Supporting Astrophysical Visualization with Sonification

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Abstract

This poster presents initial design steps exploring how sonification can be used to support visualization for comprehension of space and time in astronomical data. Radio signals travel at the speed of light. With a visualization of the universe, it is possible to travel faster than light and pass the radio waves leaving earth. We can then travel back in time. We propose to use sonification consisting of songs representing each year as a musical journey through space and time to create an engaging experience.

CCS Concepts

• ***Human-centered computing*** → *Auditory feedback; Accessibility theory, concepts and paradigms;*

1. Introduction

In the mid 1930s radio transmission had a high enough frequency and amplitude to penetrate the ionosphere [Rex21] and continue into space [KF21]. Radio waves travel with the speed of light [SR50]. This means that one light year out from earth, there is the radio broadcasts from one year ago. If we then could travel faster than the speed of light, we could travel there and listen to the hit songs broadcasted in 2023. The further out from earth we would travel, the further back in time (at least in the perspective of radio transmissions) we would travel. Somewhere out there, around 90 light years from earth we would find the first radio broadcast we humans sent out into space. Then, if we would travel towards earth again, we would travel forward in time until we are within a light year from earth and again hear the radio signals that are currently broadcast. Of course, traveling faster than the speed of light is impossible, but with a visualization of space and entirety of the universe this could be achieved.

One example of a visualization software that enables this, is OpenSpace [BAC*19], which is a collaboration project between Linköping University, the American Museum of Natural History, and NASA. This visualization software enables a user to explore more or less all known data about space. OpenSpace is often used in various planetariums, where a presenter in a live setting narrates a story about the universe showing the visuals together with background music [BHY18].

Astronomical data might be challenging to comprehend [HF11]. As an example, perception of and understanding distances and time are quite abstract and difficult to understand (see for example [MB10]). For public outreach activities, visualization must be engaging and informative and educational [LYA*21]. One way of supporting visualization could be by using sound to further support perception and understanding of the data. Sonification is the use of non-speech sounds for representing data [KWB*10, HHN*11]. Sonification has been successfully used in relation to astronomical data together with OpenSpace [EEBR21]. This opens for some interesting questions:

1. Can sonification be used to support understanding of distance and time in space?
2. Can sonification create an engaging situation for an audience of a visualization of astronomical data?

The aim of this poster is to present a master thesis work exploring how sonification can support the understanding of distance, the speed of light, and the concept of traveling in time, as well as to see if sonification can support public engagement. To investigate this, a sonification approach where popular music from each year will act as a metaphor for time has been designed and will be evaluated in a user study in a dome theatre at a science center (see Figure 1).

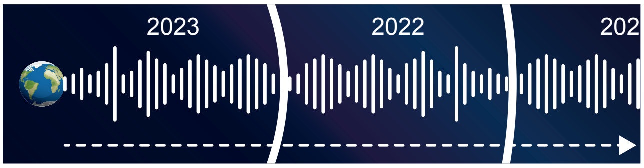

Figure 1: *An illustration of the sonification approach (the illustration does not portrait the correct scale).*

With this poster we present and hope to invite discussion about the ongoing work with sonification as a support for visualization and for understanding the concepts of distance and time in an astrophysical application. We believe that this work would benefit from conversations and discussions with visualization experts, and that using sonification for making visualization more accessible and engaging would be of interest also for visualization experts.

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2. Related Work

There is an increasing interest in sonification for data analysis and public outreach activities in the research area of astronomical data [MPB*23, RG22, ZHL*22, FCH22]. There have been some interesting studies that have explored the use of sonification to present astronomical data, such as sonification of radio astronomy data [LH11]. Data about exoplanets have also been sonified to support understanding of such data [Rib18], and data about Transneptunian objects has been sonified to engage the public, promote astronomy, planetology, and arts [RO18]. The dataset zCOSMOS that contains information about 20,000 galaxies has also been sonified [BFL*21], and one of the goals of this sonification was to support perception of the data and to break down barriers between scientists and the general audience.

Sonification has been successfully used to communicate data about the solar system that is not visible in OpenSpace [EEBR21]. Parameter mapping sonification was used to convey information not visible, utilizing surround sound to create an immersive experience in a dome theatre setting. Another study also explored sonification of the solar system [QMB16], and yet another study further evaluated the use of sonification to convey information to an audience in a planetarium setting [TWL*17]. Finally, we would like to highlight a similar approach to the one described in the present study, which is presented on the website lightyear.fm. However, this website might miss the scientific correctness of distance and the actual years to present. The presentation also lacks the connection to a proper interactive visualization tool such as OpenSpace.

3. Initial and Future Sonification Design Work

The sonification was created using the real-time sound synthesis software SuperCollider [McC02] and connected to OpenSpace with the Open Sound Control (OSC) protocol [WFM17]. Representative songs for the years 1936 to 2023 (87 songs) were selected from the Billboard Year-End chart back to 1946 and the Rate Your Music website for the remaining years. In the sonification, these songs are played within the corresponding light year.

The first exploration of the sonification design, evaluated the transitions from one song to the other, or in other words from one light year to another. Three design ideas (*Straight cuts, Cross-fades, and Noise transitions*) for these transitions were explored and evaluated (see Figure 2).

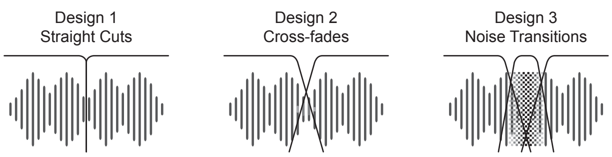

Figure 2: *The design ideas for transitions between the songs were explored: Straight cuts, Cross-fades, and Noise transitions.*

These three design ideas were explored in a small user evaluation, consisting of ten participants. The participants were asked to rank the order of preference for these three ideas when traveling back in time from earth in two different speeds. At the *Slow* speed, when each song were played for a longer time and the transition period between songs were longer, eight (8) participants rated Cross-fade as the best, seven (7) rated the noise transition as second best, and nine (9) rated the straight cuts as the worst (see Figure 3). For the *Fast* speed, eight (8) rated the cross-fade as the best, six (6) rated the straight cuts as second best, and eight (8) rated noise transitions as the worst. Based on this it was decided to continue the sonification design work using cross-fades between songs.

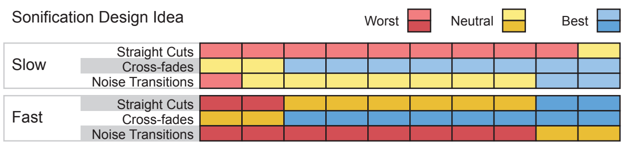

Figure 3: *Subjective ratings of the three transition ideas.*

The next part in the design work is to explore if every song should be played in higher speeds, or if the time wise resolution in song playback should be dependent on the travel speed. Furthermore, the use of surround sound to further enhance the experience of distance and traveling through space and time will also be explored. As the visualization takes the audience further away from earth, traveling back in time from the radio signal's point of view, the music portraying the previous year will fade in from behind the audience, passing through the room as the distance from the earth increases, and then fade out while becoming further and further away in the front of the audience (see Figure 4).

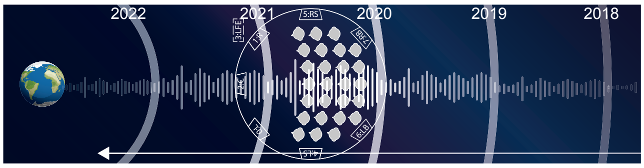

Figure 4: *In a dome theatre setting, here shown from top, surround sound will be used for an immersive experience, where the sound travels from the back towards the front (and vice-versa).*

Finally the entire sonification design will be evaluated in a dome theatre setting meant for science communication to the general public. In this evaluation the final design will be explored, by itself and in combination with the visualization. Among other evaluation approaches, the auditory interface user experience scale (BUZZ) [TNW18] will be used to assess the sonification, as well as different scales of engagement such as the Immersive Experience Questionnaire (IEQ) [RBGC19] or the User Engagement Scale (UES) [WLHS14, OCH18].

4. Concluding Remark

The master thesis project described in this text is only in its infancy and will be further developed, new design ideas will be investigated, and many interesting questions will arise along the process. We strongly believe that the outcome will be an interesting and engaging experience for the audience, and knowledge gained in this project should be relevant also for other types of data.

References

[BAC*19] BOCK A., AXELSSON E., COSTA J., PAYNE G., ACINAPURA M., TRAKINSKI V., EMMART C., SILVA C., HANSEN C., YNNERMAN A.: Openspace: A system for astrographics. *IEEE transactions on visualization and computer graphics 26*, 1 (2019), 633–642. 1

[BFL*21] BARDELLI S., FERRETTI C., LUDOVICO L. A., PRESTI G., RINALDI M.: A sonification of the zcosmos galaxy dataset. In *International Conference on Human-Computer Interaction* (2021), Springer, pp. 171–188. 2

[BHY18] BOCK A., HANSEN C., YNNERMAN A.: Openspace: bringing nasa missions to the public. *IEEE computer graphics and applications 38*, 5 (2018), 112–118. 1

[EEBR21] ELMQUIST E., EJDBO M., BOCK A., RÖNNBERG N.: Openspace sonification: Complementing visualization of the solar system with sound. In *Proceedings of the 26th international conference on auditory display (ICAD 2021)* (2021), pp. 135–142. 1, 2

[FCH22] FORAN G., COOKE J., HANNAM J.: The power of listening to your data: opening doors and enhancing discovery using sonification. *Revista Mexicana de Astronomıa y Astrofisica Serie de Conferencias (RMxAC) 54* (2022), 1–8. 2

[HF11] HASSAN A., FLUKE C. J.: Scientific visualization in astronomy: Towards the petascale astronomy era. *Publications of the Astronomical Society of Australia 28*, 2 (2011), 150–170. 1

[HHN*11] HERMANN T., HUNT A., NEUHOFF J. G., ET AL.: *The sonification handbook*, vol. 1. Logos Verlag Berlin, 2011. 1

[KF21] KALTENEGGER L., FAHERTY J.: Past, present and future stars that can see earth as a transiting exoplanet. *Nature 594*, 7864 (2021), 505–507. 1

[KWB*10] KRAMER G., WALKER B., BONEBRIGHT T., COOK P., FLOWERS J. H., MINER N., NEUHOFF J.: Sonification report: Status of the field and research agenda. 1

[LH11] LUNN P., HUNT A.: Listening to the invisible: Sonification as a tool for astronomical discovery. 2

[LYA*21] LAN F., YOUNG M., ANDERSON L., YNNERMAN A., BOCK A., BORKIN M. A., FORBES A. G., KOLLMEIER J. A., WANG B.: Visualization in astrophysics: Developing new methods, discovering our universe, and educating the earth. In *Computer graphics forum* (2021), vol. 40, Wiley Online Library, pp. 635–663. 1

[MB10] MILLER B. W., BREWER W. F.: Misconceptions of astronomical distances. *International Journal of Science Education 32*, 12 (2010), 1549–1560. 1

[McC02] MCCARTNEY J.: Rethinking the computer music language: Super collider. *Computer Music Journal 26*, 4 (2002), 61–68. 2

[MPB*23] MISDARIIS N., PAULETTO S., BONNE N., HARRISON C., MEREDITH K., ZANELLA A.: The audible universe workshop: An interdisciplinary approach to the design and evaluation of tools for astronomical data sonification. In *International Conference on Auditory Displays* (2023). 2

[OCH18] O'BRIEN H. L., CAIRNS P., HALL M.: A practical approach to measuring user engagement with the refined user engagement scale (ues) and new ues short form. *International Journal of Human-Computer Studies 112* (2018), 28–39. 2

[QMB16] QUINTON M., MCGREGOR I., BENYON D.: Sonifying the solar system. 2

[RBGC19] RIGBY J. M., BRUMBY D. P., GOULD S. J., COX A. L.: Development of a questionnaire to measure immersion in video media: The film ieq. In *Proceedings of the 2019 ACM International Conference on Interactive Experiences for TV and Online Video* (2019), pp. 35–46. 2

[Rex21] REXER T.: Radio wave propagation through the ionosphere. 1

[RG22] RIBER A. G., GARCIA F. S.: Sonification of tess data validation timeseries files. In *The 27th International Conference on Auditory Display (ICAD 2022), Virtual Space* (2022). 2

[Rib18] RIBER A. G.: Planethesizer: approaching exoplanet sonification. In *Proceedings of the 24th International Conference on Auditory Display* (2018), pp. 219–226. 2

[RO18] RENGEL M., OCKERT M.: Creating music from astronomical/planetary data: Herschel/pacs data sonification of haumea. In *European Planetary Science Congress* (2018), pp. EPSC2018–633. 2

[SR50] SMITH-ROSE R. L.: The speed of radio waves and its importance in some applications. *Proceedings of the IRE 38*, 1 (1950), 16–20. 1

[TNW18] TOMLINSON B. J., NOAH B. E., WALKER B. N.: Buzz: An auditory interface user experience scale. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems* (2018), pp. 1–6. 2

[TWL*17] TOMLINSON B. J., WINTERS R. M., LATINA C., BHAT S., RANE M., WALKER B. N.: Solar system sonification: exploring earth and its neighbors through sound. In *The 23rd international conference on auditory display (ICAD 2017)* (2017), pp. 128–134. 2

[WFM17] WRIGHT M., FREED A., MOMENI A.: 2003: Opensound control: State of the art 2003. *A NIME Reader: Fifteen Years of New Interfaces for Musical Expression* (2017), 125–145. 2

[WLHS14] WIEBE E. N., LAMB A., HARDY M., SHAREK D.: Measuring engagement in video game-based environments: Investigation of the user engagement scale. *Computers in Human Behavior 32* (2014), 123–132. 2

[ZHL*22] ZANELLA A., HARRISON C., LENZI S., COOKE J., DAMSMA P., FLEMING S.: Sonification and sound design for astronomy research, education and public engagement. *Nature Astronomy 6*, 11 (2022), 1241–1248. 2

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