his applications was restricted by the used platform. If the software would be based on a ROS like framework applications can be deployed on different hardware nodes and run in parallel.

Augmented Reality for Real Life Test Environments

The intended framework will implement a simulation environment. In this environment the usage of augmented reality is intended. This will allow a realistic movement of users in a simulation environment. Another benefit will be the usage of markers. When a marker is recognized its position, orientation and ID can be determined. E.g. a wall, a door or another obstacle could be detected. Markers can be placed in the real world to place virtual objects represented e.g. by a tone in the three dimensional space. By simulating this known environment a device could be tested in a realistic environment with realistic movements. By recording of camera data tests can be evaluated afterwards to improve results.

6 FUTURE WORK AND CONCLUSIONS

In this position paper a framework for the development of ETAs has been reasoned. Both the development and the research on ETAs profit by such a framework with improvements in user tests and exchange of results. The first step in the development process of such a framework is to evaluate whether ROS matches all requirements mentioned above. If so several sample applications and devices will be implemented and integrated to show the benefits of a framework for ETAs. The intended architecture is shown in Fig. 1 showing the main part of the framework as light gray elements. The dark gray elements illustrate the parts that should be developed and implemented by the community such as human interface devices with their related drivers and algorithms.

In the development of device drivers a uniform interface of the devices is a big advantage. By that means quality and maintainability of software in ETAs will be enhanced. A strict modular approach allows independent testing and deployment on inter-

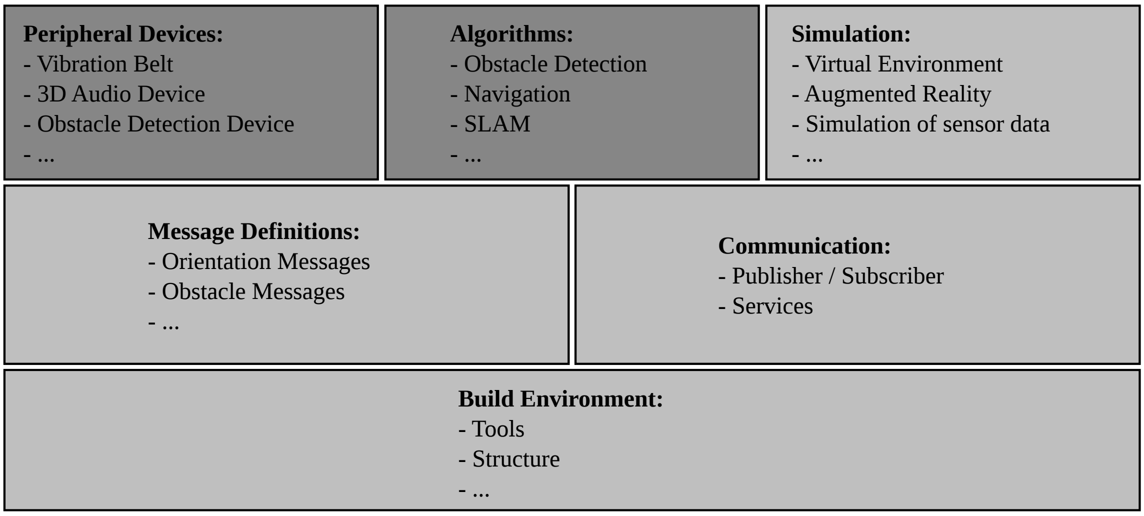

Figure 1: Overview of the intended framework. The light gray areas describe the framework itself with simulation, message formats, communication and build environment. The dark gray areas describe the community driven parts of the framework such as human interface devices as peripherals and algorithms.

connected distributed nodes. Communication modules and basic devices with its drivers will be implemented within the framework. So development efforts would be reduced by using existing modules for different tasks. During user tests of human interaction devices the main point of research projects should be the development of such a device and the method to present the data. This achieves optimal results in the task of interacting with the user. Usually research projects are restricted in time. If the development of a simulation environment or the communication between modules were part of an project, this task would consume time and costs. In providing such an environment as part of a framework this time could be saved and spent more goal-oriented. Additionally the results of different research groups are more comparable by using the same simulation environment. We think ROS is a good basis for such a framework for ETAs because of the similarity of requirements and constraints in mobile robotics and ETAs for visual impaired. ROS provides already many modules for problems in the areas of navigation, communication, self localization and image or sensor data processing. Evaluating the applicability of ROS for ETAs is worthwhile.

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