Revista Mexicana de Astronomía y Astrofísica Serie de Conferencias (RMxAC), **57**, 37–41 (2024)
© 2024: Instituto de Astronomía, Universidad Nacional Autónoma de México
https://doi.org/10.22201/ia.14052059p.2024.57.09

III Workshop for Astronomy Beyond the Common Senses for Accessibility and Inclusion (3WAI) (November 29-30, 2023)
Editors: Santiago Vargas, Beatriz García, Johana Casado, Breezy Ocaña, and Angela Pérez - DOI: https://doi.org/10.22201/ia.14052059p.2024.57.09

TRANSFORMATION OF IMAGES TO 3D TACTILE MODELS FROM OPEN SOURCE SOFTWARE

María Constanza Farjo[1], Johana Casado[1], and Beatriz García[2,3]

RESUMEN

La astronomía es una rama de la ciencia basada en la aproximación visual a los fenómenos celestes, aún cuando la radiación provenga de regiones de energía fuera de la visible. En general, la observación se basa en la percepción de la luz, lo que constituye una gran desventaja para personas con discapacidad visual. Una de las herramientas que facilita la participación, o que persigue este objetivo, es la sonorización, otra son los modelos táctiles que permiten a las personas con discapacidad visual tocar y explorar réplicas de objetos celestes y otros datos astronómicos tales como espectros o curvas de luz. En este proyecto se busca desarrollar un software en python que, a partir de una imagen, se pueda relacionar el color, la intensidad o potencia con la altura de impresión y poder crear así un modelo táctil acorde con los datos provenientes de la observación astronómica, ya sea con telescopios en Tierra o en el espacio.

ABSTRACT

Astronomy is a branch of science based on the visual approach to celestial phenomena, even when radiation comes from energy regions beyond the visible spectrum. In general, observation relies on the perception of light, which poses a significant disadvantage for individuals with visual impairments. One of the tools that facilitates participation or aims to achieve this goal is sonification; another is tactile modeling, allowing visually impaired individuals to touch and explore replicas of celestial objects and other astronomical data such as spectra or light curves. This project aims to develop Python software that, based on an image, can correlate color, intensity, or power with the height of printing. This would enable the creation of a tactile model suitable for 3D printing using data from astronomical observation, whether obtained from telescopes on Earth or in space.

Key Words: astronomy for equity — tactile models — 3D representation — software: 3D models

1. INTRODUCTION

Astronomy is a branch of science that studies both the celestial bodies in the universe and the phenomena associated with them. This discipline has inspired thousands of individuals seeking to answer questions and understand the cosmos. It is a highly visual science, with research relying on the perception and analysis of information received through electromagnetic energy, whether in the visible region or beyond. Information outside the visible range is transformed into false colors to enable visual analysis. It is important to note that nowadays, the involvement of individuals with visual impairments in astronomy groups has increased, thanks to the existence of tools that make this possible. These individuals bring unique and enriching perspectives to the field, contributing innovative ideas and creative approaches that can lead to new understandings of the universe (Beck-Winchatz & Ostro 2003; Uchima Tamayo et al. 2019).

One of the tools that facilitates participation, or that pursues this objective, is sonification. “The sonification process takes a data table and transforms it into sound, with variations in the data producing perceptible changes in the intensity, timbre, pitch, and duration of the resulting sound” (Casado, J.et al. 2018). There are various sonification software tools, and some examples include: Highcharts Sonification Studio (`https://sonification.highcharts.com/#/`), StarSoud (`https://starsound.com/`), Strauss (`https://github.com/james-trayford/strauss`), Astronify (`https://astronify.readthedocs.io/en/latest/`), Soni-Py `https://github.com/lockepatton/sonipy`) y sonoUno `https://www.sonouno.org.ar/`). The last one, is a user-focus software that allows people with and without visual disability to explore scientific data both visually and through sonification . On another hand, a globally accepted resource for education and diffusion mainly,consist tactile representation

[1]Instituto de Bioingeniería, Facultad de Ingeniería, Universidad de Mendoza, Argentina.

[2]Instituto en Tecnologías de Detección y Astropartículas (CNEA, CONICET, UNSAM), Mendoza, Argentina.

[3]Universidad Tecnológica Nacional - Regional Mendoza, Argentina.

III Workshop for Astronomy Beyond the Common Senses for Accessibility and Inclusion (3WAI) (November 29-30, 2023)
Editors: Santiago Vargas, Beatriz García, Johana Casado, Breezy Ocaña, and Angela Pérez - DOI: https://doi.org/10.22201/ia.14052059p.2024.57.09

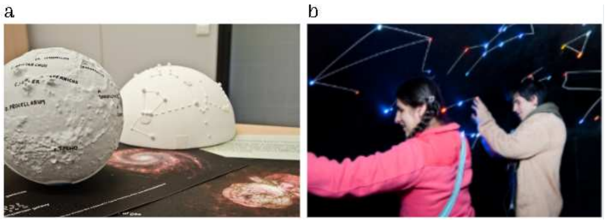

Fig. 1. a) 3D Model, Observatorio Astronómico de la Universidad de Valencia. b) Planetario inclusivo:tocar el cielo con las manos, Tecnópolis 2012-2023, Argentina.

of celestial objects and phenomena through 2D and 3D representations. The tactile experience provides a direct and tangible connection to the understanding of various astronomical concepts, but also these representations are also limited in their possibilities to transmitting phenomena for which the manipulation of physical parameters is often difficult to represent with these techniques.

The 2D tactile models are images represented with reliefs;simplification is sought by removing the less important objects to convey the most relevant information (Beck-Winchatz & Ostro 2003). As Eriksson (1999) indicated when transforming a image to relief for tactile understanding, it must be simplified. Each component should be distinguishable, not overlapping with other representations, and ensuring that they are not incomplete. To create tactile images, the paper used is considered, such as Swell Paper, which allows the representation of lines, points, and surfaces. Serigraphy is a more complicated method but enables printing on neutral backgrounds and also has greater durability (Eriksson 1999). Following the advice provident by Willings (2017) it is recommended to accompany the graphic with Braille labels and to indicate and define the graphic symbols used. This will allow the user's understanding of the model.

3D models offer a likely more comprehensive experience compared to the flat models described earlier. Being three-dimensional makes them suitable for representing astronomical objects, as it allows exploration and understanding of the shape and structure of celestial bodies. Within these models you can find "A Touch of the Universe"[4], y Un Tour a Oscuras (`https://www.eso.org/public/spain/announcements/ann19045/`). The first one is a project aimed mainly at children, that represent the moon, and some planets like Venus, Mars and Mercury with spheres (Fig. 1a). It is important to note

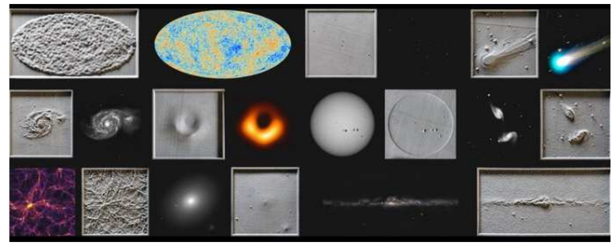

Fig. 2. Tactile models and their corresponding images of "Un Tour a Oscuras" exhibition.

that alongside this project, the software Mapelia[5] was developed to assist in 3D modeling.

The effectiveness of the described sphere representations (Fig. 1a) is under evaluation in terms of learning and the relationship between reality and the model. It is important to consider that in the case of representing the celestial sphere from the outside (tactile constellations represented on a hemisphere placed on the table or knees), this is an approximation that doesn't accurately reflect the real observation, as the observation process occurs from the Earth's surface towards the celestial sphere. There are projects that use 3D printing to represent the celestial sphere inside a printed dome (García et al. 2013), as shown in Fig. 1b). In these cases, it would be necessary to evaluate the method that best represents the object of study and allows people to study the phenomenon.

Regarding to "Un Tour a Oscuras", produced by Chris Harrison, it shows flat, non-spherical 3D models accompanied by the sonification of a set of real astronomical data. In Fig. 2, you can observe some of the 3D models used in the presentation. In addition to the mentioned projects, there are applications that allow three-dimensional modeling from images, such as Tinkercad (`https://www.tinkercad.com/`), y 3D Builder (`https://apps.microsoft.com/detail/9WZDNCRFJ3T6?hl=es-ar&gl=AR`) (for Windows) among others.

2. METHODS AND RESULTS

In the present work, we seek to develop a new open-source program in Python that, based on a 2D image representing some astronomical object or phenomenon, can relate the color or intensity in that image and the printing height;thus being enable to create a tactile model corresponding well to the image with a strong correlation between both. Ensuring the relationship between the physical parameters represented in the image and the generated 3D model

[4] Observatorio Astronómico de la Universidad de Valencia, `https://astrokit.uv.es/project_es.html`

[5] `https://joss.theoj.org/papers/10.21105/joss.00660`.

III Workshop for Astronomy Beyond the Common Senses for Accessibility and Inclusion (3WAI) (November 29-30, 2023)
Editors: Santiago Vargas, Beatriz García, Johana Casado, Breezy Ocaña, and Angela Pérez - DOI: https://doi.org/10.22201/ia.14052059p.2024.57.09

is one of the main objectives. While the visual approximation of the image is related to, for example, the false-color representation of an image acquired with detectors beyond the visible spectrum, during 3D printing, available software does not handle the physical data in the same way. Instead, they perform 3D mapping using only intensity. As mentioned earlier, Mapelia, for instance, takes a map and uses various Python libraries to create a 3D model based on intensities. Conversely, Puente Gimena (2020) utilizes neural networks for the creation of a 3D model but from three 2D images offset by 120° from each other. However, in none of these cases is there an allowance for data manipulation or selection of parameters to be translated into the 3D model.

For this project, the design of a program is proposed that from a 2d image, build a 3d model taking into account the height assigned to each pixel based on the color or intensity of each image element. The following libraries were used: *Numpy* for working with image matrix; *Pillow* for image manipulation, opening and saving; *Opencv* for image processing and analysis and *pyVista* to visualize data and images in 3D.

Initially, two codes were developed that formed the basis for the final development, enabling the generation of a 3D model based on an astronomical image. First, the focus was on the intensity of each pixel in the image, achieving approximations as described. Later, when working with an image representing Cosmic Microwave Background radiation, it was recognized that there was a need to relate to color rather than intensity to generate a fitting 3D model. The image used in this case was a representation of the Cosmic Microwave Background Radiation (CMB) at the resolution achieved with the COBE (`https://science.nasa.gov/mission/cobe/`) space telescope. In CMB images, variations in radiation temperature are observed, and the temperature scale, corresponding to the "false colors" perceived in the image, is always present.

2.1. *Intensity representation: Cartesian plot model*

The first code developed in this research processes images representing simple mathematical data from examples provided in the sonoUno software. These are graphs of linear regression (increasing and decreasing, Fig. 3a), quadratic, and sinusoidal types.The first step was to convert them to black and white. Subsequently, a mask was applied that inverts the colors, obtaining the negative of the image (Fig. 3b).

A second mask was used to thicken the lines of the image, allowing for better differentiation between

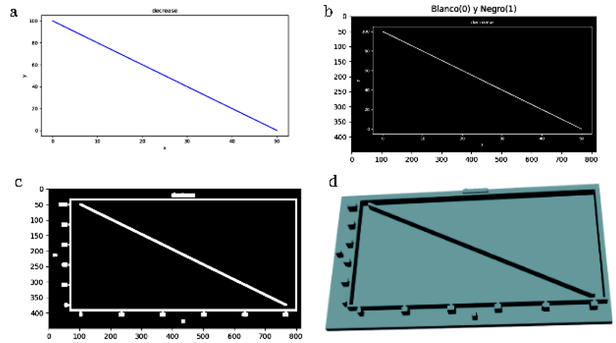

Fig. 3. a) Original Image; b) Inverted Image; c) Application of a mask to thicken lines; d) 3D Model of the decreasing function.

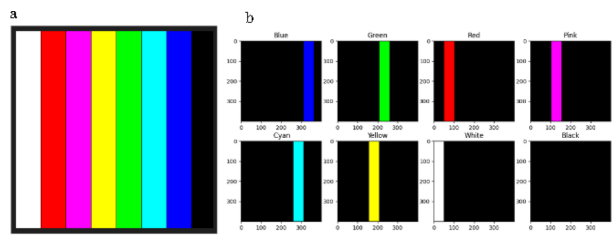

Fig. 4. a) Reference Image; b) Separation of pixels according to their color.

the background and the function (see Fig. 3c). The next step involved assigning heights; for this, the pixel values were considered. Pixels with a value of 0 were assigned a height of 0.5 cm, and those with a value of 255 were given a height of 1 cm. Finally, the three-dimensional mesh was designed (see Fig. 3d), using the pyVista library, and exported in STL format. This type of file is compatible with various 3D design programs, such as Cura and Simplify.

2.2. *The meaning of color: representation of physical parameters*

The second version of the code introduced specific aspects of the proposal, considering what the color represents in the image regarding the physical phenomenon. It's noteworthy that if intensity parameterization is used to model the CMB image, both high-intensity red and blue are represented in height, making it unable to discriminate what the color scale represents.

Firstly, the height scale corresponding to primary and secondary colors was defined. This provides a reference for subsequent colored images that one may wish to represent (always starting from images that convey information through color based on a scale). To achieve this task,an image was created (see Fig. 4a) where 6 colors, white, and black were included. From there, pixel processing began, where

III Workshop for Astronomy Beyond the Common Senses for Accessibility and Inclusion (3WAI) (November 29-30, 2023)
Editors: Santiago Vargas, Beatriz García, Johana Casado, Breezy Ocaña, and Angela Pérez - DOI: https://doi.org/10.22201/ia.14052059p.2024.57.09

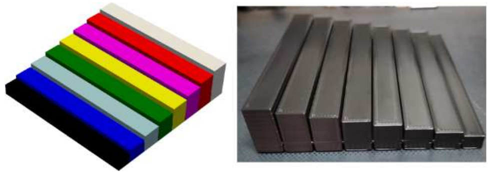

Fig. 5. Mesh of the reference image created with PyVista (left); 3D print of the model (right).

the available information from the image is the red, green, and blue components. Secondary colors are then defined as combinations of these primary colors. Additionally, to differentiate between dark and light shades, a classification based on percentages is adopted. For example, pixels with 100% red, between 0-10% green, and between 0-50% blue correspond to light red. However, those with a percentage of 10-50% red, between 0-5% green, and 0-10% blue correspond to dark red. This process is carried for all primary and secondary colors, resulting in a classification by shades that leads to a more detailed 3D model. The Fig. 4b shows the result obtained with this type of classification.

In order to assign colors to specific features in the image (for example, differences in brightness, thermal variations, chemical composition, or differential speeds), the heights are assigned according to the predetermined scale: white will have the greatest height, followed by red, magenta, yellow, green, cyan, blue, and finally black in ascending order of height. Once the heights are assigned, the three-dimensional mesh is created and saved in STL format for printing. In Fig. 5 (left), the 3D model is observed, while in Fig. 5 (right), the final print of this model is presented.

2.3. *Code for a real image*

Finally, the application of the developed code on the CMB image obtained by COBE is described. With some adjustments to the color range, it allowed the transition from an image captured by a telescope to a 3D model. Fig. 6a shows the segmentation of the CMB image into each of its component colors, with the sixth image being the original composed of the sum of the five previous ones. For height assignment, the scale shown in Figure 6b was taken into account, where it is observed that reds have more height than magentas, and so on until reaching black, which has a height of 0 cm. Fig. 7a shows the 3D model obtained from the program. On the other hand, Fig. 7b shows the 3D printed object.

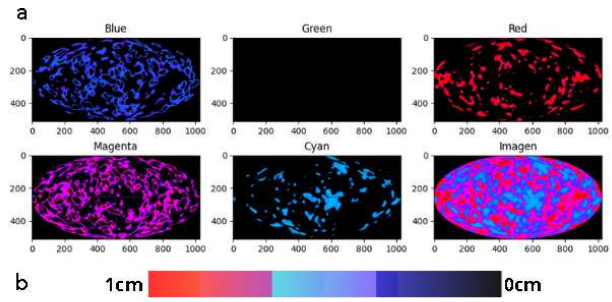

Fig. 6. a) Separation of pixels according to colors; b) Scale for heights.

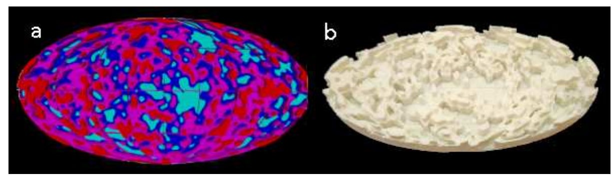

Fig. 7. a) 3D Model; b) 3D print of the model.

3. CONCLUSIONS

Tactile models of astronomical images can be enhanced through the development of open-source code, offering benefits such as a freely usable, collaborative, and inclusive tool. With this new approach to representing images in 3D models and the use of libraries like PyVista, models can be exported to STL for printing, achieving one of the central objectives of this work.

The proposed work is not exhausted by this development; it is necessary to work with a greater number of astronomical images and model them in 3D, ensuring the coherent transfer of information. The topic of tactile models has been little explored from the perceptual standpoint. Developments that establish a well-defined technique for constructing 3D models will contribute to advancements in research lines in multi-sensory astronomy. Particularly, in the future, the intention is to work with different temperature scales, allowing users to configure the scale to be used. It is essential to provide a resource that is adaptable and configurable according to the needs of the users. Optimizing the code to make it more intuitive is also part of the future work; an open-source software benefits from collaborative efforts for its growth and improvement.

REFERENCES

Beck-Winchatz, B., & Ostro, S. J. 2003, Revista de educación en astronomía, 2(2), 118-126. DOI:10.3847/AER2003018.

Casado, J., Cancio, A., García, B., Díaz-Merced, W., & Jaren, G. 2018, BAAA, 60, 291–293.

III Workshop for Astronomy Beyond the Common Senses for Accessibility and Inclusion (3WAI) (November 29-30, 2023)
Editors: Santiago Vargas, Beatriz García, Johana Casado, Breezy Ocaña, and Angela Pérez - DOI: https://doi.org/10.22201/ia.14052059p.2024.57.09

Eriksson, Y. 1999, Proceedings of the 65th IFLA (https://archive.ifla.org/IV/ifla65/65ye-e.html).

García, B., Maya, J., Mancilla, A., Pérez, S., Videla, M., Yelós, D., Cancio, A.; Broin, D., & Ferrada, R. 2013, EPSC Abstracts, Vol. 8, EPSC2013-348.

Puente Gimena, I. de la 2020, Tesis (Master), Universidad Politécnica de Madrid, E.T.S.I.

Uchima Tamayo, J.P., Salazar Manzano, L.E., Arias Santa, N.,& Quintero Salazar, E. A. 2019, Revista Científica, pp 262-270.

Willings, C . 2017, Pautas de gráficos táctiles (https://www.teachingvisuallyimpaired.com/tactile-graphics-guidelines.html).