OPTIMIZING AESTHETICS AND PRECISION IN SONIFICATION FOR PERIPHERAL PROCESS-MONITORING

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ABSTRACT

We have developed the *SoProMon* process monitoring system to evaluate how real-time sonifications can increase awareness of process states and to support the detection and resolving of critical process situations. Our initial design conveys analogue information as process-data-driven soundscape that users can blend out in favor of a primary task, however the sonification attracts the user's attention even before things become critical. As result of a first user study we gained and present here insights into usability and acceptance of the sounds. Although effective, the aesthetic qualities were not rated highly. This motivated us to create a new design that sacrifices some functional aspects to emphasize long-term use compatibility. We present and compare the new designs and discuss our experiences in creating pleasant sonifications for this application area.

1. INTRODUCTION

Real-time process monitoring is becoming increasingly important for companies and organizations. In consequence, companies and organizations provide an overview of their processes using visual means such as graphs and charts. Since users cannot keep an eye on these visualizations at all times while performing other tasks, they either are bound completely by the task, or they risk to miss critical events or alerts or perceive some with delay. In the case of auditory alerts, alarms/warnings normally come only after a condition has become critical, which is rather problem-solving than problem-anticipation and prevention.

2. THE SOPROMON SYSTEM

We acknowledge a large body of work on sonification for process monitoring [1, 2, to give few references]. Yet no system is available at the time for us to systematically research auditory displays, flexibly manipulate complex stimuli and to reproduce situations for study participants. For that, and furthermore to test how sonification and combined sonification and visualization affect users in 'monitoring as secondary task' settings, we developed the *SoProMon* system, using an 'adding numbers' main task and (for a first process model) the visual display of a simulated process involving a graph of six interconnected machines as depicted in Fig. 1. Our sonification design, called *process-data-driven soundscapes* represents any elementary machine action (e.g. production steps) as a machine-specific sonic grain. We chose forest sounds (birds, water drops, cracking branches, bees, etc.) so that the overall soundscape fuses into a texture corresponding to this environment. Furthermore, parameter mappings modify the sounds in sound level, frequency and brightness according to the related in-/output buffer levels or maintenance needs. On startup, users adjust individual sound levels so that the sounds are slightly above the threshold of conscious hearing. Thus the sonification remains in the periphery but available during the absence of problems. We have described the system in detail in [3].

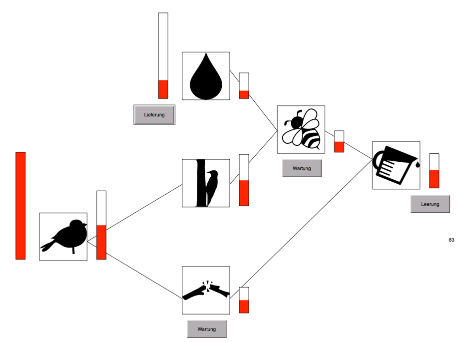

Figure 1: Visual display of our *SoProMon* test simulation process involving six machines. In-/output buffers are represented with red fill levels, machine color depicts error states, buttons can be pressed to resolve problems. (see interaction video S_0 on the accompanying website[1])

3. EVALUATION

To test our approach of process-data-driven soundscapes we designed a within-subject study using two (perpendicular oriented) screens for main and monitoring task. 18 subjects had to operate the system for 10 minutes each under the conditions visual display-only, state-of-the-art auditory displays (i.e. alarm sounds), and sonification (i.e. our soundscapes plus the alarm sounds). For all conditions the identical visual display was available as problem solving consisted in clicking specific buttons in the GUI.

The large amount of empirical data will be analyzed and discussed elsewhere. For this paper we focus solely on the questionnaire results regarding the pleasantness and acceptance of the sound.

3.1. Questionnaire Results on Pleasantness & Acceptance

Our questionnaire contained several items that implicitly or explicitly concern the sound design. These items can be roughly categorized into three types of questions: such that ask if our sound design is disturbing (e.g. if the sounds were perceived as disruptive, obtrusive or irritating), items that ask if our sound design is aesthetically pleasing (e.g. if our sounds were pleasant, euphonious or if the subjects could imagine using our system for a longer period of time) and questions that relate to the information aspect of our sonification (e.g. if the sounds and mappings are informative, helpful, understandable, logical or intuitive). The different items were measured with a Likert scale from 0 (do not agree at all) to 10 (fully agree).

It is interesting that the average of the items that are related to acoustic disturbance is higher (5.0±2.1, $q_{50\%}$=5.2), than those associated with the sound design being pleasing (4.3±2.2, $q_{50\%}$=4.6). However, the feedback related to information aspects of our sonification was in average quite positive (6.7±1.9, $q_{50\%}$=7.6). Thus, if one would summarize these findings in a simplified manner: our sound design was moderately obtrusive and unpleasant, but it worked (see Fig. 2). This is also supported by quantitative empirical data on user performance, which will be presented elsewhere.

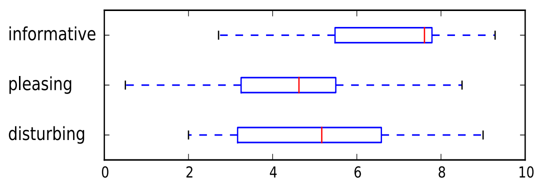

Figure 2: User feedback concerning the sound design

Verbal comments of two subjects further suggest that the distraction of our sound design will decrease with further usage and that performance will increase. However, on the other hand another subject stated that he would "go crazy" listening to our sound design for a longer period of time. Three subjects stated that two of the selected machine sounds were too similar to differentiate.

4. ECOLOGICAL STREAM-BASED SOUNDSCAPES

From the background of these questionnaire results we revisited our initial sonification approach. We identified that an important cause for the low pleasantness lies in the high regularity of event repetitions – which is due to the inherent repetitions of machine executions. Thus, the soundscape has limited variability as compared to realistic forest soundscapes. Our approach for a redesign was to sacrifice accuracy on the detail level of machine executions, and instead to use longer sound samples of several minutes lengths to represent each machine, but at the same time using our already established mappings to 'charge' the sample loops with sonic cues that allow listeners to stay aware of changes and to anticipate critical situations (sound example S_1, see website[1]). Furthermore we considered the following alternatives to the forest soundscapes: first, a soundtrack where specific musical instruments (timbre) represent machines and motifs (i.e. earcons) and where these motifs are systematically modified with criticality (sound example S_2). Finally, we used jungle sounds for a tropical forest soundscape which offers a larger variety of animal sound streams (sound example S_3). On our website[1] these can be found together with our SoProMon baseline video example S_0.

[1] Sound examples at http://doi.org/10.4119/unibi/2752965

5. DISCUSSION & CONCLUSION

Concerning the pleasantness, the alternatives S_1 – S_3 subjectively appear more variable, more complex and thus less 'mechanic'. This evaluation may be different on longer-term use, and subjective annoyance may change with time.

Concerning the interference of sounds with the acoustic environment, it may be argued that particularly the bird sounds may also be part of everyday environments and thus conflict with the auditory display, i.e. users might wrongly interpret real environmental sounds as sonification.

From a functional point of view we regard it as likely that the new variations might also be quite functional in drawing the listener's attention to the processes, particularly when the sound level exceeds by far the typical baseline. An important issue is the overall sound level: all soundscapes are designed to operate just above the threshold of listening during regular operation, so that they normally almost 'disappear'.

On reviewing jungle sounds we were surprised that they often feature highly regular patterns, i.e. clear rhythms of animals voices (e.g. crickets, certain birds). From that observation we regard it as quite promising to aim at an hybrid approach, i.e. to combine our original event-based SoProMon approach with the looped samples approach, in line with previous work by [4].

After further optimizations we aim at better understanding the function/aesthetics design space by user studies. Specifically, we'd generally expect higher ratings on pleasantness for all alternative versions (S_1–S_3), yet we'd assume S_2, the musical version, to become faster disturbing. Only quantitative tests can show whether the new designs will at the same time provide the information surplus that we have encountered with the SoProMon baseline sonification (compared to the state-of-the-art auditory alarms). However, that was the reason for creating the *SoProMon* system in the first place: to allow systematic tests towards a stepwise improvement of multimodal monitoring and basic research in sonification.

6. ACKNOWLEDGMENT

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