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T. Hildebrandt: Towards Enhancing Business Process Monitoring with Sonification
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Towards Enhancing Business Process Monitoring with Sonification

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Abstract. State-of-the-art business process monitoring systems usually base on different types of real-time visualizations, in which data is typically presented using various graphical elements such as speedometers. However, these systems have several drawbacks, such as the inability to constantly monitor process executions while at the same time working on other things. This is why this paper proposes to enhance visual process monitoring with techniques from the area of sonification (the presentation of data using sound). Even though sonification has already successfully been evaluated in several domains for real-time monitoring, there is so far no comprehensive research for its usage in business process monitoring. This paper proposes sonification techniques and user interactions that can be implemented in future applications.

Key words: Business Process Management, Business Process Monitoring, Process Visualization and Sonification, Multi-modal displays

1 Introduction

For most of today's businesses, it is very important to be able to monitor their process executions in real-time in order to be able to quickly adapt to arising problems or deviations during execution to obtain a current overview over their processes', and subsequently their businesses' performance. Current state-of-the art business process monitoring applications (such as e.g. ARIS Process Performance Manager or IBM business activity monitoring) base on dashboard and cockpit views that aggregate single process execution events and present them in real time, using visualization techniques such as speedometers [1]. Users who have an interest in monitoring process executions (such as technicians or managers) usually pay attention to these dashboard overviews periodically, while at the same time interrupting other activities they are working on. This has the drawback that users only learn about possibly time critical process events when they next look at their monitoring application or, in case users are constantly monitoring their dashboard application, that they cannot effectively perform other tasks while at the same time getting informed about occurring process events.

Process monitoring is typically a passive activity, which is usually being performed while concentrating mainly on another task (in contrast to e.g. process

analysis, a task that users typically dedicate their full attention to). However, visual means are often not ideal for areas in which monitoring occurs in parallel to other activities, as they require our visual focus and thus make it difficult to work on another task at the same time. Therefore, this paper suggests to combine existing visual process monitoring techniques with methods from the area of sonification in order to tackle some of the mentioned drawbacks of current process monitoring. Sonification is "the use of non-speech audio to convey information" [2] and has a few characteristics that make it especially suitable for process monitoring:

- It allows the visual focus to be elsewhere, allowing users to work on another task while getting informed about process performances.
- Humans are very sensitive to even small changes in rhythms and sequences because sound is inherently a temporal medium, while visualization is primarily a spatial medium. This makes sonification very suitable to convey information that changes over time, such as process execution events or KPIs (Key Performance Indicators).
- Sound is very suitable for attracting attention in possibly time-critical situations, which is why sound is typically preferred over visual means for alarms and alerts.

Due to these characteristics, several researchers (such as [3]) argue that audio is more useful than video in cases of peripheral monitoring activities which are performed as background tasks. Studies, such as e.g. conducted by [4], suggest, that while only under certain conditions are sonifications better suited to convey data than visualizations, in a majority of cases multi-modal displays combining visual and auditory elements yield better results than each modality alone.

Thus, even though it seems natural to complement current visual business process monitoring systems with methods from sonification, there exist only a few first approaches into this direction ([5, 6]).

The paper at hand paper complements a previously published paper [7], which introduces the peculiarities of business process execution data and the tasks that are typically involved in process monitoring. It also analyzes in detail the different sonification techniques and methods that have already successfully been applied for monitoring applications which base on similar tasks and data structures as business process execution data. This paper, on the other hand, focuses on giving a more general introduction into the strengths and weaknesses of sonification for process monitoring as well as on introducing an initial suggestion for a mapping of process execution data to sound, as well as possible user interfaces to control the sonifications.

2 Sonification in Process Monitoring

Due to the specific characteristics of sound and our listening capabilities that have been presented in the introduction, sonification has been researched and

applied in various disciplines, especially for purposes of real-time monitoring. Application areas of sonification in monitoring are e.g. industrial production processes (e.g. [8]), network and web-server behavior (e.g. [9]) or computer program execution and debugging (e.g. [10]). Several conducted studies proved the effectiveness of sonification for monitoring purposes. In [11] sonification has been applied for the monitoring of an assembly line. The authors concluded that users who had visual as well as auditory feedback were able to perceive more information than those who had visual information alone. Experiments conducted by [10] and [12] indicate that a developed musical sonification of program executions was useful for bug location and detection tasks.

Concluding, sonification has already successfully been applied to several application domains that have similar challenges and data structures as business process monitoring. It has however, apart from a few first considerations ([5, 6]), so far not been applied specifically to this task. Gaver et al. [8] sonified the events that occurred at a factories' individual work stations, which successfully helped users to monitor the status of ongoing processes. However, their sonification does not consider business-process-related constructs such as process models and -instances or KPIs. What is therefore missing is research concerning the domain-independent usage of sonification for business process monitoring. Such a sonification should not only consider the single events that occur during instance executions, but should also enable a sonification of continuously updated KPIs.

3 Business Process Monitoring using Sonification

During business process monitoring, companies want to keep informed about the performances of currently executed process instances and critical events that occur during the execution. Sub domains that could specifically benefit from novel monitoring techniques are probably manufacturing and logistics processes. When executing complex, company-spanning production processes across the whole supply chain it is essential, both for suppliers and customers, to obtain real-time information concerning status of production and logistics as well as being informed about situations that might delay the final delivery date (such as delays in transport or stock shortages). Therefore, it is planned to evaluate prototypical multi-modal monitoring systems in the context of the Adventure project (http://www.fp7-adventure.eu/), which focuses on creating a framework to combine and monitor virtual factories in a pluggable way.

One aspect that will be considered when developing the system is that not every user is interested in the same process information. Technicians or people working on concrete process activities are typically more interested in low-level information, such as individual events that occur or specific error or warning messages. Managers on the other hand are often less interested in the individual events, but want high-level overviews over process performances. In order to address the information needs of the different users groups, the users should be able to adjust the data granularity level of the sonification.

This paper proposes a multi-modal solution that combines visualization and sonification. During normal operation, the sonification will sonify occurring events (for which users will be able to specify the level of detail and types of events they are interested in) and notifications and alerts as *sound events* whenever they occur. KPIs on the other hand are being sonified by continuously updated *sound streams*. In general, the sonification should distract the users as little as possible from their main work. Different types of events (such as the starting or stopping of activities, variables changing their values or occurrences of notifications and alerts) will be sonified with different sounds, enabling the users to decide if they direct their immediate attention to their process monitoring application in order to take respective actions. If e.g. certain notifications or alerts are sonified, a KPI suddenly changes its value, or other peculiarities occur, the users attention is attracted. They can then use the visual dashboard of their engine to e.g. search for the root cause of an error or read the detailed text of a notification. Users will not only be able to react to occurring problems in real-time, but in certain cases might even be able to anticipate such situations before they occur (e.g. if an activity takes substantially longer than usually, or if the value of a KPI is constantly rising). Other positive effects might include e.g. that when the activities of a process are usually executed in the same order, a user might get used to hearing the respective acoustic events in that order and might immediately notice it if that execution order is different than usual.

A first prototype has been developed that sonifies execution events as they occur. The sonification bases on the principle of Earcons, where each event type is assigned to a different sound event. In this case, the sound events are short melodic sequences that are based on the principles of musical contour (the direction and shape musical notes move in) in order to increase recognizability, as previous research (like presented in the previous section) successfully applied melodic Earcons for event-based sonifications. However, for further prototypes, sonifications based on different techniques (such as Auditory Icons or non-musical Earcons) will be developed as well. Example recordings of this prototype can be found under:


http://soundcloud.com/tobias_hildebrandt/

The recording "Event types" [1] contains a sonification of five different event types in sequential order ("activity started", "variable changed", "warning occurred", "error occurred" and "activity finished"). Most melodies in this example have been played in the same instrument (piano), except for "variable changed" and "error occurred". The developed prototype uses different instruments in order to convey the information in which activity the respective events occurred (or, in the case of events of the type "variable changed", which variable is concerned). Thus, if two events are being sonified using the same instrument, it means that they both occurred while executing the same activity. The second example "Activities" [2] shows different events of the same type ("activity started") that are all played with different instruments, meaning that these events are re-

[1] direct link: https://soundcloud.com/tobias_hildebrandt/event-types-contour-1
[2] direct link: https://soundcloud.com/tobias_hildebrandt/event-types-contour

lated to different activities. The "Event sonification examples" 1, 2 and 3 (Link to example 1, Link to example 2, Link to example 3) show different sonifications of a sample processes' execution. The first example contains a warning in the second activity. In the second example, an error occurs instead of the warning and therefore the second activity does not finish. In the third example, no errors or warnings are occurring, and subsequently the second activity is finished before the first one. First informal user evaluations suggest, that if always the same instrument is used, the different event types can be distinguished and memorized very well, even after only rudimentary instructions. However, especially with a high frequency of occurring events, the telling-apart of the different event types becomes more difficult as soon as different activities (and thus different instruments) are involved. However, it seems that user performance increases with training time.

In general, it can be expected that in companies that run processes in which a high number of events occur, a sonification of all individual events (as presented in the example recordings) would not be very helpful and probably also annoying and distracting. On the other hand, for processes in which only a few events per day occur (such as for processes whose tasks are mainly executed manually) such a sonification might be beneficial. However, even for cases that are suitable to convey individual event occurrences using e.g. Earcons based on musical contour, it probably makes sense in terms of perception to only play a very limited number of notes simultaneously (if any). What this paper proposes instead is to queue occurring events in order to play them sequentially, perhaps starting with urgent events such as alarms. Therefore, not only the level of detail should be adjustable and filterable in real-time, but also how the individual events and KPIs are mapped to sound, thus e.g. taking into consideration aesthetical preferences of the users as well as data density. The system will thus be built in such a way as that it enables the exchange different modular Sonification Components, which can base on different sonification techniques and methods. Therefore it will be possible to flexibly select the sonification techniques that are best suited for a specific company and its individual users.

Figure 1 shows a conceptual view of the proposed system architecture. The central component will be the Monitoring Component, which collects occurring process events from different sources, pre-processes and sends them, according to the users' settings, over the messaging protocol OSC (Open Sound Control) to different Sonification Components. Each user can access a customized web interface where he or she can adjust the mappings from data to sound, filters and other settings that will directly effect his or her personal sonification.

Figure 2 shows a mock-up of how a part of such a customization interface might look like. The user interface should allow to adjust the way process events are sonified as well as to customize what is conveyed in what detail during run time. These settings will apply to what is being sonified, as well as what is displayed in the graphical user interface. Thus, if users e.g. hear an auditory event that sonifies the occurrence of an event of a specific type, they directly can read the detailed event description when they open their GUI.

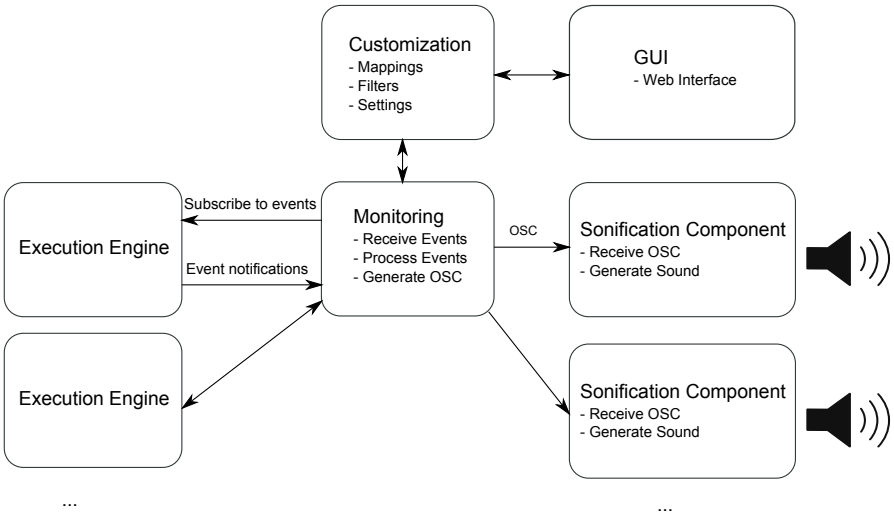

Fig. 1. Architecture proposal for multi-modal process monitoring

The left side of the screen shows how detailed settings for the event sonifications (in this case specifically events related to the data flow) could look like. On the right side, the overview for the settings for the KPI sonifications can be found.

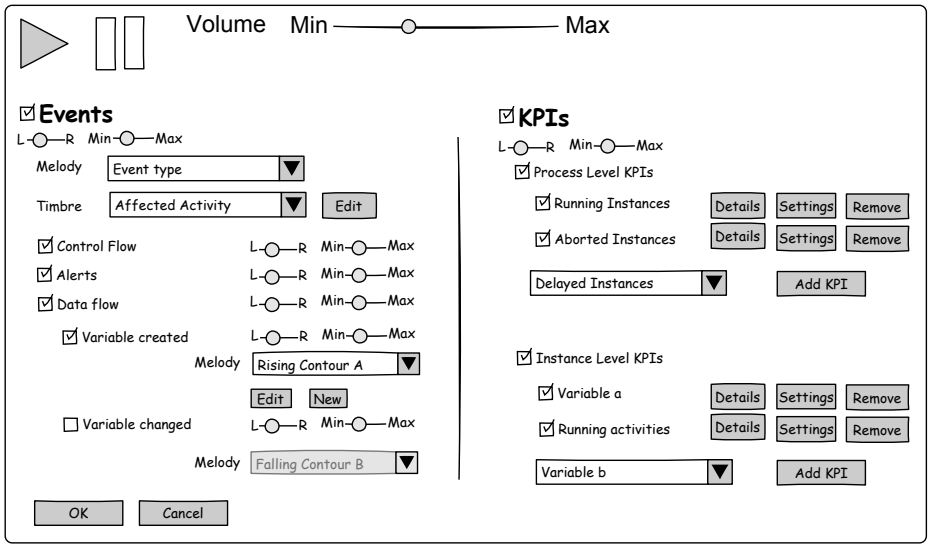

Fig. 2. Possible menu options for multi-modal process monitoring

4 Conclusion and future work

Applications that enable real-time business process monitoring usually are built around different types of visualization, which do not in all cases enable optimal user performance. Visual monitoring applications are e.g. often not suitable for time critical notifications and in general do not allow users to effectively work on parallel tasks while monitoring process executions. Sonification, the presentation of data using sound, offers certain characteristics (such as the ability to perceive sound passively while concentrating on other things) that make it seem extremely suitable to enhance visualization in business process monitoring. As sonification has already successfully been evaluated for the purpose of monitoring in different application domains, it seems plausible that some of those results can be transferred to business process monitoring. This paper therefore tries to lay the foundation for such a multi-modal process monitoring system by suggesting sonification techniques and a user interface that will be implemented in the near future. The next steps are comprehensive user evaluations for the proposed sonification techniques as well as for the user interface and the user interaction. An important aspect to consider when conducting these evaluations will be to recreate conditions that are as life-like as possible, meaning that it should be taken into account that users typically will perform other tasks in parallel to monitoring.

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