A Study of the Use of a Sonification Prototype by Astrophysicists

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Abstract

This paper presents the results of a focus group and usability evaluation of a new sonification technique (visualization using sound) by end users. Of the few sonification systems for space physicists, none have been designed and tested with end-users, which results in none of them being used in practice. In order to create effective sonifications that will be usable and useful to space physicists, user studies need to be undertaken to fully understand their needs and requirements. The focus group and usability evaluation research presented here are being used in the development of the xSonify prototype (Spdf.gsfc.nasa.gov/research/ sonification/sonification_software.html).

Author Keywords

Sonification, non-speech sound

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Human Factors

Introduction

The goal of the sonification (convey information using mainly non speech sound) prototype project at NASA Goddard Space Flight center and the University of Glasgow is to provide a capability to allow the target audience (space scientists) to explore the data, to provide other means to perceptualise the data multimodaly (using sound as an adjunct to data visualization), and for sonification to be accepted as a scientific tool for data exploration. This section presents the focus group and usability evaluation work done to continue the development of the sonification prototype xSonify. The improvements to the prototype were completely user centered. The sonification prototypes developed earlier for the sonification of space-physics data, were built with a more intuitive development of the graphic user interfaces and utilities, [1][2][3][8][9][10][11]. These prototypes perform the work of sonifying remarkably well. Most of the sonification prototypes in the review following this section have been built with the purpose of using sonification for outreach purposes. The initial intent of xSonify (in 2005) [7] was to introduce the blind to a new method of studying data, which eventually led to the idea that sighted people could benefit from sonification as well; it seemed like a more efficient means of extracting important information from multidimensional data sets than simply viewing the plots with changing colors. Sighted people would be using two senses instead of one to get information, while blind users should be more highly attuned to listening to those sounds by default, so the sighted and blind users should be aware of the same events and be able to discuss them with similar knowledge bases. This insight led the developers to create a focus groups and usability evaluation group composed of target audience (Space physicists with PhD's and publications in the field).

The focus group concentrated on the topic of needs in space science data auralization and visualization. The idea behind this was to capture interaction in use case scenarios, which we use to identify priorities. The use case scenario discussed was their needs when performing data exploration.

The authors designed an interactive development procedure where by solicit requirements and feedback from volunteers (and other interested users) who are evaluating its usability. During the focus group discussion the participant's agreed that most issues in data visualization come from data filtering, from visualizing many parameters changing at once, from knowing what is signal[1] and what is noise in the data.

Review of Sonification Prototypes and Sonification Efforts in Space Physics

Even though it has not been widely used due to lacking a strong theoretical foundation, the use of sound to analyze space science data is not a new idea. For about forty years Gurnet [10] has used sonification of Space Data and produced the first documented attempts to use sonification to analyze/unravel/convey information contained in space physics data from different missions (e.g. Cassini, Voyager).

The interest in sonification across the space physics community has been increasing since the first prototype for the sonification of space physics data was launched in September 2005[7]. The prototype was launched by the heliophysics division at NASA Goddard Space Flight Center (GSFC), with an interest of using

[1] Signal is the interesting part of the data for space physicist. It may be any where on data_stream, most likely away from the direction of gaze and masked by noise.

sound parameters to perform more detailed exploration of plasma and particle data corresponding to the solar wind. Later at the University of Glasgow the prototype was developed further as a user centered sonification prototype and improvements were performed given the usability evaluation performed at NASA GSFC and the Harvard-Smithsonian Centre for Astrophysics. The user centered prototype has been launched at the NASA Goddard Space Flight Center Space Physics Data Facility in October 2012. http://spdf.gsfc.nasa.gov/research/sonification/sonification_software.html

It was proposed by space scientists that sonification techniques might augment perception of signatures in the search for extra-solar planets acquired by the Kepler Telescope. In 2009, Greg Laughlin [11], an astronomer at Santa Cruz, California developed a data reduction tool for this purposes (http://oklo.org) [8][9]. The tool includes a sonify button (as well as other buttons, such as periodograms, etc). With this tool when the orbits are Keplerian, it will be known by the harmonics. The tool does not allow the user to map over parameters such as timbre, volume, or pitch, does no allow the user to scroll the chart as it is being sonified. It converts into audio a set of numbers (defined as a floating variable). For non linear processes the fundamental of the data waveform may change or like in the case of turbulent plasmas (like in the solar wind) the fundamental may not be the lowest component of the waveform. Then, to establish a priory the fundamental of the data waveform impose filtering and linearization in the data. The researchers working with Kepler exoplanet data propose to use the sonification prototype, xSonify , to treat each photometric point like a note with the brightness determining the pitch and duration for each note that is probably the length of a typical transit. The latter will improve the time-efficiency when new interactions with sound will enable the researcher to explore the data.

Lily Asquith [2] developed LHC sound to sonify data from the Large Hadron Collider (http://lhcsound.hep.ucl.ac.uk/page_library/SoundsLibrary.html), launched in 2010 represents real and simulated data using musical instruments.

Another example of sonification of space science data is the efforts to detect Gravitational Waves [9].These waves and or their sources like black holes may not be seen with the eye. The Laser Interferometer Gravitational Wave Observatory (LIGO) team at Syracuse University expressed the need of instruments to turn ultra-small events into something noticeable.

The physics department at the University of Iowa has used sonfication to convey information contained in the data acquired by the satellites (Gurnett). http://www-pw.physics.uiowa.edu/space-audio/. The webpage does not show the technology used to sonify the data. This group sonified the Cassini radio and plasma wave science experiment detecting Saturn’s Bowshock crossing.

Astrophysicists at the Harvard-Smithsonian Center for Astrophysics (CFA)[9][13] has used the sonification prototype developed at the University of Glasgow (xSonify) for the purpose of this research, with astero-seismic data. These space scientists use sound to decide whether a signal is real or just noise when the visual data is confusing. With databases of millions of stars or other objects, it may be a time saver to use sound in addition to visual data to classify objects. It raises the need of developing a user centered sonification prototype that may be used by a wider audience inside the space physics group. Of course this implies to prepare it to accept a wide diversity of data formats, and allow the user to adjust the sonification parameters towards maximizing sensitivity to signal detection (to maximize human perception).

The sonification prototypes reviewed in this section, successfully map and aurally display the data. These sonification prototypes seem built around the data set to be sonified and not around the needs of the target user. Undeniably these prototypes underline the need space scientists have for alternate ways to analyze their data by using multimodal perceptualization to augment signatures in the data and even to identify if a signal is real or not. This should be seen as an effort to complement the always-developing technology with human abilities.

xSonify has many novel characteristics to help the user to explore the data. xSonify has been developed strictly by following the suggestions from focus group and usability evaluation participants. The usability evaluation participants and the focus group composed of PhD space scientists working at major space science institutions (NASA and Harvard Smithsonian Center for Astrophysics), For this purpose the developer used JAVA and MIDI since it allows for the user to access the sonification program once JAVA has been downloaded to the computer desktop in any platform. Java modules can be easily assembled and managed to create sonification applications of offline data as well as of online real-time processes. The program xSonify is the first sonification prototype capable of mapping and sonifying any data saved in text format and from several NASA archives (VISBARD, CDAweb+ and CDAweb), using the Java Sound API to generate MIDI output. xSonify is the first prototype of its kind accessing data from all the missions included in the data base of the space physics data facility (SPDF), saving the data and allowing the user to mark regions of interest saving the values on a text file and allowing the import of a variety of data formats.

The program provides the opportunity to display numerical data as sound with the help of three different sound attributes. Attributes like the pitch, the volume and the rhythm of sound. In order to start the Sonification process the numerical values have to be converted into values of the internal data structure. The data values of this structure are floating point variables in the range from 0.0f to 1.0f. 0.0f represents therefore the smallest and 1.0f the largest value of the original data. Then regardless of the units or range every single data point contained in the data will be transformed into sound. To realize the idea of Sonification, xSonify takes advantage of the MIDI support from JAVA. To display the information of numerical data for instance by dint of the pitch of a played music instrument the smallest value (0.0f) represents the lowest frequency and the largest value (1.0f) the highest frequency according to the settings. Each tone represents one value and the whole sequence of different tones accordingly the whole dataset.

Given the Feedback from the target audience the application has been improved from the original version and launched at http://spdf.gsfc.nasa.gov/research/sonification/sonification_software.html

The original application has been improved in order for the user to assign different Sonification modi or different instruments to each dataset. This option is necessary if the user wants to distinguish the different da-

datasets while listening to them at the same time.

Eleven PhD-level space scientists with publications in the field and employed at major observatories participated in this study. The 11 participants engaged to be part of the focus group and of the usability evaluation.

The focus group topic set for discussion with the volunteers centered on:

1) Data types used,

2) Step by step process space scientists follow for data analysis,

3) Target audience needs for data analysis.

During the usability evaluation the tasks consisted of:
1) Data import from either one of the following: the common data format web (CDAweb) Space Physic Data Facility (http://cdaweb.gsfc.nasa.gov/ and/or fits or a text data file,

2) Mapping of data in a user chosen sonification preference (Volume, Pitch and Timbre),

3) Play back of the data. The participants had the flexibility of using data sets of their choice (in the above formats) to make the analysis more realistic.

First Stage: Recruiting Process

The volunteers were recruited via blanket email. Given the time constraints (busy schedules) of our target audience, the authors set the goal of 5 volunteers recruited via the blanket email. Eleven volunteers reported to the focus group evaluation and subsequently participated in the usability evaluation. All subjects gave informed consent according to procedures approved by the Harvard University Research Subjects Review Board.

As the number of responses to participate in this study was higher than expected, the number of participants (11) was divided in two groups. One focus group evaluation of 5 participants and another focus group evaluation of 6 participants. Subsequent to the focus group evaluation, a .jar file containing the sonification software was provided to the participants during one to one workshops in their offices. The workshop consisted on training on how to use the xSonify (download data to the prototype, choose sonification settings, playback of data and saving the data as a sound file). The 11 volunteers, space scientists, space scientists from the Center for Astrophysics in Massachusetts used the sonification prototype with their own data at their leisure after the focus group discussion. Given the responses from qualitative observation of this focus group evaluation, the participants/users interests and/or purpose to use sonification were classified in three main interests:

1) Research;

2) Curiosity;

3)Education/Out-Reach;

(3)Education/Out Reach (see table 1 at the end of the document)

Focus Group Results

The focus group topic set for discussion and gathering of qualitative data with the volunteers centered on:

1) Data types used

2) Step by step process space scientists follow for data analysis

3) Space Physicists/Space scientists needs for data analysis.

The data types used by the volunteers are listed on table 1, the theme discussed in the focus group always diverted to ways each of them would listen to the data. For example, when talking about the step-by-step process used by space scientists for data reduction, the participants described how to listen for noise when the signal and noise were both ambiguous. In the discussion, the focus group participants suggested to each other how to listen to different data sets to find different parameters being sought for at the time.

100% of the participants agreed the first stage of the data analysis is visualization of the data. This visualization is done to spot apparent signatures that may be of interest. The second stage is filtering of the data to get rid of noise. The third step is to correct for instrumental effects. Fourth step is to use mathematical morphology (set of filtering and segmenting tools to visualize digital images). Fifth step is to visualize the data again.

Participants expressed the interest to use sonification at every step of the process. The participants verbalized how and why they would use sonification in their field (see table 1). Nine out of 11 participants would use sonification solely for research purposes as opposed to its use for out-reach as the later is not their main interest. Two categories were identified from the discussion: Perceptualization techniques and visualisation techniques. 100% of the participants strongly wanted to increase the resolution of the data to be able to see and hear signatures in the data for the purposes of data mining. 100% of the participants discussed perceptualization techniques to approach their data and seek for signatures in the data (see table for examples).

Usability Evaluation

The usability evaluation gathered qualitative data on:

1. Understandability (Recognizing the logical concept and its applicability)

2. Learnability (attributes that bear on the users' effort for learning the application. In the case of this research, this means if the user is able to use the prototype to import data without assistance). 3.Operability (Is the volunteer able to use the sonification/visualisation options in the data to adjust the data to his/her perception?).

Aim

To observe the effectiveness, efficiency and satisfaction with which

astrophysicists can achieve the goals of: Retrieve Data from local and remote files, Sonify the data and Explore the data.

Usability Evaluation Methods:

1. Understandability: One to One 30(at least) Minute workshop to each participant to teach participants how to import, sonify, playback and save the data.

2. Learnability: Participants were able to use the prototype with their own data or with data provided at their leisure and without assistance.

3. Operability: Participants provided a .wav, .tiff or .AU file of their sonifications.

The .jar file provided to the participants monitored the user navigation and sonification preferences through the creation of a Console.txt file created to monitor the user navigation of the prototype and the sonification preferences as a standalone. Participants provided the Console.txt file once they finished the evaluation. The Console.txt files are kept in a password-protected file.

The usability evaluation participants were recruited from the focus group reported previously. During the usability evaluation the task consisted of:

1) Data import from either one of the following: the common data format web (CDAweb) Space Physics Data Facility and/or fits or txt data.

2) Mapping of Data in a user choice sonification preference, (Volume, Pitch and Timbre),

3) Play back of data.

The participant had the flexibility of using data sets of their choice. To overcome any unexpected events, additional to the one to one workshop the usability evaluation group were provided with link to dropBox where they could find a jar file of the prototype, a help file consisting of brief prototype description and navigation instructions, and a 2D data set corresponding to GRB 04/12/19 (Gamma ray Burst 04/12/19) from the High Energy Space physics ARCHive (HEASARCH) http://heasarc.gsfc.nasa.gov/. During the workshop, the participants imported data from the Space Data Facility using the xSonify and .txt formatted data. The participant chose the mission to import the data from, randomly. The participant provided the .txt data imported. In case the participant did not have a .txt data file, the backup provided in dropBox was used. Participants sonified the data, played back the sonification and saved the data as .wav, .au, or, .tiff format using the prototype.

These workshops were done in their respective offices where participants perform their research. After the workshops participants may use the prototype at their leisure in their offices.

Usability Evaluation Results

Generally, participants wanted to hear the data as naïvely as possible, with the gaps (if the data contain any) when there are no data points or zeroes presented (e.g. when there is a gap in the data because of the sun solar cycle). The frequency range change slider to be adjusted to a user defined range.

The Console.txt file created to monitor the user navigation of the prototype as a standalone showed that 10 of the 11 volunteers tried their own data on the prototype. Of those 10, 2 tried more than one data type (.txt and. fits). The Console.txt file consists of a print out of the user navigation (buttons pressed, sonification mappings used, values marked, etc). One volunteer imported data from the Coordinated Data Facility. The mapping of the data was done in Pitch for 6 of 11 volunteers, the rhythm option was not used and only one participant saved the sonified.data as a MIDI output. The rest of the participants saved a file as .wav. The participants praised the prototype did allow them to try more than one data type.

Conclusion:

The results of the two studies have shown some of the needs and the interest of space scientists for sonification tools and multimodal perceptualization of space extended data sets. The focus group qualitative research and the usability evaluation shows the need space physicists have to improve the resolution of their data visualization. The number of responses (11), received in a 5 day period, from the target audience to focus group and usability evaluation together to their willingness to participate from focus group and usability evaluation regardless of their busy schedule, may evidence that space scientists believe in the potential of sonification to augment signatures in data masked by noise, perform data mining and get insight of certain non-obvious events in the data (see purpose column in table 1 at the end of this document)

The xSonify prototype is the first space physics data analysis sonification algorithm package developed around the user and not around the data.

Fictitious name	Research	Curiosity	Education	Purpose	Data Type
Darin	x			Wants to increase resolution of data visualization.	Kepler Series Data
Wen	x		X	To get an idea of how all parameters in a data set are changing with respect to each other so that information can be gathered more quickly than taking the time to listen to each variable separately	Asteroseismol
Margie	x			Some changes that could not be evident just by looking at the data. It will always be better if you add another way of data characterization.	X-Ray Data
Bulent	x			Wants to prepare a sonification library of pulsar data, as it may be easier to classify the pulsar by sound.	Pulsar Data
Marc		x		Curiosity	
Jason	x				Kepler Time Data
Douglas	x			To consider two (or more) parameters in conjunction with each other - looking at how one changes with respect to the others	Heliophysics
Josh	x				Kepler Time Data
Juan	x			Melodies develop which will give insight of events in the data	X-Ray Data
Katrien	x			Determine Transits on Kepler Data	RR Lyrae curves
Dimitar	x			Hearing pure sine waves and the silence in the data for example a gap in the data because of the solar cycle	Light Curves
Emma	x			interested to do a mapping to timbre (using filters, perhaps) or other sound parameters that would draw out the features you wish to highlight	Seismology

Table 1 Participants (by fictitious name) on using sonification

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