Mountain Direct Energy Wayfinder: an Automated Assistive Laser Star Pointing Device

(Technical Topic)

Spotify: How Digital Media and Artificial Intelligence Has Changed the Consumer's Relationship with Music

(STS Topic)

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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I. Introduction

When creating educational tools and applications, engineers should consider not only their impact on users but also society throughout the design process. After all, how we think about the world depends on how we perceive it, whether it's through our eyes when we look up to the sky at night or through our ears when we listen to music. Technology aids our perception of the world passively by pointing out existing elements, like using a laser to point at stars, or actively by producing new sensations, like playing music in a quiet room. Such technological systems may also dictate how we interpret the world around us, as often these systems will automatically associate certain groups of these stars, songs, or other experiences with names and other media, building upon previously existing cultural perceptions of these objects.

This is why Donna Haraway states that "the 'eyes' made available in modern technological sciences shatter any idea of passive vision" (1988)— the systems that we create for perceiving and interpreting the world should be treated as active components within it. In stargazing, we can think of telescopes created by scientists and companies for selling the wonders of outer space, or constellation stories from our family as a means of sharing and preserving cultural narratives. When listening to music, apps like Spotify or Apple Music not only allow us to organize access to vast libraries of audio into personalized playlists but also make algorithmic recommendations for said playlists to encourage us to keep using their system. It is therefore prudent to examine technologies that influence *what* we perceive and *how* we interpret the world, and then ask *why* they are constructed to do so and *whom* those means serve.

My technical project team is building an automatic laser star-finding system for amateur educational groups as an inexpensive alternative to single-user computerized telescopes. Users of our device will input a star that they wish to view, and the device will use Global Navigation

Satellite System (GNSS) data to aim and point a laser at the target object. A battery-powered microcontroller will take in star selection via a joystick and liquid crystal display (LCD) screen and then control motors on a gimbal to rotate the laser. Users of our device will have greater access to astronomical knowledge and can therefore enjoy stargazing without needing someone else more experienced or an expensive telescope to accompany them.

For my sociotechnical research, I will study the impact of curation and recommendation algorithms in music streaming services on the relationship between listeners, music, and their data, and compare that with prior methods of music curation. I have chosen to focus on Spotify specifically because it has the most subscribers at 30.5% of the market (Kale, 2023). Michel Callon's Actor-Network Theory can model Spotify's use of artificial intelligence models and the collection of user data, both of which make up the core of the algorithmic recommendation and curation system at the center of Spotify's success. By making the means of audio distribution and consumption cheaper and more widely available through its subscription model, Spotify and other music streaming services have shifted power away from listeners who previously curated the majority of their library through buying music to curation algorithms that are responsible for searching the service's library on behalf of the user.

II. Technical Report

First-time stargazing can challenge groups of amateur astronomy enthusiasts due to (1) low-light conditions that prevent the use of paper guides and (2) lack of access to power and cell signal that may limit the use of mobile phones and other smart devices, especially in remote locations ideal for stargazing. Having a more experienced stargazer present may resolve some of these issues, but not everyone may have access to such a person. Additionally, directing attention

to a single point in the sky with only an arm in the dark still poses a major challenge, especially for larger groups of younger students. It would therefore be preferable to use an automated system with a bright reference, such as a laser for such groups.

While there are existing commercial systems for star tracking, these options typically cost hundreds or even thousands of dollars, such as the SkyProdigy 6 Computerized Telescope (Celestron, n.d.). Laser pointers made for manual star-tracking are already widely available at a much lower cost but require an already experienced user to successfully operate in the dark (Johnson, 2023). While there are some tutorials for DIY projects available online that attempt to combine the benefits of both of these technologies using an Arduino board and 3D printing (Görkem, n.d.), none of them offer a robust solution for enthusiasts who may not have such materials already available to them. Such projects may fail to address the safety, environmental, and legal concerns of pointing lasers into the night sky, which can lead to the distraction or blinding of pilots flying above depending on the power of the laser. The goal of this project is to therefore combine the benefits offered by both technologies into an affordable and robust product for astronomy educational groups that also takes into account the appropriate external considerations for such a device.

Our system is composed of five main subsystems: (1) the two-axis gimbal and laser mechanical assembly, (2) the STM32 Nucleo microcontroller, (3) an LCD screen, joystick, and push-button for user input, (4) a GNSS header board and chip, and (5) a printed circuit board (PCB) and power supply for powering each subsystem. When the device is on, the user will be able to use the joystick and push button to select a star or celestial body from a list displayed on the LCD screen. The STM32 Nucleo will then find the celestial body's coordinates in its database, calculate the current position of the pointer given the latitude, longitude, and time of

day from GNSS data, and then adjust the gimbal such that the laser is pointed at the new target location. Once the gimbal is done adjusting, the laser will come on and point to the new target star for a short period, before turning off and waiting for more user input. We chose the STM32 Nucleo since it not only met the minimum requirements for memory and computational power set by our design requirements but also already had several off-the-shelf GNSS and LCD header boards available for use in our device. After the design of the star-finding algorithm has been completed, the microcontroller can also be optimized for low-power consumption, allowing for longer operation in the more remote locations ideal for stargazing. Through this system, we hope to improve access to astronomical knowledge and convenience for first-time stargazers without the need of someone else more experienced accompanying them.

III. STS Paper

Music streaming services have grown rapidly in the past decade due to the proliferation of smartphones and cellular broadband networks, with massive collections of digital music freely accessible to users willing to listen to ads or pay a monthly fee. The IMS Business Report 2023 estimates that there are now over 600 million subscribers to music streaming services worldwide, with the Swedish company Spotify possessing 30.5% of the total market, pulling ahead of other major corporations, like Apple, Youtube, and Tencent (Kale, 2023). Spotify's business model has grown famous, with the term "Spotification" coined for groups in other media distribution industries attempting to mirror Spotify's success (Fleischer, 2021).

In addition to its subscription-based business model, the key to Spotify’s success has been its use of artificial intelligence models for curating and recommending music for users. Without such algorithms, Spotify would not be able to attract and retain enough listeners for its massive

music library to generate profit. This shift in technology does, however, beg the question: to what extent has Spotify's use of recommendation algorithms impacted the listener's relationship with music? How does this impact compare with prior methods of music curation?

These questions matter because researchers at Spotify have already shown that algorithmically controlled listening correlates with reduced consumption diversity in users (Anderson et al., 2020). Unlike physical stores or electronic app screens where users browse for specific music that they would like to listen to, algorithmic listening systems are more likely to recommend music in the same genre to users rather than exposing them to other forms of music. Spotify's default autoplay feature, which continuously plays music even after a user's chosen song has finished, encapsulates this phenomenon. Since the listener must make an effort to pause or switch tracks, autoplay causes them to listen to more algorithmically recommended tracks, thereby decreasing consumption diversity even if other genres of music are technically available for the user to choose.

Spotify's use of algorithmic recommendation models for targeted advertisements also requires an aggregation of user data only provided by large corporations that can afford the resources and expertise to manage it. Kindra Cooper reports that "Spotify logs over 100 billion data points per day based on the activities of its 207 million active users around the world" (2019). This data includes personally identifiable information, such as a user's email address, date of birth, gender, postal code, and country, as well as what songs or playlists they have liked (Common Sense Media, 2022). While the storage of account information and listening history may seem innocuous at first, one should also note that "...more than half of [the active users] are free, ad-supported users who receive ads in the form of audio, video and display banners" (Cooper, 2019). While each advertisement alone may not generate much value for Spotify, by

employing recommendation models fed by user data at scale, the service can generate targeted recommendations that result in more revenue. The more data the company can take advantage of, the better artificial intelligence models it can make, and the more profit it can generate from targeted advertisements. This revenue and data also give the company greater ability to outcompete its rivals, with a larger music library, better customer service, and more resources it can acquire for storing and making use of its data. Investigating the nature of the positive feedback loop created by Spotify's recommendation algorithm will be crucial to understanding its impact on how listeners curate their music libraries.

This STS analysis will focus on three social groups: (1) Spotify's users, (2) the Spotify corporation, and (3) Spotify's artists. Most Spotify's users are from the regions of North America and Europe, and are relatively young, lying within the age range of 18-34 (Shewale, 2023). Since the main goal of the Spotify corporation is to generate profit, it could develop its algorithms and cultivate its library to fit the tastes gathered from the data of its user base, which could limit Spotify's incorporation of artists that may appeal to older users or those not from North America and Europe. On the flip side, if the Spotify corporation wants to expand more into other regions of the world, such as Latin America, the ways it organizes musical genres by national identity on its platform through its recommendation algorithm could also reinforce cultural ideas and stereotypes surrounding certain countries or groups of people, as noted by Anne Werner's findings of Spotify's "related artists" function (2020).

I will use Actor-Network Theory to describe how the motivations of Spotify's algorithm— to maximize its user's consumption of music— may not always align with that of its developers. Depending on the data available, the algorithm trained could unintentionally amplify biases already present within Spotify's user base. For instance, if the Spotify corporation wanted

to expand its markets more to other countries, its current recommendation algorithm's potential biases for English-speaking music and media may hinder the company's ability to grow. Of course, Spotify can train different and more complex artificial intelligence models to take this into account, but such development hinges on the availability of listener data from said region, which may put them at a disadvantage compared to other existing competitors. I would also consider user data as an actor separate from the user, as their model depends on such data to generate better recommendations and therefore generate profit for the Spotify corporation. In considering not only the listener, corporation, and artist but also user data and the recommendation algorithm, Actor-Network Theory will be key to evaluating the socio-technical relationships and their societal implications in this actor-network.

IV. Looking Ahead

For my technical project, my group is currently wrapping up the first design phase of our project, with all components specified and ordered, with only the gimbal as the last off-the-shelf component to arrive. Going forward, now that we have chosen all off-the-shelf components, we are currently designing and assembling the printed circuit board for our device, in addition to testing and verifying each subsystem. Most importantly, since we have finished creating the finite state machine for the device's control scheme, we will verify its implementation in software on the STM32 microcontroller board before beginning first on our first full prototype. From there, we will evaluate the initial design based on the set of requirements we already generated with the client and iterate on our design from there.

Regarding STS research, I have focused on gathering background information and reviewing existing literature on both the business structure of Spotify and the technical details of

its recommendation algorithm, in addition to potential ethical concerns regarding its use of artificial intelligence. With the bulk of the research completed, I plan on applying the Actor-Network Theory framework to form connections between each actor in the network and identify a point of obligatory passage for every actor. As my research reveals more relevant information, I intend to supplement my findings with more literature and continue from there.

V. Key Texts

Michel Callon's "Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay" outlines the three principles of Actor-Network Theory, modeling socio-technical activity as interactions between both natural and social actors that Callon treats as the same within the framework. Callon then applies this framework to explain the success and failure of attempts by local researchers to prevent the decline of scallops in St. Brieuc Bay through four 'moments' of translation, in which the researchers enrolled both social and natural actors in their network to achieve their goals. This text matters because it lays the foundation for the Actor-Network Theory framework through which I will analyze the development and impact of the recommendation algorithm used for Spotify on users.

Anderson and collaborators' "Algorithmic Effects on the Diversity of Consumption on Spotify" gives a basic overview of the technology and data behind Spotify and explores the impact of algorithmically driven listening on consumption diversity, or the overall broadness of the content that they engage with when using Spotify. The researchers' results linked algorithmically driven listening with reduced consumption diversity, finding that users who did become more diverse in their listening often did so by curating their music. This text is significant not only because of its findings on the impact of algorithmically driven listening on

user consumption diversity but also because it provides some perspective of the researchers and developers at Spotify and how their motivations may differ from the algorithm.

Kowald and collaborators' "The Unfairness of Popularity Bias in Music Recommendation: A Reproducibility Study " also examines whether music-streaming recommendation algorithms are typically biased toward more popular items by reproducing analysis from a similar paper examining movie recommendations. The authors found that this bias towards popular music led to more niche music receiving fewer recommendations, with the algorithm less likely to match users who favored more niche music to their preferred picks. This text provides further important evidence of how bias within Spotify's recommendation algorithm may impact different users unequally with a reproducible approach for comparing model performance for differing groups through Group Average Popularity.

Werner's "Organizing music, organizing gender: algorithmic culture and Spotify recommendations" is a fantastic analysis of how three Spotify functions relating to each piece of music, the user, and the platform as a whole represent ideas of gender in their representation of music in Spotify's curated playlist. Werner argues that Spotify's recommendation algorithms reinforce cultural conceptions of gender, nationality, and race through their representation in the music presented to the user, such as presenting rock as masculine and white. This article is especially relevant because it examines reinforced power structures inherent to the labels that Spotify uses to organize its music, which a pure Actor-Network examination of Spotify's recommendation algorithms may not model well.

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