XSONIFY SONIFICATION TOOL FOR SPACE PHYSICS

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ABSTRACT

xSonify is a concentrated project to extend the space physics data capabilities of the NASA Space Physics Data Facility (SPDF) [1] for use by visually-impaired students and researchers, by developing a sonification data analysis tool using the JavaSound API and accessing data locally or via web services. xSonify is an open-source publicly-available Java application and can be easily installed (using WebStart) and run on most platforms. With sonification, a large fraction of the space physics data collection is opened to a completely new and now excluded audience (both professional and public). Besides meeting a compelling need for a more effective non-visual approach to displaying science data, this extends SPDF's goals of improving access to space physics data and helps achieve NASA's goals of diversity and public outreach. Wanda Diaz Merced, a visually-impaired astrophysicist from Puerto Rico, is instrumental in advising on and testing the tool. Anton Schertenleib is the initial developer, as part of his graduate student thesis effort.

We seek to further develop this tool with greater capabilities for rendering these data, improve its functional interface and allow for a wider variety of file input formats. Completion of this tool will open up the SPDF space physics data collection to a new community of researchers and students now excluded from space physics research. Development and evaluation will be guided by a user group of space scientists (sighted and visually-impaired) and experts in adaptive technologies from the National Federation of the Blind (NFB).

1. INTRODUCTION

xSonify is intended to provide greatly-improved accessibility to space science data for visually-impaired scientists and students. Common non-visual methods for examining data (such as reading aloud and memorizing data values or using raised plots printed by specialized hardware) are often inferior, less independent, and more costly than visualization methods. In addition to visually-impaired users, many others are aurally-oriented rather than visually-oriented and sonification provides them a more meaningful mode for doing science. We also want to support the educational community, making space physics more exciting to students and the general public.

Besides providing assistive technology for visually-impaired and non-visually-oriented people, sonification provides other benefits for all students and researchers, including being able to:

- Analyze complex or rapidly/temporally changing data,
- Explore large datasets (particularly multi-dimensional datasets),
- Explore datasets in frequency rather than spatial dimensions,
- Identify new phenomena that current display techniques miss,
- Find otherwise hidden correlations and patterns masked in visual displays,
- Monitor data while looking at something else (background event-finding),
- Complement existing visual displays (since the ear is sensitive to different frequency bands and patterns than the eye),

For example, when searching for bow shock and magnetopause crossings, we expect that distinctive signatures will be especially apparent above the background noise when sonifying the data. These boundary signatures appear as characteristic changes in the whole spectrum (including the background noise) while other emissions appear as tones at distinctive frequencies or time-frequency spectra (such as electron plasma oscillations, magnetic noise bursts in the magnetosheath, and whistler mode emissions marking regions of currents).

2. SPACE SCIENCE AND SONIFICATION

With sonification, space physics data is opened to a completely new and now excluded audience (both professional and public). Examples of sonification in space physics include audification of Jupiter radio-astronomy data which led to the now common science terms whistlers, hiss and chorus; Cassini's Radio and Plasma Wave Science (RPWS) crossing the bow shock of Saturn [2]; and detecting micrometeoroids impacting Voyager 2 when traversing Saturn's rings (these impacts were obscured in the plotted data but were clearly evident as hailstorm sounds) [3]. My own work in using an early Beatnik/JavaScript-based tool, tested several sonification techniques on Hawkeye magnetic field and plasma measurements for magnetopause, bow shock and cusp crossings [4].

3. CURRENT XSONIFY IMPLEMENTATION

Our demonstration version of xSonify sonifies 1-dimensional data from text files and from sample CDAWeb's space physics holdings (via web services [5] using the ViSBARD software library [6]). We will extend it to handle multi-dimensional data and add more features and polishing. xSonify is based on Java 1.5 with Java Sound API, MIDI, JavaSpeech, WebStart, and web services technology. Some notes on ensuring compatibility with JAWS are in the Appendix.

xSonify currently features three different sonification modes (Pitch, Loudness, Rhythm) with various controls (Play, Stop, Loop, Speed, Time point). It has limited pre-processing of input data (Limits, Invert, Logarithm, Averaging). We will expand it to handle all 1-dimensional plus multi-dimensional data and add additional necessary features. This software follows a modular data pipeline approach [7] of:

- Data Transformation: to appropriate geophysical units,
- Normalization: convert to abstract normalized view,
- Sonification Transformation: to abstract sound parameter space, and
- Auditory Display Transformation: sonic rendering.

4. EVALUATION CRITERIA

We have a committee of interested users and experts in assistive interfaces acting as a board of directors to define the requirements and evaluate the software. We hope to apply research in psychoacoustics, semiotics, ergonomics, commercial sound design, and music as groundings for these requirements. We plan usability testing, including participatory design by local scientists and focus groups, to determine the usability of the various sonification techniques and our implementations (with comparison to current visualization tools) in three ways:

- effectiveness (improvement in the amount and quality of users' science knowledge derived from displaying the data using these techniques and accuracy/errors in detecting geophysical events in the data),
- efficiency (learning time and time/effort to analyze the data) , and
- satisfaction (attitude and comfort rating surveys, users' preferences).

5. CURRENT PLANS

We have a working although limited prototype with source code openly available at SPDF's web site [8] and now at SourceForge [9] under the NASA Open Source Agreement (NOSA). As it becomes more stable and capable, we will advertise it widely and develop a community of active users. We plan an iterative development process, where we elicit requirements and feedback from the user committee and other interested users, prioritize the requirements by importance, usefulness, and difficulty of implementation, and produce the next version for further testing. We so far have identified the following additions:

- Add alternative language interfaces (Spanish first),
- Add additional sound modes, such as audification (play data directly, scaled into audible range), multiple oscillators (for frequency/energy band as plotted in spectrograms), apply Shephard's tone illusion of ever-increasing pitch and rhythm [10], and especially physical parameter models (drum size, footsteps, etc.),
- Add stethoscope mode where the user mouses over the plot of multispectral data playing sounds correlated with some of the data parameters (as proposed by R. S. Wolff [11] and others),
- Add variations in timbre, phase, and direction for representing additional information about main variables, such as variations in anisotropy, noisiness, uncertainty, and polarization,
- Add a plot library such as Scientific Graphics Toolkit (SGT) [12],
- Tie in TIPSOD display of 3D orbits [13], synchronized so spacecraft move in coordination with sounds,
- Add more mapping options (asymptotic, log, inverse, other scalings),
- Improve data input (OpenDAP, CDF, HDF, more flexible ASCII),
- Improve GUI, add options and better controls, add automatic gain control (AGC),
- Develop easy command line routines for batch or automated mode or called by other programs (read_data, modify_data, sonify_data),
- Represent multi-dimensional datasets (for instance, represent plasma wave data with sound loudness representing intensity, pitch for frequency (or energy in particle data), and left-right amplitude and phase for polarization differences), and
- Use the upcoming simplified CDAWeb interface, automatically defaulting to most recent time period for key variables.

The Headspace AudioEngine is currently used in JavaSound in Java 1.5, but will be removed in the next version since the rights to the source code are not openly available. This will leave the not yet fully-functional JavaSound AudioEngine as the only available AudioDevice (although disabled by default). Sun plans to encourage the development community to implement an AudioEngine using Java Bindings for OpenAL / Sound3D Toolkit (JOAL) [14].

6. CONCLUSIONS

Although we hope the improved program will be used extensively worldwide (measured by downloads), the best measure of its impact will be on producing more effective scientific understanding and new science results (although not easily measured). This innovative and non-visual presentation of NASA research data and processes will attract a diverse (particularly visually-impaired) population to careers in science and technology by inclusively engaging students in hands-on research. Ms. Diaz is currently using the prototype regularly with a group of visually-impaired and other interested students and researchers at U. Puerto Rico.

7. REFERENCES

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