On Applying Sonification Methods to Convey Business Process Data

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Abstract. Visualization of business process models with large numbers of process activities and running instances in different execution states shows various limitations. Hence, using sonification methods becomes a promising idea to enable users to gain insight into process information that cannot be conveyed by using purely visual means. This visionary short paper aims to envision the usage of sonification methods in order to represent business process-related data in all phases of the process life cycle. Sonification methods are presented and analyzed in terms of their potential suitability for representations of process data. Overall, this paper aims at breaking new ground for designing and applying multi-modal approaches for making process information more accessible to users.

Keywords: Business Process Management, Sonification, Process Representation

1 Introduction

During the individual life cycle phases of business processes (design & simulation, operation and analysis), different kinds of process model- and process instance-related data accumulate. For all phases, especially for the design & simulation phase, graphical user interfaces and visualization methods are widespread. However, visualization techniques can reach their limits. As an example, process models in the design and simulation phase can have a huge number of events and activities, which can make it difficult to visually identify deadlocks or weaknesses in process models. In the operation and evaluation phases, processes can have thousands of simultaneously running process instances, which can make it hard to find deviations from regular process execution paths or monitor the health or processes and process instances using only visual means.

The usage of data sonification as an enhancement to process visualizations might be able to tackle some of these challenges. Sonification can be defined as the "presentation of data using sound" [5]. This presentation is usually intended to support the listener or user to gain new insights on the presented data.

Although many reasons appear to apply sonification for representing business process-related data, only very few approaches have addressed this issue so far (e.g., [4]). Gregory Kramer et al. [10] found out, that the auditory perception is especially sensitive to temporal change. Furthermore, sonification, in contrast to a static visualization, can only exist in time. As process instances per definition can only exist in time as well, sonification naturally lends itself to this area. Georg Spehr [16] further concludes, that sonification is more suitable than visualization for complex, irregular or even chaotic data. This promises advances when trying to convey process exceptions and changes to users. Moreover, sonifications can very well be recognized, remembered and recalled later on [5]. Studies, such as the one conducted by Salvador et al. [14], point out that sonification can, under certain conditions, yield better results than visualization in terms of the accuracy and efficiency of data exploration while interfaces that combine both modalities yield significantly better results than each of the modalities alone. Beside the usage of sonification to enhance visual means, it is also applied in situations where the visual focus and attention are needed elsewhere (e.g., in cockpits or operating rooms) or to support blind or visually impaired people.

This visionary short paper provides an analysis of sonification methods with respect to their suitability in the area of business processes. Existing basic sonification methods are discussed and their potential to convey information in consideration of the business process life cycle is analyzed. This is a first step towards a multi-modal approach in order to make information related to business processes more accessible to users.

The paper is structured as follows. Section 2 presents basic sonification methods. Possible solutions regarding how sonification methods can be used to make process-related data more accessible to users are discussed in Section 3. Finally, Section 4 concludes the paper and gives an outlook on future work.

2 Basic Sonification Approaches

Nowadays, there is a growing amount of research in the fields of areas of applications, methods, and perception of sonification. Regarding the application of sonification there is, among others, research in the fields of astronomy, volcano activity, ice glaciers, RNA structures, brain activities or weather data. Other examples are sonifications of software code and sonically enhanced data mining. Furthermore, there are a few examples in the fields of social sciences: sonifications for population developments and election outcomes, sport sciences or economics (e.g., sonification of stock market data [2]). McKinney et al. [12] describe a system that aurally and visually presents peer-to-peer networking traffic. There is several research (e.g., [13,1,6] that investigates methods for interactive sonifications. Other research aims towards multi-modal sonification (systems that combine sonification with graphical user interfaces and visualization techniques) in different application areas (e.g., [9,7]).

After this brief introduction into the field of sonification, in the following the four probably most widely used and researched sonification methods (audification, auditory icons, earcons and parameter mapping) will be introduced.

Audification. An audification is the direct conversion of data points into sound. It interprets data sequences as an audio waveform by mapping the data to sound pressure levels. Therefore, a very high number of data sets is needed in order to produce audible results, which is limiting the field of possible modes of operation. [5]

Auditory Icons. Auditory icons are everyday sounds that directly represent the events that are being sonified [5]. As an example, the sound of a paper basket being emptied can be stated that is played back upon emptying the metaphorical paper basket in the Windows operating system. *Pure* audifications convey only the information that certain events have occurred, not other quantitative data that might be connected to those events.

Earcons. Earcons are non-verbal audio messages consisting of motives, which are short rhythmic sequences of pitched tones with variable timbre, pitch and amplitude. Timbre describes the *basic properties* of sounds and is a subjective characteristic that enables the differentiation of two sounds, even though they might have the same loudness and pitch [5].

The concept of earcons is similar to that of auditory icons with the difference, that auditory icons are everyday sounds that directly represent the event that is being sonified, whereas earcons can be *abstract* symbols that are not similar to the real world sound of the represented event or object.

Parameter Mapping. Parameter mapping is the mapping (either direct or by scaling) of data values to specific attributes of sound. These attributes are typically volume, pitch, panning (the position of a sound in the stereo field) or timbre. Other possibilities to map parameters of sound are repetitions and pauses between distinct sound events in loops. Other approaches are to filter out specific ranges of frequencies according to data. Due to these characteristics parameter mapping is often being said to be the sonic pendant to a scatter plot diagram. [5]

Parameterized Auditory Icons and Earcons. Parameterized auditory icons and earcons are mixtures of parameter mapping and auditory icons/earcons and combine the *simple* event-occurrence method of auditory icons/earcons with parameter mapping. In these, sounds convey the occurrence of events, but at the same time quantitative data can be mapped to these sounds. This mapping is analogous to the parameter mapping way of mapping data to sound attributes. Parameterized earcons usually provide more extensive means to map data to sound attributes in comparison to parameterized auditory icons. [3]

3 Applying Sonification Methods to Business Processes

Even though a substantial amount of sonification research has accumulated, so far there seems to be no research concerning the application of sonification in the different life cycle phases of business processes. One of the few examples of the usage of sonification concerning processes in business environments is Grooving Factory [17]. It explored the sonification of production process-related data in order to find bottlenecks and improve logistics. Evaluation showed, that the developed prototypes fulfilled these requirements. Gaver et al. [4] explore with their "ARKOLA Simulation" the production processes of a bottling plant in a multi-modal representation that combines visual and auditory means. It sonifies events during the production process (such as spills of liquid) using real-world recordings of such events. They concluded that the auditory feedback helped in diagnosing problems in the production process. There are a few publications that explored the sonification of different process data (e.g., [8]). Besides the mentioned projects "Grooving Factory" and the "ARKOLA Simulation" there seem to be however no publications that deal with sonifications of process data in a business environment. This leads to the assumption that there is a substantial amount of untackled research potential in this area.

This section will discuss possible solutions in terms of how sonification can be used to make process-related data more accessible to users and to reduce the potential limitations of process visualizations. Therefore, the respective process life cycles phases are analyzed in terms of which sonification techniques might be suited best to support the tasks users typically have to perform in those phases.

Sonification in Process Design. *Audification* relies on a huge number of quantitative data, which makes this technique seem unsuitable in cases where no or little quantitative data needs to be sonified, but instead merely events. *Auditory icons*, on the other hand, seem very suitable for sonifications in the process design phase: for process instances that are created during the simulation of process models, the sonic pendants of the involved activities and events could be played back upon their incidences. Depending on the industry and the type of processes, there is often a variety of self-explanatory sounds that can be used in order to sonify the respective events and activities. In auditory-based sonifications, the relevant events and activities could be sonified by using sounds that naturally represent these events and activities as accurately as possible. As an example, the sound of a shopkeepers bell could signify the reception of a new order. Analogous, the process event "customer has payed his invoice" could be conveyed by playing the sound of a cash register being opened, while the activity "delivery" could be sonified by applying motor sounds. Fig. 1 shows a schematic overview of how such a sonification of a process instance could be realized. The x-axis is the time axis, whereas each row on the y-axis contains a sound file that represents one activity or event. These sound files are played back sequentially from left to right.

In this example, the sounds that convey events have been assigned a fixed length of 1.5 seconds (as the time axis in the lower part of the figure shows). The

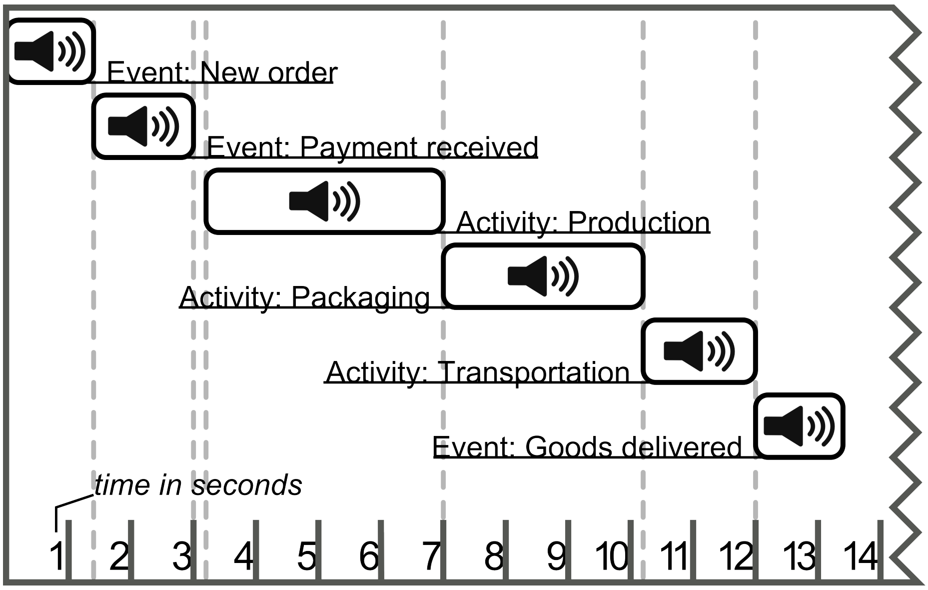

Fig. 1. Schematic overview of an auditory-based sonification of an exemplary process instance

lengths of the audio signals that convey activities, on the other hand, represent the actual duration of the represented activities. Thus, a motor sound with a duration of three seconds could, depending on the scaling, for example signify that the transport took three days. Analogous, a *silence* between activities and events could signify a waiting period. If, for example, there is a gap of two seconds between the playback of the sounds that represent the activities "production" and "packaging", one can conclude that there has been a waiting period of two days between the production of goods and the transport of said. This could be a hint that there are inefficiencies in the process.

Audio files of three different instance sonifications of this example process are available online[1]. The audio file "Example one - average process instance"[2], shows a sonification of an average process instance. The audio file "Example two - no payment"[3] is a sonification of a process instance, in which no incoming payment has been registered. The audio file "Example three - Production and transport delayed"[4] is a sonification of a process instance, in which the activities production and transport have been delayed (which can be recognized by the pauses before the respective audio signals). This simple example tries to show, that auditory icons are able to point out deviations in process instances.

[1] http://soundcloud.com/tobias_hildebrandt/
[2] direct link: http://soundcloud.com/tobias_hildebrandt/business-process-sonification
[3] direct link: http://soundcloud.com/tobias_hildebrandt/business-process
[4] direct link: http://soundcloud.com/tobias_hildebrandt/business-process-1

However, due to its simplicity, this example cannot serve as a comprehensive demonstration of the strengths of sonification (like its ability to convey complex or irregular data). Further prototypes that combine visual and auditory means and base on more complex process models will help in evaluating, if the inherent features of the auditory perception (like the sensitivity to rhythm and its ability to recognize even small changes in sounds over time) can help to convey process instance-related information better than purely visual means.

Earcons are in a similar fashion suitable for process data sonifications but more flexible. For some process events it could prove difficult to find real-world-sonic analogies. For example, it could be a challenge to find sounds that are sonic analogies to the states "customer is already registered" and "new customer". This differentiation would therefore be hard to convey using auditory icons, so the usage of earcons might solve that problem (even though studies suggest that earcons are harder to recognize than auditory icons). By using parameterized auditory icons or earcons, not only the information can be conveyed that a certain event has occurred, but also one or several quantitative data attributes that are connected to that event. For example, one could imagine an auditory icon that conveys the occurrence of an event "incoming payment", while the sum of the payment is mapped to the pitch of that auditory icon.

Parameter mapping might not be the most obvious choice for the process design phase - parameter mapping relies on quantitative data that varies over time, rather than on information on events and their sequences of occurrence, as it is typically the case for process instance-related data.

Sonification in Process Operation and Analysis. Sonifications that aim to assist users during the process operation phase and the process analysis phase probably have to fulfill similar requirements. In both, potential users might want to obtain aggregated information about processes and associated instances and analyze conspicuous phenomena in detail.

Audification does not seem not very suitable for the sonification of data that is related to the process operation and analysis phases, as it seems inflexible in terms of sound design and the structure and format of input data (high amounts of quantitative data that lie within a specific range).

Auditory icons should offer the possibility to recognize deviations of process instances from the process model by the fact that the respective sounds are being played in a different order, or in a different *rhythm* while monitoring and analyzing individual process instances. The same is true for (parameterized) earcons, analogous to what has been said for the process design phase.

Parameter-mapping sonifications might be especially useful during the process operation and the process analysis phases. During these phases, usually quantitative data accumulates that might be mapped to one or several sound streams. These sound streams might then, for example in the process operation phase, be played back continuously which should make it feasible for the user to recognize patterns and modifications as well as to get an overview of the general *health* of individual processes or a complete system. During process operation, an advantage over the usage of purely visual means would be that users would not need to focus their visual attention to specific displays. Thus, they would be able to work on other things while at the same time they could be informed about background activities. Of course, such a sonification would have to be designed in a non-disruptive way.

In the process analysis phase one could imagine a *sonic summary* of a certain time period (for example a shortened sonification of the last 24 hours). In such a sonification it should, after a learning phase, be possible to detect deviations or critical situations during the execution of process instances.

4 Conclusion

Sonification is gaining more and more importance in various disciplines. Due to the existing limitations of visualizations (e.g., keeping track of high numbers of running process instances in different execution states), the authors of this paper propose to introduce it as an enhancement to visualization methods to convey business process information. To achieve this goal it is first necessary to understand how sonification methods can be used to represent business process-related data. The motivation of this paper was to give a first overview of different sonification methods. Possible directions and solutions concerning how sonification can be used to make process-related data more accessible to users were discussed.

Of the presented sonification methods, parameterized earcons and parameterized auditory icons seem to be best suited for sonifications during the process design phase, while the monitoring in the operation phase and the analysis in the evaluation phase seem to be well suited for a parameter mapping sonification.

A multi-modal combination of visualization and sonification should consider the individual strengths and weaknesses of both methods. In general, it should use the abilities of visualization to convey exact information and of sonification to convey changes in temporal developments.

In future work, we will develop and combine sonification methods with visualization methods – particularly for scenarios where visualization techniques come to their limits – that can best be combined into an integrated multi-modal approach for each phase of the business process life cycle. Further, we plan to conduct user studies to evaluate the design of the multi-modal approach and the findings of the evaluations will influence the further design process to improve our approach iteratively.

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