ShadowAstro: Levitating Constellation Silhouette for Spatial Exploration and Learning

Jiatong Li*
jtlee@uchicago.edu
University of Chicago
Chicago, Illinois, USA

Jesse Gao*
jessegao7@uchicago.edu
University of Chicago
Chicago, Illinois, USA

Ken Nakagaki
knakagaki@uchicago.edu
University of Chicago
Chicago, Illinois, USA

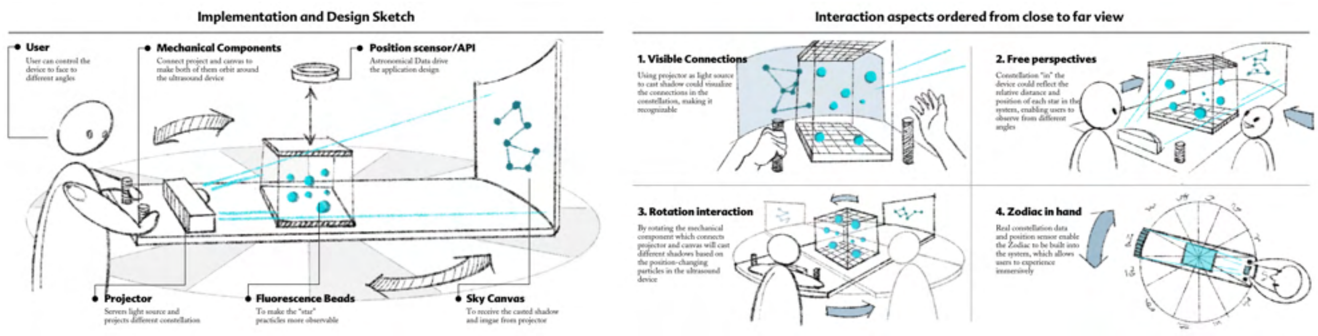

Figure 1: ShadowAstro Configuration: User can scan the 12 constellations on the zodiac and inspect a single constellation in great detail

ABSTRACT

We introduce ShadowAstro, a system that uses the levitating particles' casted shadow to produce a constellation pattern. In contrast to the traditional approach of making astronomical observations via AR, planetarium, and computer screens, we intend to use the shadows created by each levitated bead to construct the silhouette of constellations - a natural geometrical pattern that can be represented by a set of particles. In this proposal, we show that ShadowAstro can help users inspect the 12 constellations on the ecliptic plane and augment users' experience with a projector that will serve as the light source. Through this, we draw a future vision, where ShadowAstro can serve as an interactive tool with educational purposes or an art installation in museum. We believe the concept of designing interactions between the levitated objects and their casted shadows will provide a brand new experience to end user.

KEYWORDS

Levitation, Physical visualizations, mid-air UIs, immersive astronomy

*Both authors contributed equally to this research.

UIST '22 Adjunct, October 29-November 2, 2022, Bend, OR, USA

ACM ISBN 978-1-4503-9321-8/22/10.
https://doi.org/10.1145/3526114.3561345

ACM Reference Format:
Jiatong Li, Jesse Gao*, and Ken Nakagaki. 2022. ShadowAstro: Levitating Constellation Silhouette for Spatial Exploration and Learning. In *The Adjunct Publication of the 35th Annual ACM Symposium on User Interface Software and Technology (UIST '22 Adjunct), October 29-November 2, 2022, Bend, OR, USA.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3526114.3561345

1 INTRODUCTION

Astronomers and stargazers believe that astronomy requires direct observations (i.e. observing the night sky from outdoor locations) to facilitate learning experiences [2, 9]. However, outdoor stargazing is easily to be affected by weather conditions. Therefore, some researchers developed AR-based system (e.g. M-VSARLS [8]) as an alternative. One disadvantage is today's planetarium softwares (e.g. Stellarium [1]) [3] are mostly confined in traditional 2D Graphical User Interface (GUI) or AR glasses. Although the software contains lots of useful information, such as coordinate grids and compass support, the 2D screen cannot better reflect the structure of 3D constellations (e.g. distance can be distorted based on how the user scrolls the screen). To solve this problem and add more immersive interactive elements to planetarium applications, we propose leveraging acoustic levitation's 6 Degree-of-Freedom (DOF) to build a 3D star map.

Since organza-based shape set and polystyrene beads set will be provided, we decided to narrow down our topic to constellations that can be represented by dots and lines. ShadowAstro is built on top of the concept of creating interaction between the levitated objects and their casted shadow [2] and enable user to inspect the

[1]https://stellarium.org/
[2]inspired by the award-winning game *Shadowmatic* which requires players to spatially rotate a 3D object until the casted shadow forms a recognizable geometric pattern. Link: https://apps.apple.com/us/app/shadowmatic/id775888026

12 constellations on the zodiac. As indicated in Figure 1, users can rotate the section which contains a projector in the near side and a canvas in the other side by using the mechanical mechanism—as part of our final design, and see the silhouette of each constellation. Since the location of each constellation was defined based on the location of the sun in a given year, the *rotate* interaction can not only educate users on the spatial location of each constellation, but also create a "travel through sky and seasons" experience.

2 RELATED-WORK

Shadow Sculptures: The concept of using shadows have already been investigated in media art and computer graphics. For example, media artist, Ryota Kuwakubo used a LED light source mounted on a modified railroad to cast dynamic shadow movement in his work *10th sentiment (dot / line / surface)* [1]. Besides, Fabrizio Corneli designed outdoor shadow sculpture which will change based on the weather and the eye of the beholder [6]. In the field of computer science, researchers have proposed a computational tool that enable users to design complex shadow sculpture (e.g. simultaneously casting three different shadow from one single object) [5]. Our work is inspired by the aforementioned shadow sculptures and intend to use levitating particles to cast 2D shadows based on volumetric data.

Astronomical Observation System: In the field of astronomy, star maps are a crucial tool to help students learn and stargaze. Past research has demonstrated how star maps can be useful as an educational tool for teaching celestial coordinate systems [7] and constellations [4]. Researchers have also tried to integrate new interface technologies (e.g. Augmented Reality) into astronomical observation [9]. Our work aims to develop an interactive system with levitation technology not only to teach astronomy concepts, but also to make astronomy accessible and fun through embodied and spatial interaction.

3 SYSTEM-AND-IMPLEMENTATION

The overall system of ShadowAstro consists of *casting shadows on canvas*, *applying fluorescence on levitated beads*, *using astronomical data to position each bead*, and *a mechanical component to rotate the light source*. We discuss our preliminary plan on how we will implement each component.

Shadow - Casting shadow requires us to set a separate light source (i.e. projector) next to the ultrasound boards as indicated in (Figure 2 right). The projection will serve as an augmentation to user experience by displaying the constellation pattern as well as the "sky map" around it.

For the purpose of evaluating the feasibility of producing shadows with levitated particles, we experimented using the acoustic levitation toy [3] (Figure 2 left). The casted shadow is clear and easy to spot on a white surface.

Fluorescence Beads - Applying fluorescence paint on beads can serve as a visual guidance for users in dark environments. The "glowing-in-the-dark" effect can also be aesthetically appealing.

Astronomical Data - We will use astronomical data to define the relative distance of each star in the constellation after scaling it by a factor. The wonderful open-source community makes accessing astronomical data easier and faster. For example, the github repository [4] we found contains a curated list of APIs and softwares we can reference and it contains a variety of data sources such as constellation position and even space debris.

[3]https://bit.ly/3zlIr5p

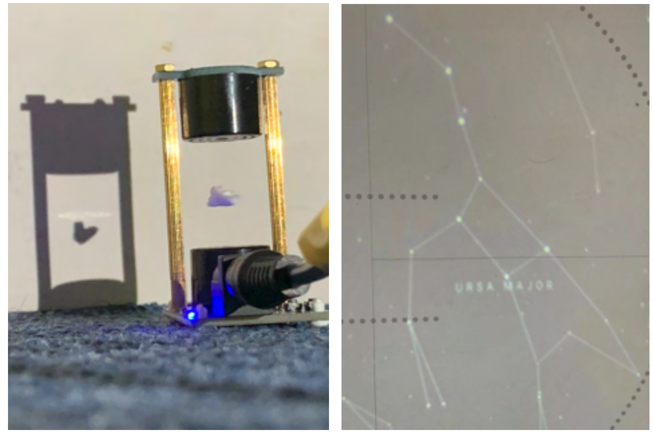

Figure 2: Proof of concept (left). Projection: augment user experience by adding graphical cues (right).

Mechanical Components - As indicated in Figure 1, our project requires a mechanical structure to support rotation and a bridge that connects the projector, ultrasound boards, and canvas. This can be done by 3D printing mechanical attachment and retrofitting off-the-shelf devices such as rotating tray [5].

4 USE CASE/USER SCENARIO

In this section, we introduce a user scenario with a persona, James, who is a ten years old boy, to demonstrate the experience we deliver in the contest .

James wants to explore the 12 constellations on the ecliptic plane. He is not quite sure what each constellation looks like so he uses ShadowAstro to explore. He first rotates the light source in order to scan the ecliptic surface and stops at Scorpius since it is his star sign. ShadowAstro filters out other constellations and only displays Scorpius for James by levitating the related beads in the ultrasound area and placing them to relative positions. The position of each star is scaled based on astronomical data so that James understands the structure of this particular constellation (e.g. Shaula is closer to Earth than Lesath [6]). He invited his friends and each of them observe the levitated particles (or "stars") from a unique angle.

5 FUTURE APPLICATIONS AND UTILITY

Astronomy education - By adding aerial gestures such as *rotate to the left*, we can create more interaction techniques in ShadowAstro. For example, students can control the particle sets and even *zoom in/out* star clusters. Through direct sensation and interaction, students can use ShadowAstro to explore other constellations and even comets that are not limited to the one on the ecliptic plane.

[4]https://github.com/orbitalindex/awesome-space
[5]https://amzn.to/3Oi8nTT
[6]both stars represent Scorpion's Stinger stars

Museum exhibition - ShadowAstro can also become a large-scale museum exhibition. One possible museum setup would be replacing the current rectangle canvas with a dome-shape screen (similiar to the one in the dome theatre). People can walk in the dark room and have an immersive experience.

REFERENCES

[1] Alessio Chierico. 2015. Ryota Kuwakubo: the reality of shadows. http://digicult.it/news/ryota-kuwakubo-the-reality-of-shadows/

[2] Ryuji Hirayama, Giorgos Christopoulos, Diego Martinez Plasencia, and Sriram Subramanian. 2022. High-speed acoustic holography with arbitrary scattering objects. *Science Advances* 8, 24 (2022), eabn7614. https://doi.org/10.1126/sciadv.abn7614 arXiv:https://www.science.org/doi/pdf/10.1126/sciadv.abn7614

[3] Stephen Hughes. 2008. Stellarium-a valuable resource for teaching astronomy in the classroom and beyond. *Science Education News (SEN)* 57, 2 (2008), 83–86.

[4] Annette S Lee, William Wilson, Jeff Tibbetts, Cark Gawboy, Anne Meyer, Wilfred Buck, Jim Knutson-Kolodzne, and David Pantalony. 2019. Celestial calendar-paintings and culture-based digital storytelling: cross-cultural, interdisciplinary, STEM/STEAM resources for authentic astronomy education engagement. In *EPJ Web of Conferences*, Vol. 200. EDP Sciences, 01002.

[5] N. J. Mitra and M. Pauly. 2009. Shadow Art. *ACM Transactions on Graphics* 28, 5 (2009). to appear.

[6] Pinar Noorata. 2014. Incredible shadow art by Fabrizio Corneli. https://mymodernmet.com/fabrizio-corneli-shadow-art/

[7] Paul B Selz. 1959. Teaching Aids in Astronomy. In *Proceedings of the Iowa Academy of Science*, Vol. 66. 365–368.

[8] Ke Tian, Mamoru Endo, Mayu Urata, Katsuhiro Mouri, and Takami Yasuda. 2014. Lunar Observation Support System Using Smartphone AR for Astronomy Education. *International Journal of Interactive Mobile Technologies (iJIM)* 8, 1 (Jan. 2014), pp. 32–39. https://doi.org/10.3991/ijim.v8i1.3457

[9] Ke Tian, Mamoru Endo, Mayu Urata, Katsuhiro Mouri, and Takami Yasuda. 2014. Multi-viewpoint smartphone AR-based learning system for astronomical observation. *International Journal of Computer Theory and Engineering* 6, 5 (2014), 396–400.