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# AN APPLICATION OF SONIFICATION AS AN ALTERNATIVE FOR THE ACCESSIBILITY OF ASTRONOMICAL IMAGES TO THE VISUALLY IMPAIRED

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ABSTRACT

Astronomy's dependence on visual perception makes it difficult to be accessed by the visually impaired. Nevertheless, there are efforts to communicate astronomy to the visually impaired with the help of auditory perception and tactile perception. Screen reader applications are accessibility tools which help the visually impaired perceive images with the help of words. One of the disadvantages of screen reader is abstract astronomical concepts may be difficult to be recognized, especially for those who are visually impaired since childbirth. In this research, an image sonification program is designed as an alternative to screen reader applications to communicate astronomical images to the visually impaired using shape-approach sonification. The program was written using Python 3.8 programming language. The program is able to sonify shapes automatically and is also responsive to changes and differences in shapes. The result from program is a MIDI file which is then polished and exported using DAW to create music in the form of MP3 file. After a series of evaluation with the help of six people with visual impairment, we found that this method of sonification has potential as an alternative to the accessibility of astronomical images for the visually impaired with sufficient practice.

RESUMEN

La dependencia que tiene la astronomía de la percepción visual dificulta el acceso a ella de las personas con discapacidad visual. Sin embargo, hay esfuerzos para comunicar la astronomía a discapacitados visuales con la ayuda de la percepción auditiva y la percepción táctil. Las aplicaciones de lectores de pantalla son herramientas de accesibilidad que ayudan a las personas con discapacidad visual a percibir imágenes con la ayuda de palabras. Una de las desventajas del lector de pantalla es que los conceptos abstractos de astronomía pueden ser difíciles de reconocer, especialmente para aquellos que tienen problemas de visión desde el nacimiento. En esta investigación, se diseña un programa de sonificación de imágenes como una alternativa a las aplicaciones de lectores de pantalla para comunicar imágenes astronómicas a las personas con discapacidad visual utilizando la sonificación de enfoque de forma. El programa fue escrito utilizando el lenguaje de programación Python 3.8. El programa es capaz de sonificar formas automáticamente y también responde a cambios y diferencias en las formas. El resultado del programa es un archivo MIDI que luego se pule y exporta usando DAW para crear música en forma de archivo MP3. Después de una serie de evaluaciones con la ayuda de seis personas con discapacidad visual, encontramos que este método de sonificación tiene potencial como alternativa a la accesibilidad de imágenes astronómicas para personas con discapacidad visual con suficiente práctica.

*Key Words:* Sonification

## 1. INTRODUCTION

Astronomy makes heavy use of visual perception. Stargazing, appreciation of astronomical images, and scientific analysis with graphs or tables are examples of the usage of visual perception in astronomy. This dependence makes astronomy difficult to be accessed by the visually impaired. However, can disabilities be the reason to deny others access to science?

Sonification can be defined as the presentation of data with sound (Lunn & Hunt 2011). Kramer et al. (1999) define sonification further as "The use of non-speech audio to convey information." Kramer's definition is what differentiates sonification from screen reader applications that describes what is in an image.

In this research, the potential of sonification to communicate astronomy to the visually impaired was tested. This research put the focus on the visually impaired general public, therefore the sonified

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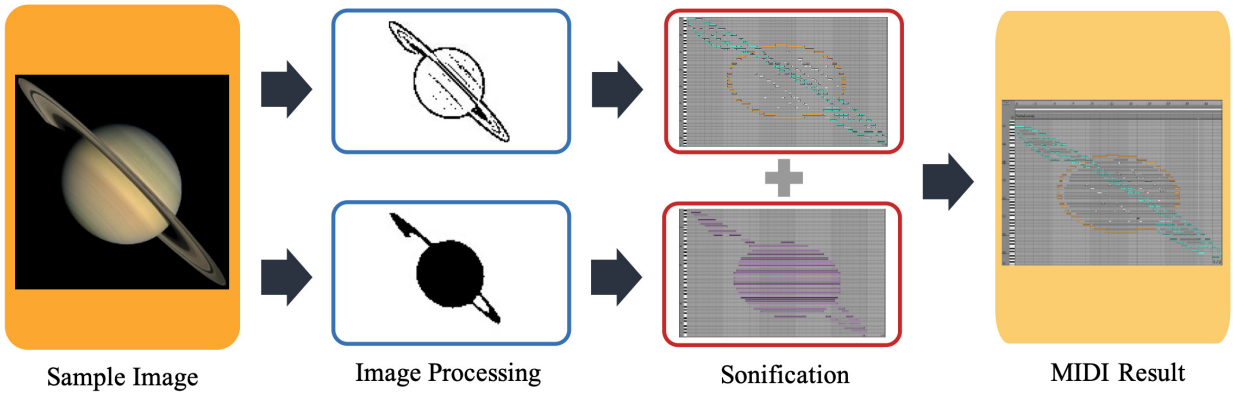


Fig. 1. Illustration of the sonification method, with an image of Saturn as sample image. Other images shown in each step serve as illustration of the result from said step. The MIDI result is visual representation of the MIDI file generated as seen on Ableton piano roll. Actual result is an audio file in MP3 format. Saturn image used is taken from https://space-facts.com/saturn/.

objects were astronomical images and not scientific data. In this test, a program was designed to semi-automatically sonify images. The visually impaired were then displayed the result of this sonification method.

## 2. SONIFICATION METHOD

The method uses a shape-approach sonification, which represents shapes and position of object analogically with sound pitch, and not using a color-approach sonification, which represents colors analogically with pitch. Figure 1 gives an illustration and example of the sonification method. The image processing step consist of image adjustments before the image is sonified. The two sub-steps of the image processing steps are as follows:

- Preprocessing step converts image mode into grayscale and changes the image into $w \times 88$ px where 88 pixel is the image height and $w$ is the image width. The resizing is done as such to conserve the image aspect ratio. Preprocessing step converts image mode into grayscale and changes the image into $w \times 88$ px where 88 pixel is the image height and $w$ is the image width. The resizing is done as such to conserve the image aspect ratio.
- Image thresholding step is done to determine the object from the image. Adaptive thresholding is done to give outline to the object and various detail accents of the object. The outlines produced by adaptive thresholding give the base shapes of objects in the image. Global thresholding is done to give the fullness of the object.

The sonification step is inspired by MIDI Arts, where the result of image processing step is imagined as to be traced to MIDI piano roll. Image height is represented by 88 pitches commonly found in pianos and image width is represented by music length. To reduce dissonance, the MIDI is filtered based on the C pentatonic mayor scale. Image processing step is done automatically using a program written in Python 3.8. After applying a filter to the MIDI, the sonification step is then continued manually using DAW. This manual step is done to add an instrument, as well as to further polish the music created. Specifically with the Saturn image in Fig. 1, consecutive notes of the same pitch were combined to create one long note. MIDI result from the adaptive thresholding was split into three parts: the ring, spheroid body, and accents. These parts, along with the MIDI result from the global instrument, were added different instruments before combined and exported as MP3 file.

## 3. EVALUATION OF THE SONIFICATION METHOD

The evaluation is done in *Panti Tuna Netra Titipan Anak Bangsa* (Titipan Anak Bangsa Home for the Blind), in Cimahi, West Java, Indonesia. The evaluation consists of three steps: training step, shape test, and image test. The training step was done on July 30th 2021 until August 21st 2021. Both tests were done on August 21st 2021 with six participants ranging from age 16 to 21. The training step was done to instruct participants to associate shapes and sound with the sonification method by introducing the sonification of simple lines and curves.

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In this step, participants were given sonification of lines and curves as seen in Fig. 2. To help recognize the sonified lines and curves, participants were given cutouts of paper from a drawing book that had been embossed with the lines and curves. At the end of training step, participants were given random sonified lines and curves, and then were asked to identify which line or curve was sonified as an assessment to determine whether this step could be considered a success or not. Each participant's correct answers were noted. The shape test was done to determine whether participant could identify sonification of basic shapes consisting of lines and curves introduced in the training part. Participants were given sonification of 10 of the shapes seen in Fig. 3 and then asked to identify which shapes were sonified. Each participant's correct and wrong answers were noted. The image test was done to assess each participant's ability to identify a sonification of an image as combination of lines and shapes. In this step, sonification of Saturn's image as seen in Fig. 1 was given. Participants were asked to identify how many shapes are there in the sonification. The number of perceptible shapes and description of one of the perceptible shapes from each participant were noted.

Fig. 2. Lines and curves used in the training step.

Table 1 shows that the simple shape perception using this method of sonification has correlation with how successful the training step was to create association of shapes and sounds, with participants who give more correct answers in the practice step assessment generally give more correct answers in the shape test. Further analysis of shape test answers suggests that participants were better to perceive sonification of different straight lines than curves. However, the result of image test, as seen in Table 2 shows, that participants are more perceptive to curves than to straight lines. This discrepancy is likely due to image of Saturn having more dominant curves than straight lines, the choice of instruments, and the poor volume adjustments of each part. Admittedly, the result found is inconclusive because the

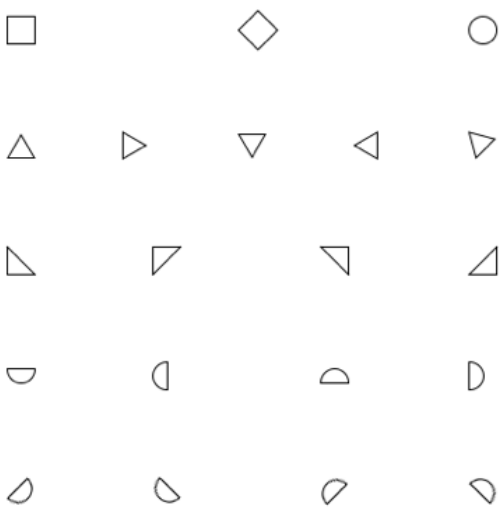

Fig. 3. Shapes used in shape test.

TABLE 1

NUMBER OF CORRECT ANSWERS FROM EACH PARTICIPANT

| Participants | Correct Answers | |
|---|---|---|
| | Practice Step Assessment | Shape Test |
| 1 | 3 | 1 |
| 2 | 4. | 0 |
| 3 | 5 | 3 |
| 4 | 1 | 0 |
| 5 | 0 | 0 |
| 6 | 3 | 0 |

TABLE 2

DESCRIPTION OF ONE OF THE PERCEIVABLE SHAPE FROM IMAGE TEST

| Participants | Description |
|---|---|
| 1 | Semicircle |
| 2 | Curve |
| 3 | Straight line |
| 4 | Crescent |
| 5 | Dome |
| 6 | Round |

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evaluation process was far from being perfect. The training step applied was considered not effective. A low number of participants have the potential to produce bad data.

## 4. CONCLUSION AND POTENTIAL

In this research, a method of sonification that is able to semi-automatically sonify shapes and images was designed. With better training to build association of shapes and sounds in participants, this method of sonification may be used as a medium to communicate astronomy to the visually impaired. A method to convey both shapes and color with modification of this method can be designed with further development. This research only explored one method of sonification. It is possible that other methods of sonification could be better to communicate astronomy to the visually impaired than the one explored in this research. Astronomy communication can also be done with a multi-sensory approach using both auditory and tactile perception. One such idea is to use sonification to convey colors and tactile perception to convey shapes. However, in the event of multi-sensory method not possible to be applied, it might be preferable to prioritize shape perception over color perception.

## 5. ACKNOWLEDGEMENT AND AUDIO FILE LINK

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