ADSM: AUDIBLE DISPLAY OF THE STOCK MARKET IN REAL TIME

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ABSTRACT

Whilst trading (buying/selling shares) in the stock market, the number of data streams that can be monitored has never been greater. Consequently, traders who do not have years of experience can become overwhelmed and miss multiple opportunities due to visual fatigue. This study investigates using sonification to utilise the auditory channel so that the user can focus primarily on technical analysis whilst still receiving information in a serendipitous peripheral fashion. A custom sonification tool was designed and built to enable NYSE index data to be sonified in real time. One pilot study was conducted during the testing phase with an additional user study of 5-10 participants to take place after. Through this study it was found that having a continuous stream of data allowed for the trader to have knowledge of the NYSE whilst focusing on cognitively-demanding tasks such as technical analysis and research into further opportunities in different stock exchanges.

1. INTRODUCTION

Technical analysis (the prediction of price movements based on historical data) has been at the forefront of stock market trading for many years. When making decisions to enter or exit a position (i.e., buy or sell shares), traders analyse stock performance to inform their choice. The oldest recorded method of analysis is the Japanese candlestick method [1], originating in 1654 Japan where rice merchants would use these candlestick charts to enable them to determine the fair price to sell at Dōjima Rice Exchange [2, 3] during the Edo/Tokugawa period. The technique was adopted by western traders in the 19th century and became the industry standard in Wall Street and across the globe, and is credited as one of the most prevalent trading techniques in use [4] (see Fig. 1). With such techniques, traders can become aware of new patterns that could hold significant importance when trading in a volatile market.

A stock's volatility is crucial when monitoring stock prices. With most larger index funds and blue-chip stocks, volatility does not usually affect them on a day to week basis, however there are exceptions such as Tesla™ [5]. When viewing historical data, changes due to volatility can span months and even years, with multiple swaying factors. In a study conducted with over 129 years of data (1857–1986), the main impacts on price fluctuation

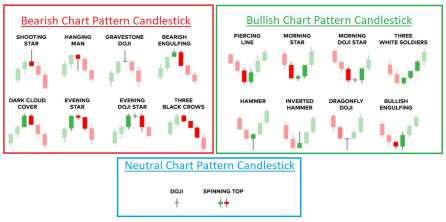

Figure 1: Various patterns inside candlestick charts

were found to be the long-term risk of holding shares, the inancial stability of a company, and constant dividends [6]. However, while this was a favourable theory in the late 20th century, multiple evaluations for pricing have since been developed. This led to the modern portfolio theory. This proposes maximising returns for a given risk, those returns calculated out prior to the entry of the trade. Taking this into account, judging whether the market is currently in a bull (rising prices) or bear (falling prices) state will most likely sway the overall pattern but will directly correlate with an index fund. Thus, understanding a market's history and volatility will play a key part in understanding the data, and is a strong candidate for transformation into an audible data stream.

Traders tend to rely on an wide variety of tools and software to help them gather as much data as possible which they can then turn into successful trades [7]. Outside of Wall Street, even casual traders have an array of different tools at their disposal, the most common ones which are used together are news and social media monitoring tools, algorithmic trading systems, AI/ML tools, screeners, and portfolio management software. This situation poses the same problem as the professional software — eventually the user gets exposed to more data than they can meaningfully analyse and comprehend. Large institutions and all prominent investment banks tend to rely on the Bloomberg terminal [8] which condenses and displays multiple data streams. Such software requires constant attention which means that only limited data can be apprehended and used at a given time. When trading, seconds can be the difference between a small and large return, so having the correct data to hand is vital. In large organisations, traders tend to have multiple monitors to make the most of their peripheral vision [9]. While tried and tested, this method till requires the traders' full attention and they can still miss small changes.

Over the course of a day's trading this can lead to user fatigue, draining their energy and, ultimately, lead to mistakes [9]. Along with user fatigue, other distractions can occur, leading to inconsistent visual monitoring in crucial times.

Unlike previous stock sonification systems [8, 7, 9, 10] the

present ADSM system was designed around the calm technology principle of placing interaction between system and user at the perceptual periphery instead of making it the centre of attention [11].

The rest of this paper describes the ADSM (Audible Display of the Stock Market) tool. All code and links to audio examples can be found in the project's online repository [12].

2. DESIGN

The design of the tool fell into two categories: audio design and visual design. Following the basic concept creation, expanding and allowing for discussion for the audio and visual concepts made sure that each use case had a utilitarian purpose while still adhering to calm technology principles.

The tool was built using the ReactJS and ToneJS frameworks. ReactJS allows for DOM manipulation without the need for refreshing the interface for changes to be registered. This led to hooks which allow for values to be stored in state and lifecycle methods. Since React is built on NodeJS and is made for web applications, this allows us to communicate with existing websites to retrieve data through sources like websockets. For this software, all data was captured through a web socket on the Yahoo Finance website and then decoded in the back-end of the software. ToneJS is a audio framework built on top of the web audio API that allows us to map data to sounds [13]. It offers both high level digital audio workstation (DAW) functionality as well as low level functionality allowing the creation of synthesizers, effects, and control signals.

2.1. Audio Design

One major issue when designing with sound is that if it annoys or fatigues listeners they are more likely to ignore or even switch the audio off. Coloured noise is found within everyday life [14], the most common being white and brown, however, the difference is perceptually stark. White noise can become very fatiguing and abrasive after a long period of time, though it can lead to shorter participant reaction time than pink noise [15]. Unlike white noise which has a constant intensity, brown noise contains more energy at lower frequencies making it tolerable to listen to for long periods. Guo *et al.* [15] recommended investigating the use of brown noise in attention tasks. It has also been found to boost productivity within workspaces by allowing employees concentrate and keep them relaxed in stressful situations [16]. Therefore, brown noise was selected as the carrier sound to be modulated by the sonification variables as this allows for the user to concentrate (potentiially without fatigue) and to remain calm in a stressful situation.

A lowpass filter was initially set to 1 kHz to restrict high frequency components. The filter cutoff was then adjusted within ToneJS to manipulate the sound in step with the incoming data. The filter allows or blocks frequencies depending on the movement of the stock in comparison to the opening price.

The focus of this tool is the trend of the stock market throughout an intraday time series. In Table 1 stock data over a three hour period in thirty minute intervals is presented with the opening price for a visual comparison. This shows the variation of the price throughout a day with some prices going above their opening and some below. This research proposes to create a constant stream of sound that will rise or fall in comparison to the change since opening. For instance, two of the seven times recorded were below the opening price. This would mean that the sound would be falling in

Time	Current Price	Opening Price
9:00	$405.67	$405.67
9:30	$405.31	$405.67
10:00	$405.89	$405.67
10:30	$407.51	$405.67
11:00	$406.12	$405.67
11:30	$406.73	$405.67
12:00	$405.34	$405.67

Table 1: Stock data generated by a Python script to simulate half a day's trading.

intervals until the price rises above the opening resistance or hits the threshold and vice versa for rising. Thresholds were necessary as when the filter was being manipulated the sound starts to rise to a point that becomes displeasing for the user or drops to a point where it becomes very hard to distinguish, even in a silent testing environment. To eliminate this, logic was implemented so that the filter which rises or falls in 10 Hz increments when data is received can only reach a high of 3.5 kHz and a low of 50 Hz. These values were selected through heuristic testing and act as a boundary before the sound becomes draining and requires a large amount of focus. Once these values are reached, the filter resets to 1 kHz acting as a way to resolve the sound whilst also giving the data a tempo making pattern recognition significantly easier.

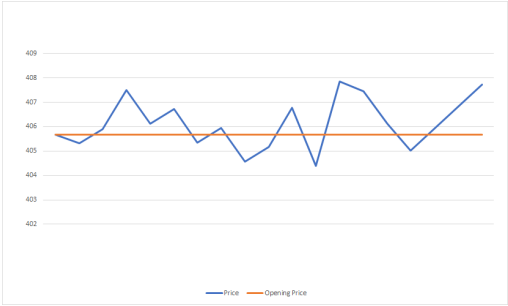

Figure 2: Visualisation of the stock data with a baseline

When the price line is above the opening price baseline (see Fig. 2) the filter will continue to rise, creating a rising sound which then resets. When the stock data is below this line a gradual falling sound will be generated, indicating that this is a bearish stock/index fund. This allows the user to understand which trend the market is following so that they can be use visual tools (e.g., candlestick diagrams) to carry out technical analysis on other stocks whilst knowing what patterns to look out for due to the bullish or bearish nature of the market that day. Monitoring this through an audio stream means that even though there is a visual dashboard, the user can be monitoring the data in a serendipitous-peripheral fashion [17].

Additionally, an alarm function was implemented to allow for extreme changes to alarm the user and gain their attention. Once alarmed, the trader can then choose to do more analysis to understand why the sudden change, and if there are any trading opportunities arising from this. For the alarms a Dorian Scale with a tonic of A was used, with the root and third representing one stock and the root and dominant representing another for clarity. Due to the customisability of the software, which stocks are assigned an alarm can be changed easily with the use of a custom React hook

linked to the toneJS library, along with the sudden price change in percentage.

A prototype was created (Fig 3) with a minimal UI style in mind to adhere to calm technology principles. It displays all needed information in a clear and concise format allowing the user at glance to gain all information needed. Using a monochrome colour palette ensures that the users attention is not directly captured due to colours or features implemented on the application. The dark mode toggle located in the top right will invert the whole application for late evening/night viewing leading to less fatigue [18].

3. TESTING

This first iteration of the software was built using React and ToneJS and acts as an offline dashboard, collecting data from the Yahoo Finance websocket (see Fig 3). It conforms to all requirements mentioned, being informative, whilst not requiring full user attention. The simple design allows for it to be opened for short periods in which time the user can gather all needed data. Alternatively, it could be placed on another monitor to take advantage of the user's peripheral vision.

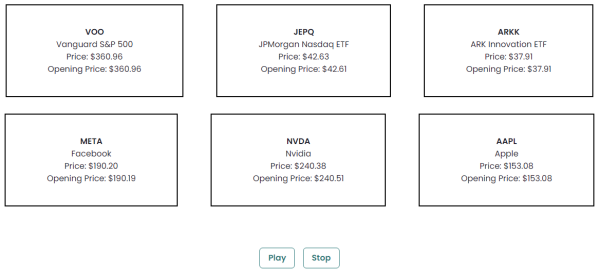

Figure 3: First version of the visual dashboard

To test that the software was effective within a trading environment, a full day of fantasy trading was conducted by the first author using the tool's sound as the primary source of information whilst performing technical analysis. Fantasy trading, also known as a virtual trading simulator, is the process of trading stocks, ETFs and futures with virtual money. They are primarily designed for educational contexts, but use real time stock data through an API. A benefit of using a trading simulator allows for no real money or shares to be at risk whilst learning or testing new trading algorithms or software. For this pilot test, a stock simulator was used to emulate a real trading day, using it to place purchase and sell orders whilst doing technical analysis within TradingView, a desktop charting analysis application. The sonification played continuously, providing additional peripheral information so that when trading the user would know whether the New York Stock Exchange (NYSE) is following a bullish or bearish trend. It also permitted them to do analysis on other markets or stocks not included within the fund being monitored by the tool whilst still understanding how the US markets are moving in the case of open positions, that is an incompleted trade that still has the potential to incur a profit or a loss.

Throughout this mock trading day, the parameters monitored were Vanguard S&P 500 ETF (exchange traded funds) ($VOO) for the noise. Alarms were placed for VOO, ARK Innovation ETF ($ARKK), Apple ($AAPL) and Tesla($TSLA). VOO was monitored for the trend of the market as most large blue chip stocks which can dictate the movement of the market that day are inside the Standard & Poor's index fund. This acts as an anchor point for all analysis when trading inside the NYSE. Each alarm was given different parameters for change as they monitor very different industries. VOO, being one of the largest index funds, was given the threshold of 3% each way as any further correction would indicate trading opportunities for a bounce back or further gain. ARKK, being a volatile ETF, down 5.72% over a month but up 24.84% as of 14th March 2023, was given a 5% threshold allowing for more movement before an alarm was sounded as this ETF acts as a long term option inside a trader's portfolio. For individual stocks two of the most frequently traded companies were monitored: Apple and Tesla. Both have extremely different intraday behaviours so alarms would also have to be tailored carefully to ensure no trading opportunities were missed but such that it was not sounding in unneeded times. Tesla is very unpredictable and can be explosive compared to other traditional companies. Because of this, a 5% threshold was given both ways to allow for fluctuating price ranges. In contrast Apple is very stable and only becomes erratic during new launches, so because of this a 3% threshold was added as if one is trading Apple, monitoring these events and rumours is mandatory so spikes during this time will be understandable. Within this day, five alarms were used meaning five octaves were needed for clarity. The pitch range A3–A7 was used, using the root-third combination on the index funds and root-dominant on the individual stocks. Once familiar with the sounds, the variation was easy to distinguish with alarms sounding only three times maximum per trading day. The reason for such fluctuation in price near the start and end of the day is because during these periods the market is most active, trading large volumes [19]. The start of the day is normally more volatile as the news has a direct impact on stock prices and new events have yet to affect the pricing of the stock after hours. The close being an active time frame began during the 2008 financial crisis as traders did not want to have open positions so closing their position would avoid this risk [20].

During this test trading day, ambient sound and external sounds like music and background noise were a concern as if the sonification was easily masked then most casual traders would not be able to effectively use this tool. However, the noise and alarms were able to cut through various genres of music such as Classical, R&B, Country, Pop, Hip-Hop and Punk. This is because the sound resolves to the 1 kHz filter as this creates a gradual change that can be heard over other sound.

After the initial values being gathered from the websocket populated the useStock hook and Noise function, the sound was directly manipulated by the received data. During the first hour of the trading day, the sound varied, rising and then falling until it eventually settled to rising for the rest of the day. This allowed for the participant to look for patterns in the candlestick charts (Fig 1) of various stocks. It also allowed the trader to look outside the New York Stock Exchange, for instance the Tokyo Stock Exchange (TSE/TYO) or the London Stock Exchange (LSE) for more opportunities for swing trades. Whilst looking for various opportunities through social media monitoring or further technical analysis, the participant always knew how the American market was acting through the use of the sonification of the S&P 500.

4. CONCLUSION

During the trading day, a few improvements were found with the sound design and bugs inside the software, these will later be implemented before a user study takes place. Originally the noise and alarm sounds were too overpowering when listening for a prolonged period of time. This became slightly fatiguing during the middle of the trading day so a slight tweak of the volume to ensure that this issue is resolved is a quick fix. Also the alarms all having the same tonic caused some confusion which led to the visual dashboard having to become a main focal point when one was sounded. To eliminate this issue for the next version fewer stocks will be tracked by the alarm system, to allow greater differentiation between each alarm.

When first launching the software, a bug occurs on the visual dashboard that does not hold the correct value within the opening price section. This tends to correct itself after a few minutes leading to the bug coming from the use of the useRef function to hold the first value passed in from the websocket object inside the useStock hook.

While tracking multiple sources of information becomes overwhelming with the increase of tools and software available, it is important to understand how the sound channel can be used to effectively monitor data whilst being able to focus on other tasks. By creating a software package that comes complete with a visual dashboard as well as sonification of real time stock data, traders can now start to take advantage of work efficient audio that frees their visual channel, allowing them to do more technical analysis. To monitor a trend takes little to no musical background, however, the alarm system could be taxing and hard to comprehend without a musical background.

5. NEXT STEPS

Following this study, experiments with participants all with background experience in trading is planned. This will help gauge the utility of this software inside a real trading environment with traders who have used industry standard technology. This will allow for sophisticated feedback and critique that will then be used to create another iteration of the software. Additional experiments with inexperienced traders could test whether this tool can help beginners gain an understanding of the principles of trading. Furthermore, variations of the sonification will be investigated as the possibilities to use the base program to predict price changes could be implemented. This would be achieved by using trading algorithms and AI/ML learning models on historical data.

6. REFERENCES

[1] G. S. Wagner and B. L. Matheny, *Trading applications of Japanese candlestick charting*. John Wiley & Sons, 1993, vol. 38.

[2] U. Schaede, "Forwards and futures in Tokugawa-period japan: A new perspective on the dōjima rice market," *Journal of banking & finance*, vol. 13, no. 4-5, pp. 487–513, 1989.

[3] C. Lambert, *Candlestick Charts: An introduction to using candlestick charts*. Harriman House Limited, 2009.

[4] Y. Santur, "Candlestick chart based trading system using ensemble learning for financial assets," *Sigma Journal of Engineering and Natural Sciences*, vol. 40, no. 2, pp. 370–379, 2022.

[5] B. Cornell and A. Damodaran, "Tesla: Anatomy of a run-up," *The Journal of Portfolio Management*, vol. 41, no. 1, pp. 139–151, 2014.

[6] G. W. Schwert, "Why does stock market volatility change over time?" *The Journal of Finance*, vol. 44, no. 5, pp. 1115–1153, 1989.

[7] F. C. Ciardi, "sMAX a multimodal toolkit for stock market data sonification," in *ICAD 2004 - The Tenth Meeting of the International Conference on Auditory Display*, S. Barrass and P. Vickers, Eds., Sydney, 6–9 July 2004.

[8] R. H. Scott III, "Bloomberg 101," *Journal of Financial Education*, pp. 80–88, 2010.

[9] P. Janata and E. Childs, "Marketbuzz: Sonification of real-time financial data," in *ICAD 2004 - The Tenth Meeting of the International Conference on Auditory Display*, S. Barrass and P. Vickers, Eds., Sydney, 6–9 July 2004. Available: http://hdl.handle.net/1853/50899

[10] D. Worrall, *Parameter-Mapping Sonification of Tick-Data*. Cham: Springer International Publishing, 2019, pp. 237–252. Available: https://doi.org/10.1007/978-3-030-01497-1_8

[11] M. Weiser and J. S. Brown, "Designing calm technology," *PowerGrid Journal*, vol. 1, no. 1, pp. 75–85, 1996.

[12] MasatoStudios, "real-time-sonification," 2023. Available: https://github.com/MasatoStudios/real-time-sonification. DOI: 10.5281/zenodo.7867834

[13] Y. Mann, "Tone.js," 2015. Available: https://github.com/Tonejs/Tone.js

[14] Y. Belinkov and Y. Bisk, "Synthetic and natural noise both break neural machine translation," *arXiv preprint arXiv:1711.02173*, 2017.

[15] K. Guo, Y. Wu, and H. Zhang, "The effects of color noises on attention," in *2022 International Conference on Science Education and Art Appreciation (SEAA 2022)*. Atlantis Press, 2022, pp. 576–583.

[16] K. Vassie and M. Richardson, "Effect of self-adjustable masking noise on open-plan office worker's concentration, task performance and attitudes," *Applied Acoustics*, vol. 119, pp. 119–127, 2017.

[17] P. Vickers and J. L. Alty, "Using music to communicate computing information," *Interacting with Computers*, vol. 14, no. 5, pp. 435–456, Oct. 2002. Available: https://academic.oup.com/iwc/article-lookup/doi/10.1016/S0953-5438(02)00003-6

[18] K. Kim, A. Erickson, A. Lambert, G. Bruder, and G. Welch, "Effects of dark mode on visual fatigue and acuity in optical see-through head-mounted displays," in *Symposium on spatial user interaction*, 2019, pp. 1–9.

[19] J. Lakonishok and E. Maberly, "The weekend effect: Trading patterns of individual and institutional investors," *The Journal of Finance*, vol. 45, no. 1, pp. 231–243, 1990.

[20] D. Strumpf, "Stock-market traders pile in at the close," May 2015. Available: https://www.wsj.com/articles/traders-pile-in-at-the-close-1432768080