SONIFICATION AS A TOOL TO RECONSTRUCT USER'S ACTIONS IN UNOBSERVABLE AREAS

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ABSTRACT

This paper deals with the sonification of log data gathered during a field test of an innovative toilet system. These tests have been carried out in a day care center for multiple sclerosis patients in winter 2004/05 in the framework of the EU funded Friendly Rest Room project (FRR). For ethical reasons, no direct observational data are at hand to validate the design concept. We will show a way to solve this dilemma by sonification of the log data. This sonification must be designed in a way that enables the researcher to reconstruct the user's actions s/he could not directly observe.

1. INTRODUCTION

Researchers in social fields, be they sociologists, psychologists or design researchers, sometimes face the problem of studying actions in an area which is not observable due to ethical considerations. This was especially true in the context of a RTD project (Friendly Rest Room – FRR), which was partly funded by the European Commission. The project's aim was the development of a useful and easy to use toilet for older persons and persons with (physical) disabilities. In order to meet that objective an interdisciplinary consortium was set up, bringing together specialists of various backgrounds like industrial design, technical engineering, software engineering, user representation as well as social scientists.

In the final stage of the project, a prototype was installed at a day care center for patients with multiple sclerosis (MS) in Vienna in order to validate the design concept in daily life use. This paper deals with the sonification of log data gathered during this validation phase. Being unable, for ethical reasons, to gather observational data, the log data provide us the sole way to get an insight into the actions taken by the user. It is these actions we are interested in, as they provide information on the user's interaction with the given technical equipment, and thus on the usability and usefulness of the toilet system.

As part of a research project which is up to develop a generalized sonification environment ("SonEnvir", [1, 2]), these log data are currently being sonified, thus providing a reconstruction of the events that the sensors installed in the toilet environment indicate. Preliminary results of the sonification suggest that it will enable us to take a heuristic step forwards in the investigation of how users interact with the given toilet system prototype, an insight that presumably would not have been gained without the sonification.

Though sociology was always considered as a promising field of application [3], sonification to date is not widely known within the social sciences. Thus, a purpose of this paper is to raise the awareness of the benefits sonification can bring to social research by describing a realization of a sonification in the context of a sociological research question.

2. TECHNICAL BACKGROUND

The guests of the mentioned day care center are patients with varying degrees of MS; some need support from nurses when using the toilet while others can use it independently. Due to security considerations as well as for pragmatical reasons, not all components developed within the FRR-project were selected for this field test [4]. The main features of the installed conceptual prototype are:

- Actuators to change the height of the toilet bowl, ranging from 40 to 70 cm.
- Actuators to change the tilt of the toilet bowl, ranging from 0 to 7 degrees forward.
- These actuators can be controlled via a hand-held remote control comprising six buttons: toilet up, toilet down, tilt up, tilt down, as well as flush and alarm triggers.
- The toilet has two horizontal support bars that can be folded up manually.
- A new type of door handle easier to use for people with physical disabilities was mounted on the outside of the entrance door.

Figures 1 & 2: *Pictures from the toilet and the remote control used at the field test.*

Since direct observation of the user's interaction with the toilet system was not possible, several sensors were installed in the toilet area that continuously log the current status of the toilet area. These sensors record:

a) the height of the toilet bowl (in cm, one variable),
b) the tilt of the toilet bowl (in degree, one variable),
c) the status of the buttons of the remote control (pressed/not pressed, six variables),
d) the status of the entrance door (open/not open, one variable); further,
e) we provided the guests of the day care center with smart cards (RFID mid range technology) and mounted a user identification module in the toilet area, thus registrating the identity of the present person (four cards can be detected simultaneously).

The log data matrix resulting from this sensor is of rather high complexity, especially due to its time resolution (about 0,1 sec) and the sequential properties of the information transported by the data. It is comprised of about 25 variables, of which 11 are primarily relevant for our analysis. These are the ten variables described above plus the timestamp. Of these eleven variables, seven are binary. Each log file records the events of one day. In case there is no event for a long time (e.g. during the night where the Day Center is closed), a so called 'watchdog' implemented in the software is giving a signal every 18 minutes.

As it is our goal to exploit the log file as a source of the user's actions, we have to reconstruct sequences of actions of a user out of the mere technical indications of events registered by the sensors. The technical data must be interpreted in terms of user's interaction with the equipment; otherwise the toilet prototype cannot be evaluated. The technical data themselves are not sufficient for validation, as we need to validate whether or not the proposed technical solution results in an improvement of the user's quality of life (which clearly is a social phenomenon). Therefore, we need to figure out unobserved actions of users on the basis of the logged technical events.

Due to the sequential character of the information hidden in the log files, established and well-known routines from the realm of multivariate statistics cannot be applied as they usually abstract from the time sequence of the initial data set and condense and recombine information regardless of its sequential character.

3. STEPS OF ANALYSIS

3.1. Step 1: Graphical Screening

On a graphical display, on the contrary, it is not very easy to follow the sequential order of the events, above all because such a sequence implies several variables. Yet, as the first step of analysis, we will rely on graphs with the purpose on identifying episodes. An episode in our context is defined by a user's visit to the toilet. The prototypical minimum episode implies the following logged events in the described order:

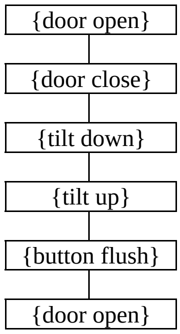

Figure 3: *Prototypical minimum episode.*

This prototypical episode is characterized by the fact that the height and the tilt of the toilet bowl are not changed via remote control. It is the chain of events that would be measured if the Friendly Rest Room prototype would be used like a standard toilet, i.e. without making use of its supportive properties. The logged events {tilt down} and {tilt up} result from the weight of the person sitting on the toilet.
In the first step of analyzing the data material, we use graphical displays looking for sections that can be identified as a user's visit to our toilet prototype (i.e. as an episode). Therefore, we use the scheme described in figure 3 to single out episodes that built up our new entities of analysis. The episode displayed graphically in figure 4 is an example of such an episode. It is obvious that the graph is not easy to interpret due to its complexity, here also additionally complicated by the lack of colors. It further should be noticed that this graph represents only a minimum episode. But, more important for our purpose, the sequential character of the events is not easy to follow with the eye. One can see that the starting event is that the door opens and then closes, followed by the event that the toilet bowl tilts forward (the tilting degree grows) without the respective button on the remote control having been pressed. We can assume that the person is now sitting on the toilet. After the weight has been removed (the person stood up), the flush is pressed twice and the door opens again. The other variables remain unchanged.

3.2. Step 2: Investigating patterns of use

As we are interested not primarily in the way a single person behaves in the Friendly Rest Room but rather in the question if people, for instance due to a similar physical limitation, show similarities in interacting with the given technical equipment and consequently action patterns of various user groups, we are eager to cross-reference the log-data with data from other sources. Characteristics like sex, weight, age of a person, her/his

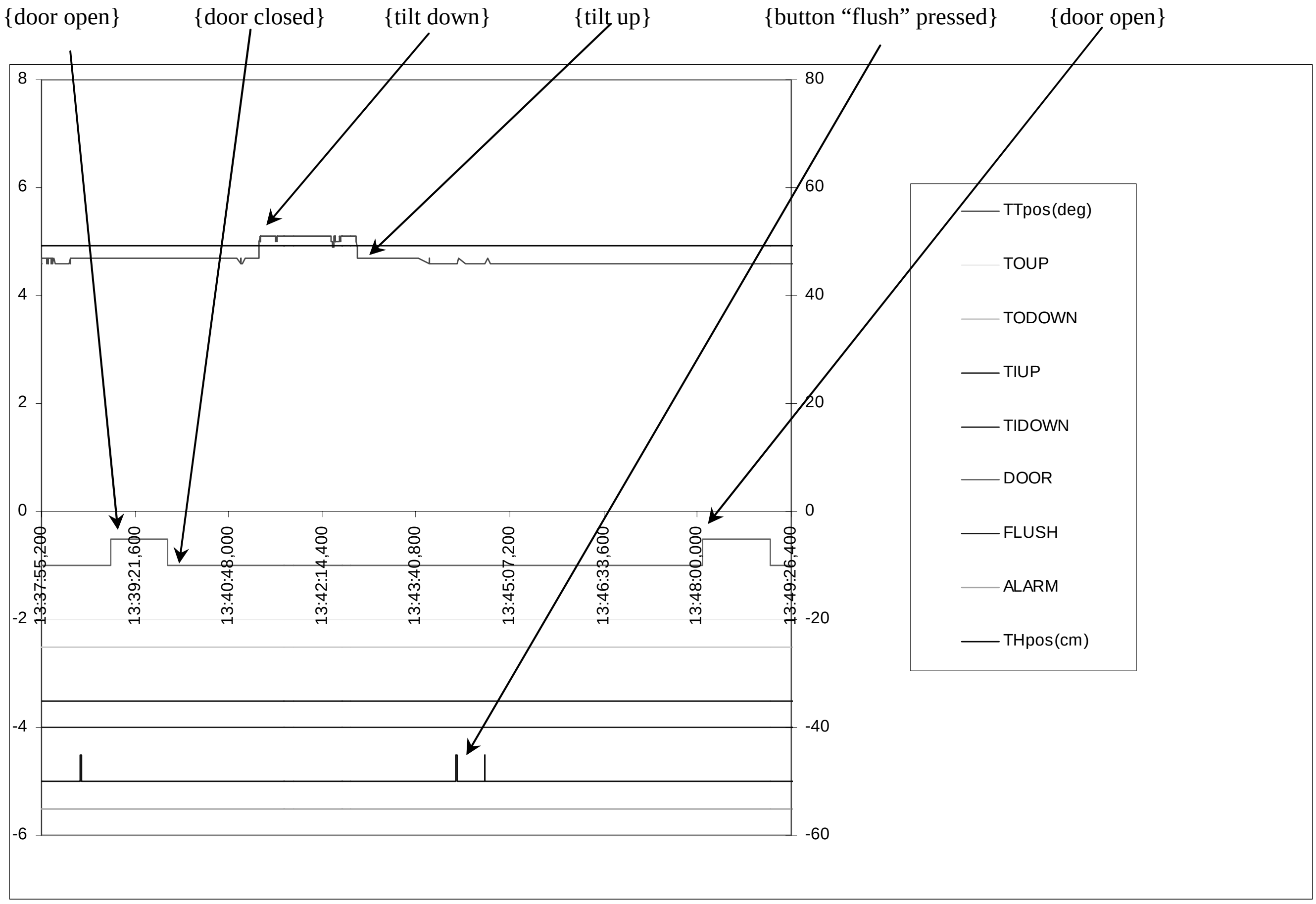

Figure 4: *Graphical display of one episode.*

physical and cognitive limitations, additional information like whether s/he is using a wheelchair, crutches or whatever are important to widen the interpretation and give room for causal assumptions.

For this purpose, a user identification module was mounted behind the cover of the water reservoir of the FRR toilet prototype. It enables us to relate the reconstruction of the actions undertaken in the Friendly Rest Room by the user with other information about her/him.

One simple example might show why this can be of importance for us: usually, people who use wheelchairs need more time than non-wheelchair users to open a door, enter the room and close the door again. This is partly caused by the space needed to manoeuvre the door when sitting in the wheelchair, partly by the fact that standard door handles are hard to use (especially when, as it is the case with MS, people have restricted mobility in their arms). Therefore, if an analysis delivers the result that the time needed by wheelchair users to enter the room (defined by the time the door is open) is at average shorter than with a standard door, we can conclude that the FRR door handle provided at the field test is easier to use for wheelchair users than standard ones.

In this context, we further can identify patterns of use and possibly relate them to characteristics like the mentioned above. These patterns are not only of crucial importance for the evaluation of the given equipment, but also in the respect described in the following paragraph.

3.3. Step 3: Comparing anonymous episodes with patterns

The problem with the mentioned identification module is that, due to the metal construction of the prototype, it is working only with a restricted range of about 50cm around the toilet. The consequence is that not every person using the toilet is identified by the smart card. We thus have 'anonymous' episodes for which we do not have the opportunity to relate them to data from other sources. In our heuristic perspective, these data are more or less useless. As this applies for 53% of the 316 episodes, this certainly concerns the validity of our results.

Therefore, it was decided to study the episodes of identified users in order to find patterns that possibly further our ability to identify anonymous episodes. For some of the anonymous episodes, direct identification is possible, as the identification module one day but not the other can detect one and the same user. For others, most likely for users who did not use the prototype often, we can rely on conjecture based on the knowledge we could derive from the episodes of identified users. By comparing it with the patterns identified in step 2, we make use of the 'anonymous' episodes – we analyze it by approaching it with empirically founded categories.

4. SONIFICATION DESIGN

The sonification of the described log data is designed as follows: In case the door is open, a colored noise similar to diffuse ambient outside noise plays which fades out when the door is closed. When the buttons of the remote control are pressed, height control and tilt control events (up or down) play looping glissandos, up or down, identified by different basic pitch, glissando rate, and timbre. The alarm is represented by a doorbell-like sound. For the flush button, we chose (for obvious reasons) a noise burst as the representing sound event.

Current (static) tilt and height are both represented as soft background drones and turned louder when there are changes; then they recede again.

In order to simplify learning for the users of this log sonification, both state variables (door open/closed, current height and tilt) and the FRR user control interface are also represented visually: Button presses are indicated as GUI (Graphical User Interface) buttons that light up when pressed (in the log), and absolute height and tilt levels are displayed numerically as vertical sliders. This gives the data users a choice of mainly following visual or acoustic cues; once the audio cues are learned, temporal patterns may be easier to infer from them.

Choice of data log(s), playback time scaling, event volume levels, and other tunable parameters are currently set from scripts only, which also serves as documentation of particularly useful settings; as we acquire more data user experience, recommended settings for specific aspects will be provided.

4.1. Implementation

Prototypes for the log reader, the sound synthesis and event scheduling, and the visual display have been implemented in SuperCollider3 [5]; the current sketch for the GUI looks like this (see figure 5):

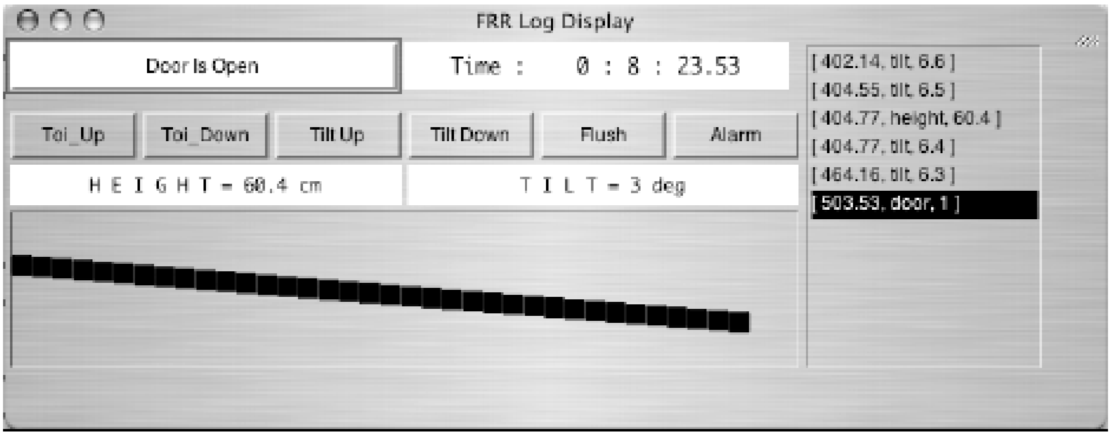

Figure 5: *Screenshot of the GUI*

5. CONCLUSIONS

In this paper, we propose to use sonification as a tool for reconstructing actions of users in unobservable areas. These actions are of major interest when having to validate a design prototype. However, when having to exploit technical log data, established tools like statistical routines or graphical display fail to deliver insights at the desired level of complexity. Sonification possibly provides a way out of this dilemma.

It is noticed that the time scaling of events helps understanding the meaning that lies behind the sequential order of events. Especially the time between events, the breaks, are instructive as they possibly refer to problems of the user with the given equipment.

In the described context, sonifying log data can be of scientific value in two respects: First, it provides a first basic tool for reconstructing the sequence of events and assuming the actions of the user these events might refer to. Second, these reconstructions might help us to level out systematic missings. Though our starting point, the FRR-project might be seen as relatively unique, we argue that the use of sonification as a tool for reconstructing unobserved behavior (be it human or not) can deliver valuable results in different contexts than ours, too.

6. REFERENCES

[1] See: http://sonenvir.at

[2] A. de Campo, C. Frauenberger, & R. Höldrich, "Designing a Generalized Sonification Environment," *Proc. 10th Meeting of the International Conference on Auditory Display*, Sydney, 2004.

[3] See e.g. G. Kramer, "An Introduction to Auditory Display", *Auditory Display: Sonification, Audification, and Auditory Interfaces*. Reading, Menlo Park etc., 1994.

[4] P. Panek, C. Dayé, G. Edelmayer et al., "Real Life Test with a Friendly Rest Room (FRR) Toilet Prototype in a Daye Care Center in Vienna – An Interim Report, " t.b.p. in *Proc. 8th European Conference for the Advancement of Assistive Technologies in Europe*, Lille, 2005.

[5] http://sourceforge.net/projects/supercollider/