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

A. Deandra¹, M. Putra¹, M. I. Mandasari², C. Kunjaya¹, D. Herdiwijaya¹, and Aprilia¹

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.

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
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 ana-
logically with sound pitch, and not using a color-
approach sonification, which represents colors ana-
logically 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
greyscale 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. Preprocess-
ing step converts image mode into greyscale 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 im-
age 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 vari-
ous detail accents of the object. The outlines
produced by adaptive thresholding give the base
shapes of objects in the image. Global thresh-
olding 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 imag-
ined 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 pro-
cessing 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 man-
ually 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 adap-
tive 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 ex-
ported as MP3 file.

3. EVALUATION OF THE SONIFICATION

The evaluation is done in *Panti Tuna Netra Titipan
Anak Bangsa* (Titipan Anak Bangsa Home for the
Blind), in Cimahi, West Java, Indonesia. The eval-
uation 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 par-
ticipants ranging from age 16 to 21. The training
step was done to instruct participants to associate
shapes and sound with the sonification method by in-
troducing the sonification of simple lines and curves.
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.](image)

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

<table>
<thead>
<tr>
<th>Participants</th>
<th>Correct Answers</th>
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<tbody>
<tr>
<td>Practice Step Assessment</td>
<td>Shape Test</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

**TABLE 1**
NUMBER OF CORRECT ANSWERS FROM EACH PARTICIPANT

<table>
<thead>
<tr>
<th>Participants</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Semicircle</td>
</tr>
<tr>
<td>2</td>
<td>Curve</td>
</tr>
<tr>
<td>3</td>
<td>Straight line</td>
</tr>
<tr>
<td>4</td>
<td>Crescent</td>
</tr>
<tr>
<td>5</td>
<td>Dome</td>
</tr>
<tr>
<td>6</td>
<td>Round</td>
</tr>
</tbody>
</table>

**TABLE 2**
DESCRIPTION OF ONE OF THE PERCEIVABLE SHAPE FROM IMAGE TEST

![Fig. 3. Shapes used in shape test.](image)
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

Special thanks to co-authors that served as advisor and examiner professors in the undergraduate final project work on which this proceeding is based upon (Deandra 2021). Additional thanks to the participants from Panti Tuna Netra Titipan Anak Bangsa. Sonification result of Saturn image seen in Fig. 1 is available on the following link: https://bit.ly/SaturnSonification.

REFERENCES

Deandra, A. 2021. Aplikasi Sonifikasi sebagai Alternatif Aksesibilitas Citra Astronomi bagi Tuna Netra. (Bandung: Bandung Institute of Technology)