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A performance comparison between 2D and 3D candlestick charts for cryptocurrencies market operations

Work presented in partial fulfillment of the requirements for the degree of Bachelor in Computer Science

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ABSTRACT

This work presents a comparison of traders' performance between 2D candlestick visualization, used nowadays in day trading platform tools, and a novel 3D candlestick chart. All trading platforms provide a set of tools to traders that can increase their confidence in making an operation. The most important tool is the price visualization timeline. The past price movement is condensed into candlesticks and the platforms display it in a two-dimensional format. Each trader can have a visualization of one individual asset at a time or a split-screen with various assets to observe price changes.

Instead of using the traditional two-dimensional candlestick visualization, the design in this work displays many assets at a time, using the same candlestick chart presenting multiple cryptocurrencies' price timelines in the depth coordinate. This technique was developed with the intention to assist traders to compare assets to perform buy or sell operations.

An experiment was conducted with users (N=18) on a trading task in either 2D or 3D chart types, with a 50% chance of executing market operations in one of them and measuring the performance. No significant difference in performance was found between charts, and no learning effect was identified overall in a sequence of 15 operations. However, for the 3D chart only, comparing the performance in the initial block of 6 operations with the second block of 9 operations, indicated a significant difference in the means (normal distribution). While a loss occurred in both cases, it was significantly larger ($p = 0.01593$) with the 3D chart (-9.8%) than with the 2D one (-1.9%), which is an indication that the novel design can be further refined.

Keywords: Trading. Candlestick chart. 3D visualization. Market operation decision.

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

TAQ   Trade And Quote

SP   Standard and Poorś

HTTP   Hyper Text Transfer Protocol

HTML   Hyper Text Markup Language

DBMS   Database Management System

JSON   Javascript Object Notation

GIF   Graphics Interchange Format

GPS   Global Positioning System

RFID   Radio-frequency identification

SUS   System Usability Scale

TLX   Task Load Index

CONTENTS

1 INTRODUCTION

The trading market data in shaped by people and machines negotiating every fraction of time. People who place orders to negotiate assets are named traders. They use as many tools as possible to predict how the price of an asset will behave, but the most important one is the candlestick chart. This chart holds, in each candlestick, information about the price and the trends observed in the near history. Traders constantly watch for patterns that will guide the decisions to buy or sell an asset.

These traders need platforms to be able to watch the market movement of prices and volumes of orders deals being closed, and place their own orders. All platforms have the indispensable candlestick chart, but they do not explore different visualization formats which could impact in traders decisions. In our work, we propose to bring the comparison of multiple cryptocurrencies' prices using the third dimension displaying them in parallel and distributed in the z-axis.

In the Chapter 2, we present other works of market data visualization that are alternative options to base decisions along with other techniques for other kinds of data visualization. Chapter 3 starts describing the basic elements used in exchange platforms display data. Then, it details our 3D candlestick design and implementation. We present in Chapter 4 a comparative evaluation of the conventional candlestick visualization with the proposed novel chart type, including the experiment design, task and protocol used to obtain the assessment from users. The relevant findings are written in the Chapter 5, revealing facets and faults of this experimental design. Conclusion and future work are presented in Chapter 6.

2 RELATED WORKS

Numerous solutions were implemented to assist the market conditions understanding. They range from applied graphic interfaces highlighting visual aspects of the price variation (ROBERTS, 2003) to auxiliary tools that signalize the stocks price directions interfered with by external events (SORENSON; BRATH, 2013).

2.1 Market data visualization

One of the most popular market visualizations is Map of the Market by Smart Money[1] splitting the market share into business categories, and sizing boxes by their percentage (Fig. 2.1). This market map uses the treemaps by Asahi, Turo e Shneiderman (1995) to create hierarchical data spaces that augment capabilities of the Analytic Hierarchy Process (AHP) for decision-making.

Figure 2.1 – Map of the market from SP 500

Source: Smart Money[1].

Stock market ticks are the atomic clock ticks of the market. Roberts (2003) used the NYS Trade and Quote (TAQ) database to test the hypothesis that information visualization improves trader's performance in intraday equity trading. The proposed visualiza-

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[1]https://finviz.com/map.ashx

Figure 2.2 – Data Mapping for Context and Focus Views
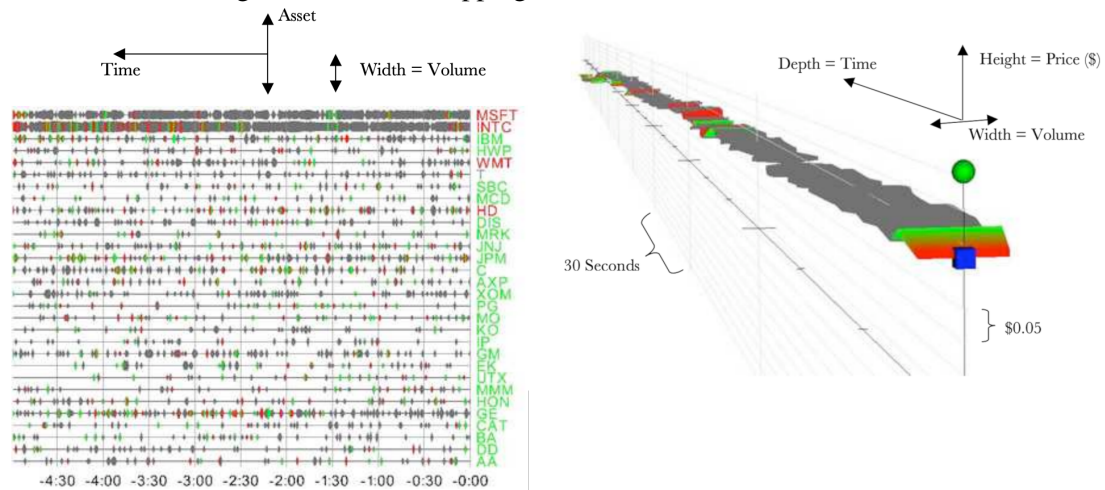
Source: (ROBERTS, 2003).

tion creates a new visual description of the equity prices (Fig. 2.2).

To visualize the correlation of certain events with the market behavior, Sorenson e Brath (2013) proposed a design to organize in one screen a high volume of events for financial time series. As seen in Fig. 2.3, it provides a workflow to display them in a single point of access in the chart, synchronizing the time they occurred and price data to inform the possible causes.

Figure 2.3 – Price aligned with events in the time axis

Source: (SORENSON; BRATH, 2013).

2.2 Three dimensional data visualization

Three-dimensional visualizations have already been widely explored for data analysis. While it has often been more directly applied when spatial location is a component of the data, the third dimension has also been used as an additional space also for abstract data. This section just points a few examples to provide context for the reader.

A combination of navigation in a 3D globe spacial positioned data and 2D charts techniques was made by Satriadi et al. (2021) to add more context to quantitative geo-positioned data in two main factors. First, using a 2D bar, 3D bar, and circles, second, the orientation of the primitives with tangents, normals, and billboards. They presented a study with 50 participants using 5 different visualization techniques, and the results guided the development of a novel globe visualization called by the authors *Geoburst*. In the Fig. 2.4 we can see the points placed in the map of the position (latitude and longitude) of the reference of data and the bars are the numbers captured of that place together with rings to help to visualize scale from those numbers.

Figure 2.4 – Grouping, bars placement, and linking

Grouping   **Bars placement**   **Linking**
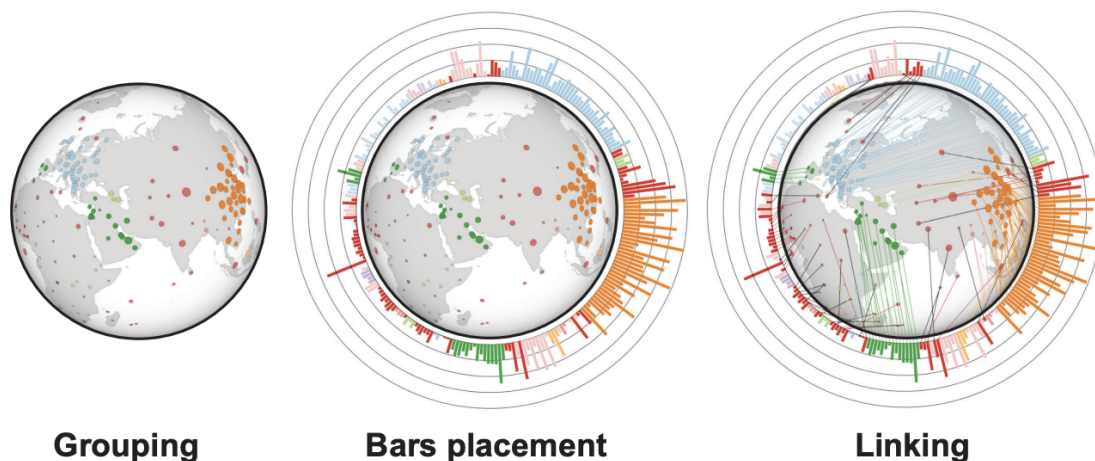
Source: (SATRIADI et al., 2021).

A different approach is taken in Büschel et al. (2017). The authors created a windowing view from a tablet tracked in space, to control the virtual camera position and rotation (Fig. 2.5). They assess comparison of individual objects, and the understanding and memorization of structure in the data tasks between this novel three-dimensional navigation and touch interactions (Fig. 2.6). They discovered a number of usage patterns of use and recommendations for interacting with 3D data. Also, perceived more supportive

and preferable spatial interactions by the users.

Figure 2.5 – (a) Prototype used to visualize (b) height-map of the navigation task, (c) bar chart of comparison task, and (c) scatterplot used for strutural understanding task
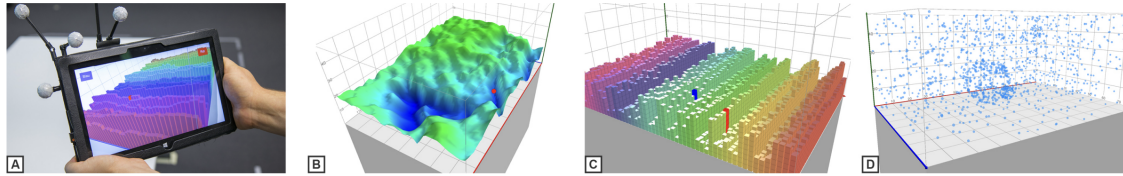
Source: (BÜSCHEL et al., 2017).

Figure 2.6 – 3D navigation task
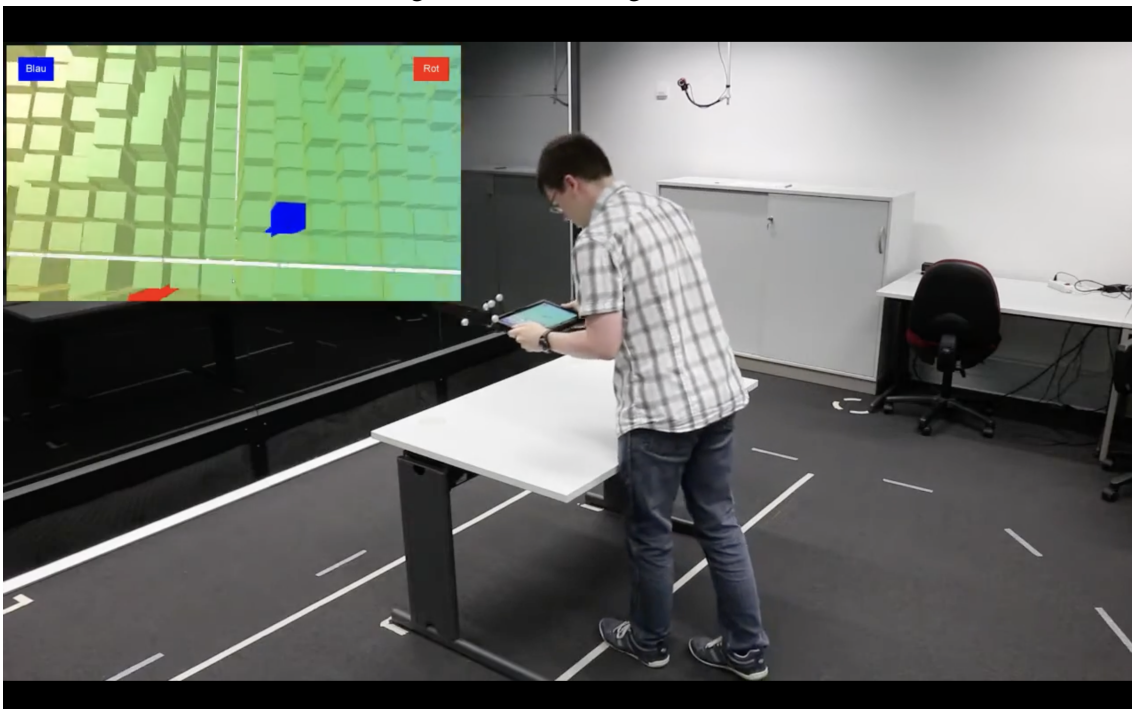
Source: (BÜSCHEL et al., 2017).

2.3 Comparison between 2D and 3D data visualization

The comparison between more conventional 2D visualizations with novel 3D visualizations has also been of interest in the research community. We present some examples in this section.

In the work by Amini et al. (2014), data visualization of GPS and RFID is compared, pointing to the time-collected positions of the GPS, between a 2D and 3D visualization of the same location on a map. The authors found that using the 3D is slightly

advantageous when navigating in the timeline for temporal sampled recorded data as it is collected from GPS and RFID. One of the possible reasons that the authors attribute is the overly complex navigation in visualizations in 3D. In their experiment, they propose another controlled 2D and 3D comparison, and the tasks they assigned to the users were to find specific data points in time, space, and comparing the object inside the system (Fig. 2.7), but the tests also resulted in 3D still being only relevant to navigate the timeline and 2D remaining better for the other tasks.

Figure 2.7 – Tasks questions between 2D and 3D visualization of movement data
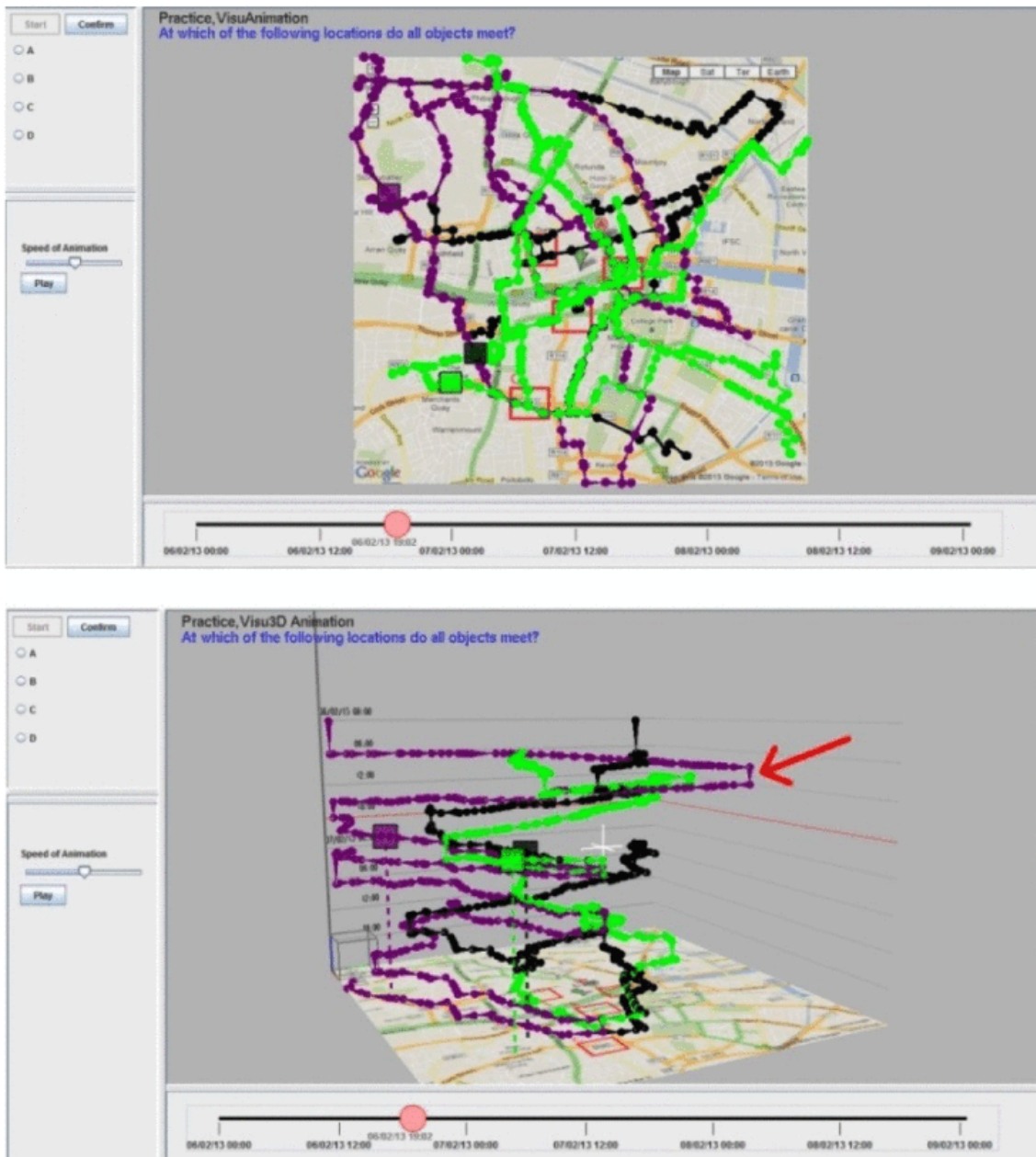
Source: (AMINI et al., 2014).

An assessment of tasks in a scatterplot chart is explored by Wagner Filho et al.

(2018) comparing the performance of 2D (Fig. 2.8), 3D (Fig. 2.9) and Immersive reality (Fig. 2.10) conditions. The study was conducted with 30 participants through a task with an empirical approach to assess their perception. The performed task was to point and click in a blinking point, and the perception of error was calculated using Euclidian distance in all of three conditions (2D, 3D, and IM). The results showed less effort to find the information and less navigation using the IM approach, but all of three conditions had low perception errors and similar performance.

Figure 2.8 – In the 2D condition, data points are distributed along screen space (left), and the user is allowed to zoom and pan (right)
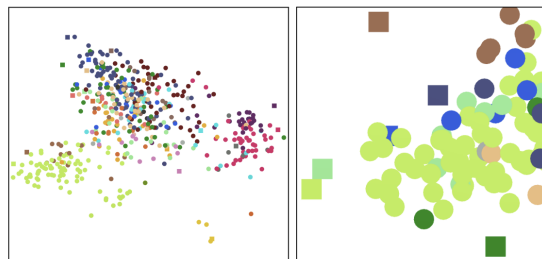
Source: (WAGNER FILHO et al., 2018).

Figure 2.9 – In the 3D conditions, the user is allowed to freely navigate through the data, which is distributed along a 3D virtual environment
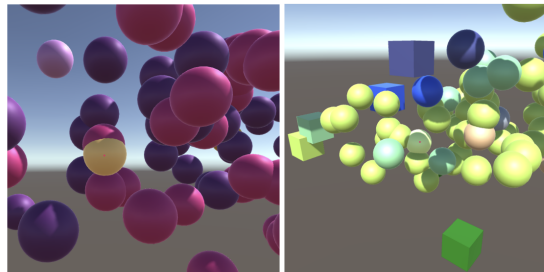
Source: (WAGNER FILHO et al., 2018).

2.4 Summary

In this work, we propose a comparison between a 3D and 2D visualization technique for market data using the cryptocurrencies dataset. Wagner Filho et al. (2018) showed that 3D could have similar effort finding the information as in 2D, but Amini et al. (2014) stated that 3D is relevant to navigate in timed recorded information. Reviewing the literature in the area, we could not find works extending the candlestick chart beyond the plane dimension. Moreover, it is important to synchronize the price time-series with other events to make more informed decisions in equity assets acquisition (SORENSON;

Figure 2.10 – Dimensionally-reduced data scatterplots. The user is equipped with two position-tracked hand controllers (left), being allowed to interact with the data through selection pointers (right)
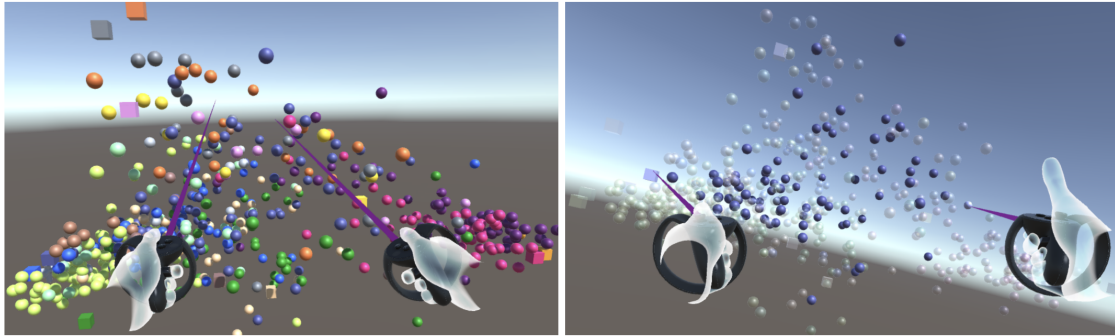
Source: (WAGNER FILHO et al., 2018).

BRATH, 2013). It was noted that a broader context can be understood when displaying multiple stocks at once (ROBERTS, 2003), while the focus context (Fig. 2.2) is important to assist the trader on choosing the buy and sell points in time.

Differently from previous approaches, in our approach the third dimension is used to obtain a time-synchronized candlestick dataset visualization. This design aims to use the third dimension to assist in comparing the prices variation of multiple assets synchronized in time navigation. The highlighting candlesticks (Ref. 3.1.1) data and hovering give the focus to analyzing trends of the price and the patterns formed in the chart. Market operations are available for all assets in rows (Fig. 3.16) to avoid context switching. In this chart, all quoted prices of assets need to be based on the same currency to keep the price scale the same.

3 DESIGN OF A 3D INTERFACE FOR CRYPTOCURRENCY TRADING

This section first describes how candlesticks are read and how trading cryptocurrencies is executed. Then, we present our proposed alternative design, the implementation details and the data we are using for assessment.

3.1 Basics of cryptocurrency trading

Traders use many different sources of information to make their decisions to buy, sell or hold an asset. One of these sources is the past market data that assist in analyzing the view of price trends, patterns, the volume of negotiations, and which is the best timing to make a decision. The platforms commonly used by traders to negotiate cryptocurrencies are named exchanges. These exchanges work as a brokerage that helps in trading different cryptocurrency values between users. These platforms provide a two-dimensional chart showing past price quotes where the traders can extract their analyses.

In this chart, the users can select the division of this market price information in timeframes as in Fig. 3.1, showing the candlesticks representing one day versus 15 minutes slices of price variation. In the platform (Fig. 3.2), we can see the buy and sell buttons (Fig. 3.4) where the user can select the amount of the currency they hold to place an order in the orderbook (Fig. 3.3) displaying the price askers require to sell and the biders want to pay to buy along with the volume they both want. The order they appear is sorted by higher to lower price and time placed on the red and the green texts. When the top green matches the price of the bottom red one, a negotiation occurs. Also in this screen, the recent trades are listed (the accordance between askers and biders price, Fig. 3.5) and the list of other currencies to select for the user to be able to operate on them (Fig. 3.6) with the history of orders that are opened and the ones already completed placed by the user (Fig. 3.7).

3.1.1 What is a candlestick?

Candlesticks (Fig. 3.8) are a description of an asset price during a time in a timeframe. They display the information on the highest, lowest, open, and closed prices negotiated. This visualization is inspired by an ancient Japanese annotation of price variations

Figure 3.1 – The candlesticks representing the price variation in days versus 15 minutes slices.
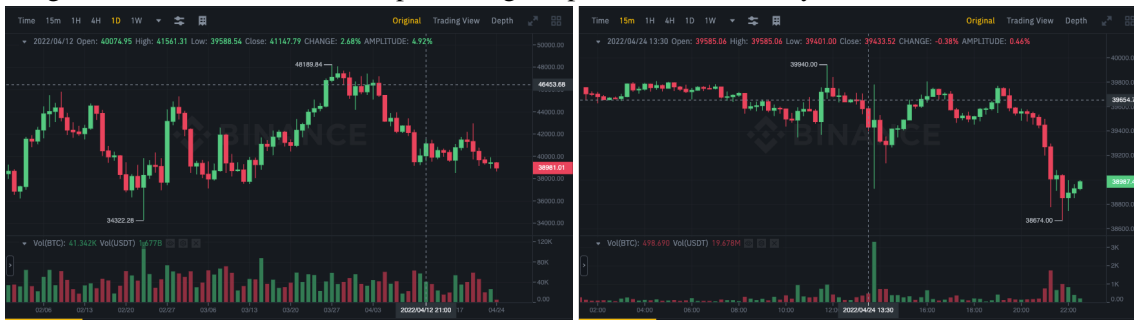
Source: https://www.binance.com/en/trade

Figure 3.2 – Binance trading platform with the candlesticks chart displaying the price variation, the orderbook in the left pane, history of orders in the bottom pane, the available operations in the bottom tab with title "Spot", the recent trades occurred, top pane with price statistics, and other currencies menu based on the same coin selected in the chart.
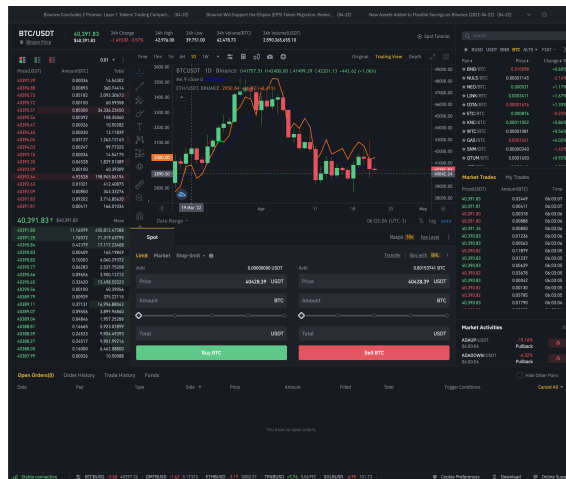
Source: https://www.binance.com/en/trade

Figure 3.3 – Binance trading orderbook
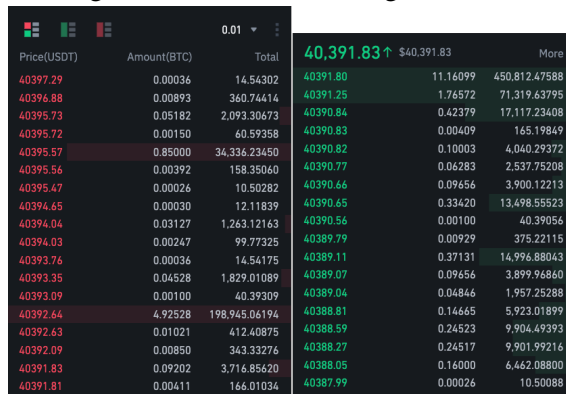
Source: https://www.binance.com/en/trade

for rice in previous days (NISON, 1991). The candlestick consists of two thin parts and a rectangle. The line at the top points the highest value negotiated and the bottom one the lowest. The rectangle shows the open and close prices of the period. The indication

Figure 3.4 – Binance market operations
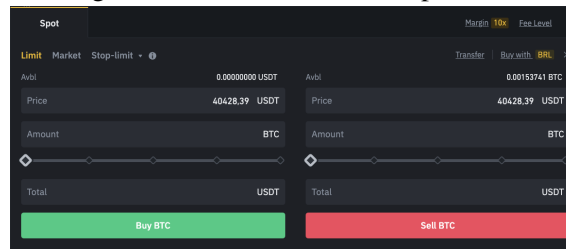
Source: https://www.binance.com/en/trade

Figure 3.5 – Binance recent trades

Source: https://www.binance.com/en/trade

is that inside this timeframe, the opened price (the first price negotiated in this period) is lower than the closed price if the color is green (or white), red (or black) otherwise, but color could be changed depending on implementation. In chapter 6, (SCHWABISH, 2021) candlesticks are defined as distribution chart.

They are shown as a temporal time series in timeframes, and the timeframe variations depend on the platforms. The timeframes can be minutes, hours, days, weeks, months, or even years, and each candlestick refers to the choosen one.

Figure 3.6 – Binance select another currency to execute operations
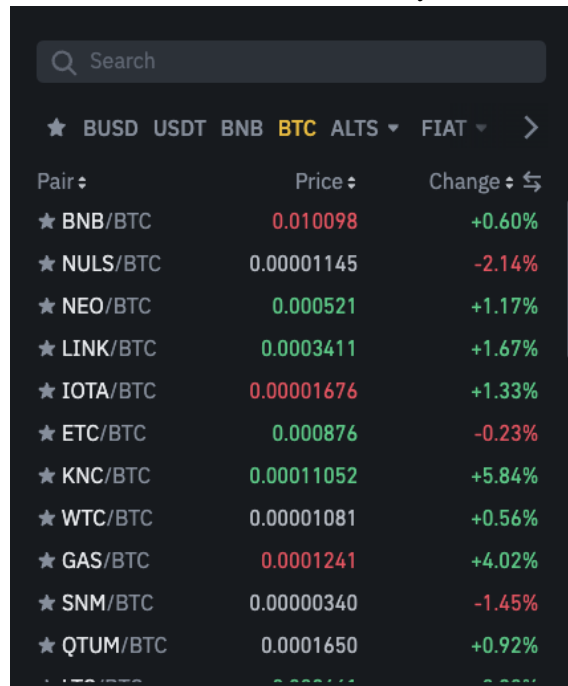
Source: https://www.binance.com/en/trade

Figure 3.7 – Binance user's order history
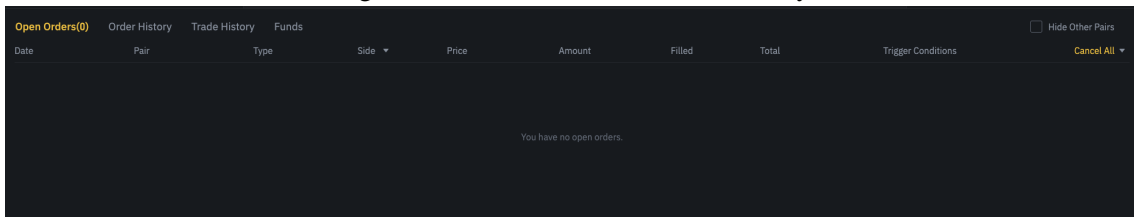
Source: https://www.binance.com/en/trade

Figure 3.8 – Candlestick definition
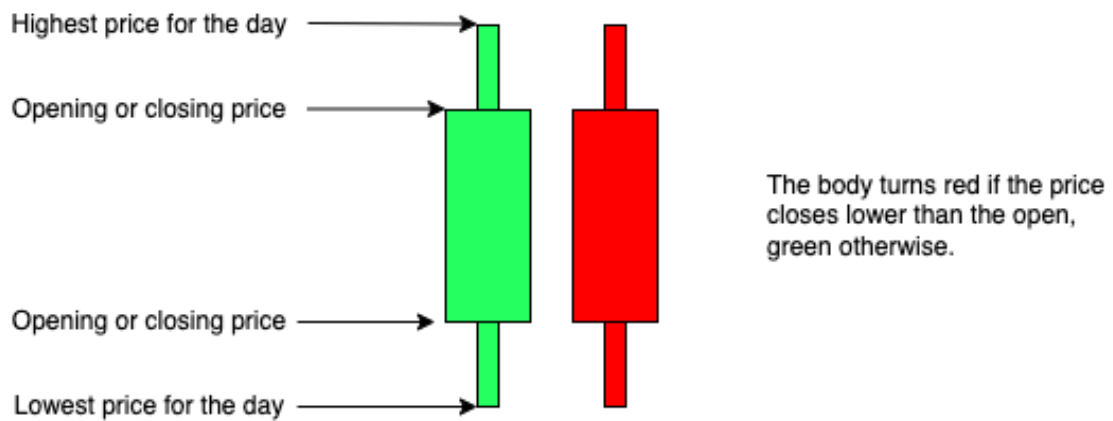
3.1.2 Displaying data

When traders need to compare assets, they look for the best option by opening tabs for each asset they want to observe (Fig. 3.9) in which the price information could be cumbersome to be obtained, especially if this is used to compare entry points. They can also have multiple monitors that open different cryptocurrencies in each of them to watch the market price movement. Both approaches have the physical limitation that, to show more currencies, splitting screens or a larger number of monitors to look at.

Figure 3.9 – Split screen for a day and minute candlesticks for BTC/USDT and ETH/USDT
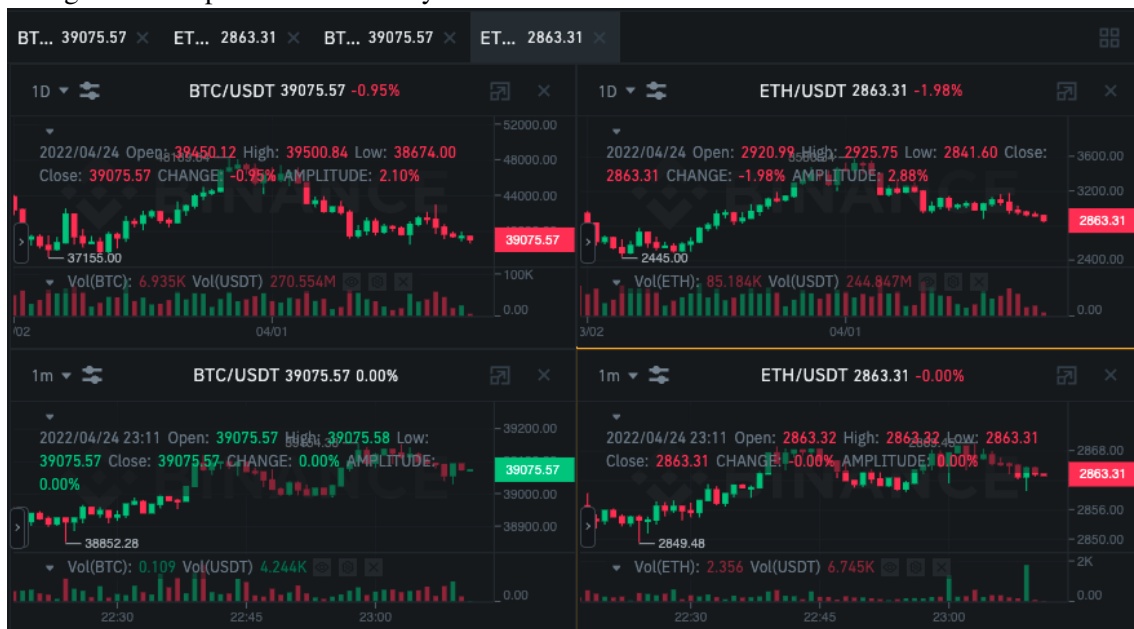
There are plenty of strategies to be used to make better informed decisions. Some of the strategies are based on the price being near the moving average (MA) (SOUZA et al., 2018) price, indicating lower volatility and the negotiations have a higher chance of following the previous trend. When they decide how to make an entry in one of the assets, they need to indicate the amount they want to buy or sell and the price they accept a trade to occur in the negotiation bottom menu as in Fig. 3.4.

In the following section, a new design is proposed to combine multiple assets viewed, on the same screen using the third dimension to display it synchronized in time and price scale. This new design can help to accommodate the multiple cryptocurrencies in the space to compare.

3.2 Our 3D candlestick visualization for crypto

Nowadays, exchange platforms display the market data for each coin individually. Traders have to select which coin to visualize at a time as made in Kraken[1] (Fig. 3.10) and Binance[2] (Fig. 3.11), split the screen (Fig. 3.9) to see many in the same monitor or use multiple monitors to observe different ones. Our new design addresses this issue of displaying multiple assets on the same screen utilizing the third dimension to show them in parallel. The timestamp displayed on the x-axis synchronizes the candlestick's price information in time.

Figure 3.10 – Kraken trading platform selecting coin pair

Source: https://trade.kraken.com/charts

The proposed design presents candlesticks (Sec: 3.1) in the third dimension without adding information to it in the depth coordinate. The z-axis position is used to distribute the time series for other cryptocurrencies. The timeframes, the open and close dates, and the price scale for candlesticks are the same. This way, each line corresponds to a coin, and all of them are pairs to the same base coin (Fig. 3.12).

In this interface it is possible to perform the equivalent action as in trading platforms:

- See past periods;
- Navigate in a previous time window;
- View more past data "zooming out";
- See candlestick values by hovering over it;

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[1]https://trade.kraken.com

[2]https://www.binance.com/en/trade

Figure 3.11 – Binance trading platform selecting coin pair
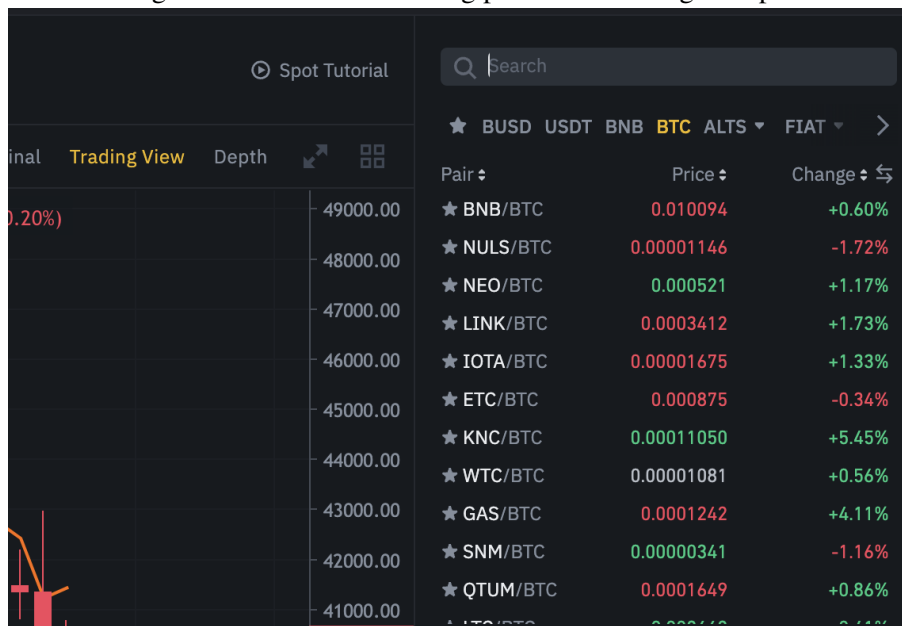
- buy and sell.

In addition to the market operations, the hold is also present, which helps to simulate the time passing when the user takes the action of staying with the asset that was owned before.

Figure 3.12 – Proposed three-dimensional interface
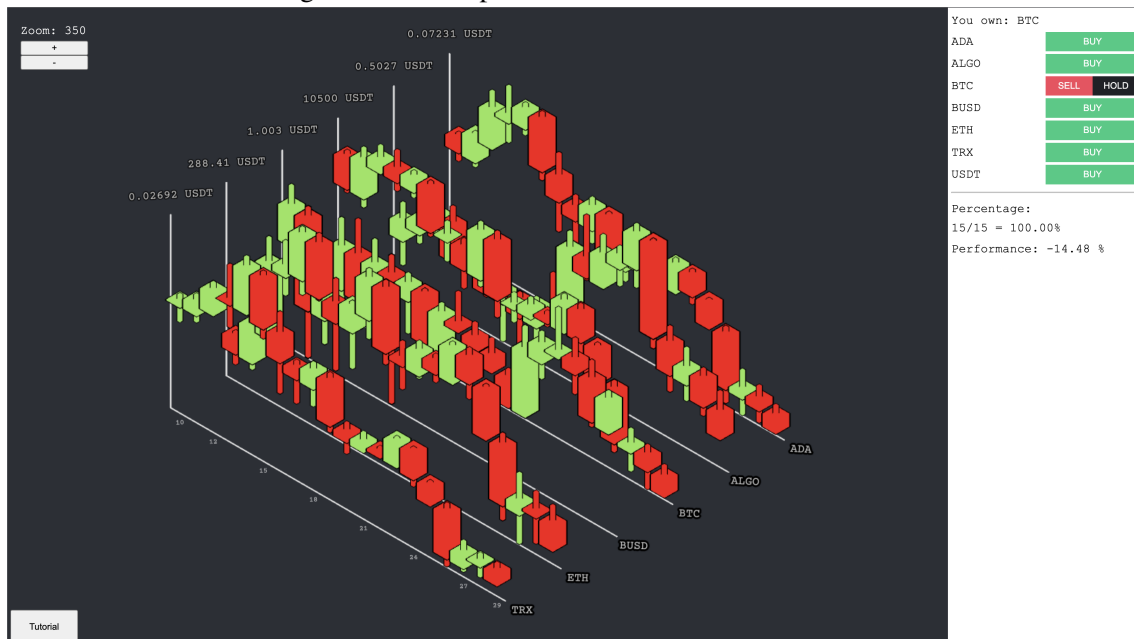
3.2.1 Interaction with the interface

The already used solutions to browse market data were mimicked. Seeing past periods (Fig. 3.13) can be achieved using the mouse or touchpad scroll that will show more candlesticks in the current time window as in Fig. 3.14 right. Navigating the time window is executed by clicking or double-tap and dragging in the X direction to a positive or negative axis as in Fig. 3.14 left.

Figure 3.13 – Binance viewing past market data

Source: https://www.binance.com/en/trade

Figure 3.14 – Time window scroll (left) and change size (right)
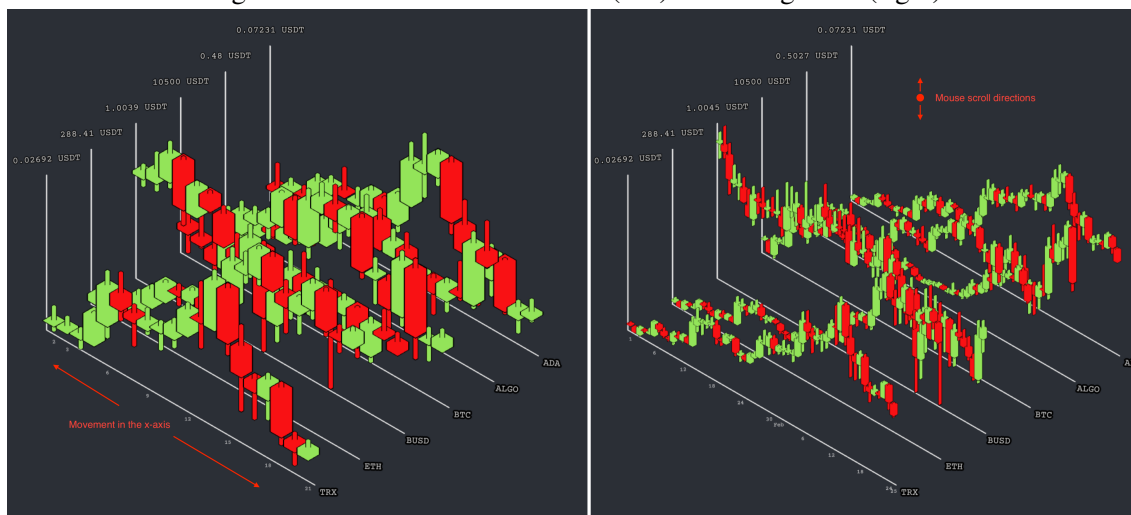
However, three-dimensional data needs more visualization tools to be able to un-derstand what is presented on screen. With the concept of a camera, it is possible to rotate the chart's point of view. Using the right button of the mouse or two-finger press and drag, the camera's position (Fig. 3.15) is changed but conserving the target, the observation of the candlesticks can be made from multiple points. As it is possible to change the asset

Table 3.1 – Actions table per chart type

Actions	3D chart	2D chart
Scroll to view past data	X	X
Hover individual candlestick and get the price data	X	X
Zoom to view more days data in the same space	X	X
Execute (buy, sell, or hold)	X	X
Change which currency is being operated and the displaying chart		X
Rotate the camera viewport	X	
Highlight line of candlesticks	X	

in evidence in the current visualization of data by nowadays platforms, our solution also provides a way to highlight one of the coin lines by clicking or tapping on the name of the coin and executing the equal command to undo it (Fig. 3.15). All possible actions are synthesized in Table 3.1.

Figure 3.15 – Viewing past data with angle and highlight

As we consolidate multiple assets into one screen, the market operations also need to be in this single interface. All coins paired are listed in a right-side menu as in Fig. 3.16, with the possible actions and the last row with the base coin. The actions can be: buy, sell or hold. The buy for any of the coins is going to switch the current value from the base to the target one. When owning a coin different from the base, the buy operation is enabled for the base which executes a sell action of the coin in hand for the base amount. The sell operation can only occur when holding another coin other than the base, and it is as a conversion to the base again. The hold operation is made for the experiment to simulate the time passing maintaining the coin in possession without executing any other action.

Many other approaches were taken to provide more feedback on market data visually to assist traders' decisions for observing one asset or another, the timing for executing

Figure 3.16 – Proposed available market operations

buy or sell operations, and some level of prediction of where the price goes. This data visualization tool allows the trader to have many assets' prices synced in time, and scale compared side-by-side to help choose the asset and to make the operations condensed in one screen only.

3.3 Implementation

This new design is going to be compared to the commonly used type of interface of trading platforms (Binance[3], Kraken[4], Coinbase[5]). To be compared, the commands of Sec. 3.2.1 were also developed for a simplified two-dimensional chart version (Fig. 3.17), where rotation and highlight are not enabled, and only one coin price history is shown at a time. The user of the system have to press a button with the coin name to access the price history of other coins, simulating the selection made inside the trading platforms. A description of the features enabled for the 2D chart is going to be made in the chapter 4.

Figure 3.17 – Commonly used chart type and operations
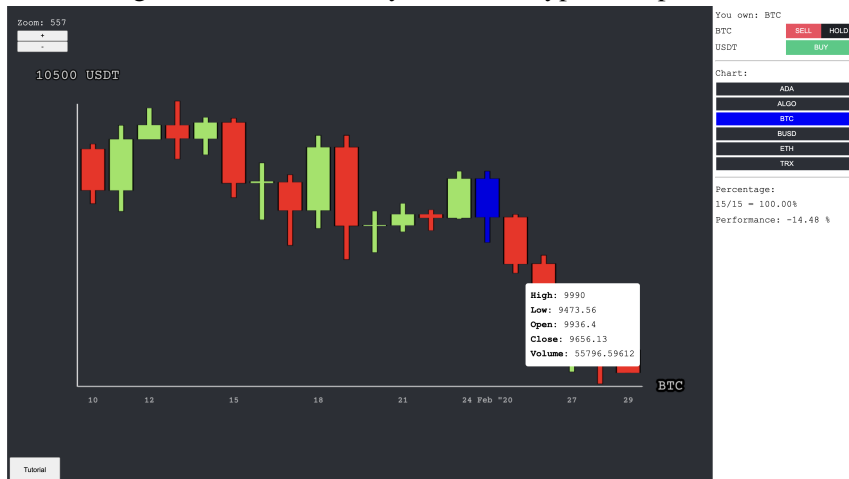
3.3.1 Software packages

The system was developed using a web-based interface with client-server architecture. The language used was Typescript[6] compiled to JavaScript[7] executed with NodeJS[8] interpreter engine. The center framework used was NextJS[9] that receives HTTP requests using a folder structure to organize the request paths and ReactJS[10] to build the visual interfaces rendering HTML. In addition to the built user interface, the charts were constructed using the ThreeJS[11] and the scale made using the D3js[12] libraries. The DBMS used for storing the data of this experiment was PostgresSQL[13].

3.3.2 Execution steps

The data collected from this software is centered on cookie based session. When the user navigates to the website application, an *HTTP* request is made to the server at the path */api/start_random* to get the experiment chart type randomly assigned, with a fifty percent of chance of being the 2D or 3D version and register the cookie inside the users browser.

The first screen is the agreement for participating in the experiment, and the sec-

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[6]https://www.typescriptlang.org/

[7]https://www.javascript.com/

[8]https://nodejs.org/

[9]https://nextjs.org/

[10]https://reactjs.org/

[11]https://threejs.org/

[12]https://d3js.org/

[13]https://www.postgresql.org/

ond one was made to contain profile questions. The profile questions are going to be used later to subdivide the experiment in groups.

The market operations happening when the user clicks on buy, sell or hold buttons, invokes an *HTTP* request at the path */api/step* with the body in JSON format containing the operation name and the coin on which it should occur. The response is also in JSON format containing and advance in one day in time. This next day's candlestick data is displayed into user chart. After the user have executed 15 operations, the task execution is ended.

Hereafter, three kinds of questionnaires are required to the user. The first is a couple of comprehension/attention questions asking about the price and candlestick period that is being used to calculate the performance, and the timeframe a candlestick represents of the negotiations. Correct answers to demonstrate the user understands what the system is presenting. The second is the task effort scale index (HART; STAVELAND, 1988) and the third is the system usability scale (JORDAN et al., 1996).

3.3.3 Data

Historical market data is stored independently of the experiment, but limited to the defined timeframes of one day for candlestick and time window from January 1 to February 30 for cryptocurrencies pairs ADAUSDT, ALGOUSDT, BTCUSDT, BUSDUSDT, ETHUSDT, TRXUSDT. All users participating start executing the experiment in the date February 15 and end in February 29, but can see candlesticks down to January 1. Data was retrieved from Binance K-lines historical data repository[14] that is free and contains cryptocurrencies market information needed for candlesticks.

The data model is centered into the *experiments* entity, which connects via *experiment_id* foreign key to the *experiment_steps*. The *experiments* has a link to the *sessions* ids for each session stored and accessed using the users cookie stored into the browser. Each action made by the user is stored as a step and contain the coin (ADA, ALGO, BTC, BUSD, ETH or TRX) and the operation name (buy, sell or hold) along with the information of the last candlestick displayed on the chart. When buy operation is performed on the USDT, the registered operation is the sell and the coin is the last one the user was holding.

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[14]https://www.binance.com/en/landing/data

4 EXPERIMENTAL EVALUATION

This experiment aims to compare percentual returns between users of the traditional 2D chart and the new 3D chart design, proposed in the previous chapter, by their trading in the cryptocurrency market. In our experiment, the main value we will assess is the performance of the users, but we also verify the relevance of the time taken to execute the operations and their user's self-declared experience level.

4.1 Overview

The experiment will compare the performance of swing trade[1] during 15 days of operations from 15 February 2020 to 29 February 2020 with cryptocurrencies pairs ADAUSDT, ALGOUSDT, BTCUSDT, BUSDUSDT, ETHUSDT, TRXUSDT in the experimental group using the new proposed design and control group receiving a simplified version of the candlestick 2D chart (Fig. 3.1.1).

The 2D chart is a simplified version of the trading data presented on the platforms previously mentioned. Both charts can execute the same operations, but the control group will need to select the other currency by right-side menu button to switch the history data being displayed simulating the user interaction needed into the exchanges (Fig. 3.10 and Fig. 3.11) with a less cluttered menu by having more limited options (Fig. 4.1). Click and drag the view in the x-axis scrolls to view past candlesticks, and roll mouse wheel (or touchpad scroll) show more candlesticks changing their sizes to adjust within the screen space (Fig. 4.2).

4.2 Experiment design

The main task is to decide which market operation to execute (buy, sell, or hold) for one cryptocurrency at a time displayed for each day represented by the candlestick as if they are making a decision based on the closing price of the day. The rightmost candlestick represents the current day in which the user will choose the operation to execute. The motor task of articulating a choice is equivalent in the 2D and the 3D conditions.

Data is anonymized with no recording of information that can identify the user.

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[1]https://www.investopedia.com/terms/s/swingtrading.asp

Figure 4.1 – View currency history data through buttons with the name of the paired one
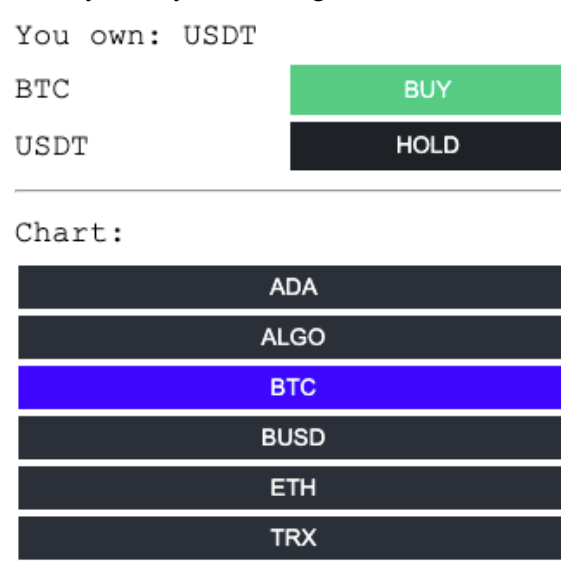
Figure 4.2 – Viewing past with highlighted candlestick and zoom out

The internet address forwarded from the client and the timestamp of the access are recorded to try to avoid multiple trials of the same user. In case the user erased the browser cookies and make another try, only the data of the first attempt, with at least one interaction step, will be used.

The dependent variable is the performance, the percentage return between days of operation, of the user in the swing trading. The study is conducted between subjects with the independent variable being the chart type each user received (2D or 3D). The chart type is assigned to each user using a pseudo-random number generator (PRNG).

The nominal variables used for groupings are defined by the profile questions which are going to be analyzed individually comparing the users of each chart looking for relevance. The ordinal variable is the self-declared experience with cryptocurrencies trading comparing performance between their levels.

The hypothesis is that users viewing multiple cryptocurrencies' price variation

history will make operations resulting in a higher percentual return than using the conventional 2D chart.

4.3 Protocol

Participants were gathered online by accessing the page where the experiment is hosted[2]. The link to this page was shared on social media and email groups. There were no specific grouping targets other than the ones formed by profile questions.

The agreement for participating in the experiment is the first screen, when accessing the page, to avoid the users quitting before accepting it. After, the profile questions ask if using a mouse or touchpad, in the case of using a laptop, how many hours use a computer or laptop a day, if they ever made some trading with cryptocurrency, and which is the frequency.

Afterward, the user is presented to tutorial describing the task and what is going to be measured, a concise explanation of what is a candlestick (Fig. 3.8), and the features of the chart they are viewing with a short animation video each in GIF format.

Post tutorial, they view the chart with the candlesticks and the last one, in the positive x-axis, being the first day of the negotiations. They will execute operations for the next 15 days from the data available (Sec. 4.1). Every action of the user, after clicking to buy, sell, or hold, add one more day that is displayed in the chart, and the system saves the action taken by the user.

Subsequently the last user action, after the 15 days, questions of understanding are presented, asking: What is the value that is used to calculate the performance? and Which timeframe each candlestick represents? In the next screen, the Nasa-TLX ((HART; STAVELAND, 1988)) form requests to select the perceived effort. Finally, in the next screens, the System Usability Scale (SUS, Jordan et al. (1996)) questionnaire collects the subjective usability.

At the closing screen, the system provides feedback to the user about the percentage return obtained along with an example of much they would have earned if they had applied a thousand dollars in USDT.

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[2]https://trading-experiment.protic.systems/

5 RESULTS AND DISCUSSION

This experiment groups participants from 4 single choice profile questions which have 2, 5, 4, and 6 possible answers, totalizing 240 clusters. The information these questions are trying to understand are:

- Which type of device is being used to participate (Mouse or Touchpad);
- How often users use a computer or notebook;
- Past experience making operations with cryptocurrencies;
- Frequency of trading cryptocurrencies.

5.1 Demography

In total, 18 participants completed all the 15 steps of interaction. All of them reported a regular use of computers for one hour or more per day. None of them reported having prior experience with cryptocurrencies or trading. Eleven were using mouse and 6 touchpad to perform the task.

5.2 Main hypothesis

The hypothesis was that visualizing multiple cryptocurrencies' prices history will have higher performance than the ones seeing the conventional 2D chart.

We assume the data follow normal distribution by applying Shapiro-Wilk resulting in p-value > 0.05 (0.2719808). In result, we applied Student's t-test for means analyses showing no significance in percentile performance between the two interface types for alpha > 0.05 (p = 0.8793), with medians -18.97% and -21.46% and means -17.94% and -19.04% for the 3D and 2D performances respectively (Fig. 5.1). With this result, we cannot prove our hypothesis nor disprove it.

A second evaluation is the time used to perform the task per chart and could not assume normality due to application of Shapiro-Wilk resulting in p-value < 0.05 (p 0.02506). We applied Kruskal-Wallis to the results and also no significance presented for alpha > 0.05 (p = 0.4239). The medians are 75.23 and 82.59 seconds for 3D and 2D charts respectively (Fig. 5.2). We removed data from participants that took 2 times the standard deviation additional time to complete the task. Since the experiment was conducted on-

Figure 5.1 – Percentual performance per chart type
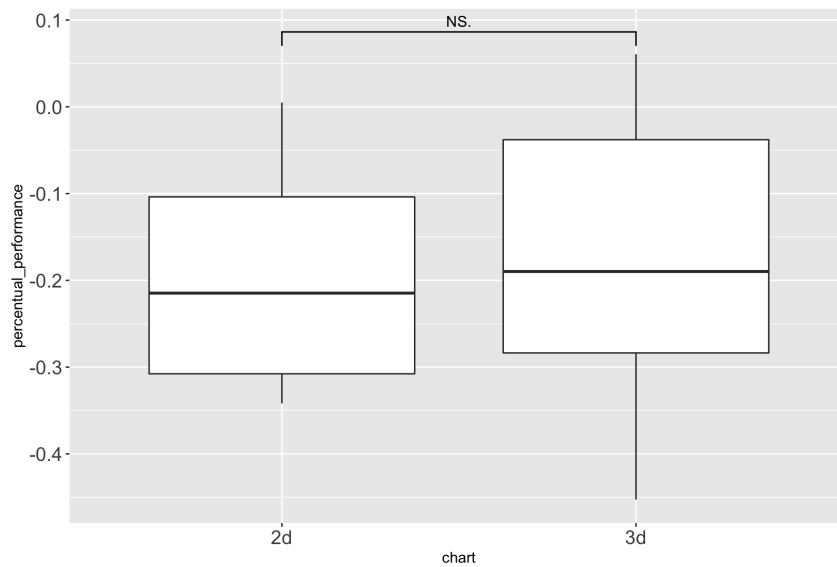
Figure 5.2 – Time in seconds taken to finish the task
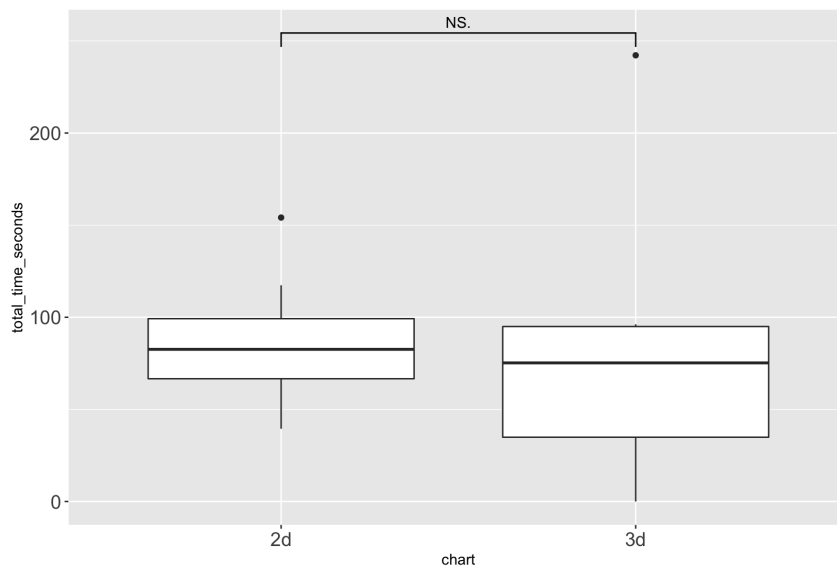
line without supervision, these outliers probably divided the attention of the task with external distractors. We obtained again a p-value > 0.05 (p = 0.6374), and medians 72.36 and 75.54 seconds for 3D and 2D charts (Fig. 5.3).

One of the possible reasons that the significance level was low is due to the small sample of participants with adherence to the experiment. The most impactful factor, however, seems to be that none of the participants has previous experience in trading, and probably could not make informed decisions from the data provided, independently of the interface. Another factor that could improve significance would be having a wider time window for trading.

Still, the differences measured point to a slight advantage of the 3D visualization

Figure 5.3 – Time in seconds taken to finish the task without outliers
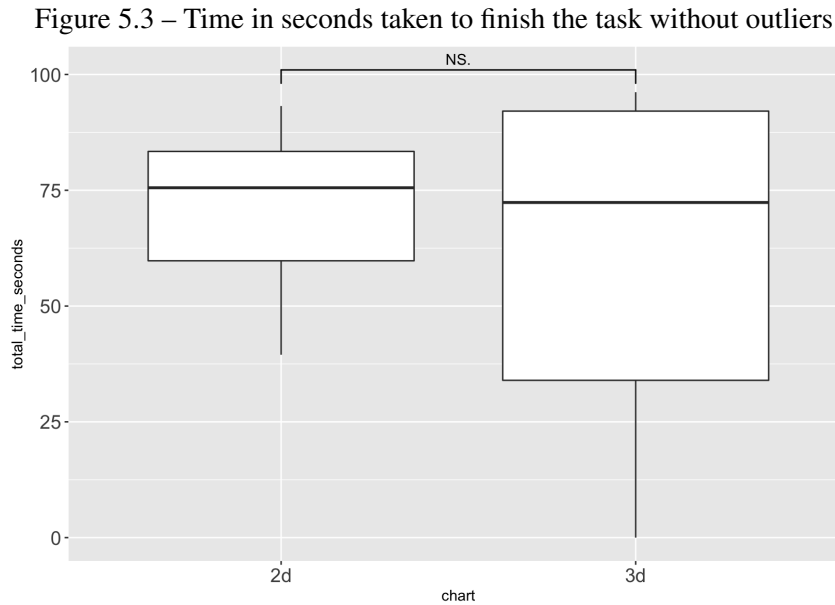
both for profit and time performances.

5.3 Results by groups

Having no participants with experience trading cryptocurrencies, other groups were tested. To explore learning effects, we tested splitting the performance of the first 6 interactions and compared with the last 9 ones. The initial 6 interactions were tested with Shapiro-Wilk for normality, obtaining p = 7.106e-06. Then, as we cannot assume the sample follows a normal distribution, we applied Kruskal-Wallis for the initial interactions and found no significant difference for the medians (-0.37% and -3.11% for 3D and 2D charts respectively) with p-value > 0.05 (p = 0.3496). See also Fig. 5.4.

For the first part there is an outlier out of 2 times the standard deviation. Removing the outlier having N = 17, tested with Shapiro-Wilk resulting in p < 0.05 (p-value = 0.02) not allowing us to assume a normal distribution. Then, tested with Kruskal-Wallis with p > 0.05 (p-value = 0.3698) not finding significance and with medians -0.37% and -3.11% for 3D and 2D respectively (Fig. 5.5).

When accounting for the remaining 9 interactions, the result of the Shapiro-Wilk test (p = 0.08222) allows us to assume normality. We then applied the test Student's t-test between 3D and 2D charts and no significance was found with p-value > 0.05 (p = 0.6303) for medians -10.81% for 3D and -14.80% for 2D charts (Fig. 5.6).

After testing the variance with Kruskal-Wallis between the first 6 (Fig. 5.4) and the means with Student's t-test for the remaining interactions (Fig. 5.6) have not found

Figure 5.4 – First 6 interactions per chart type
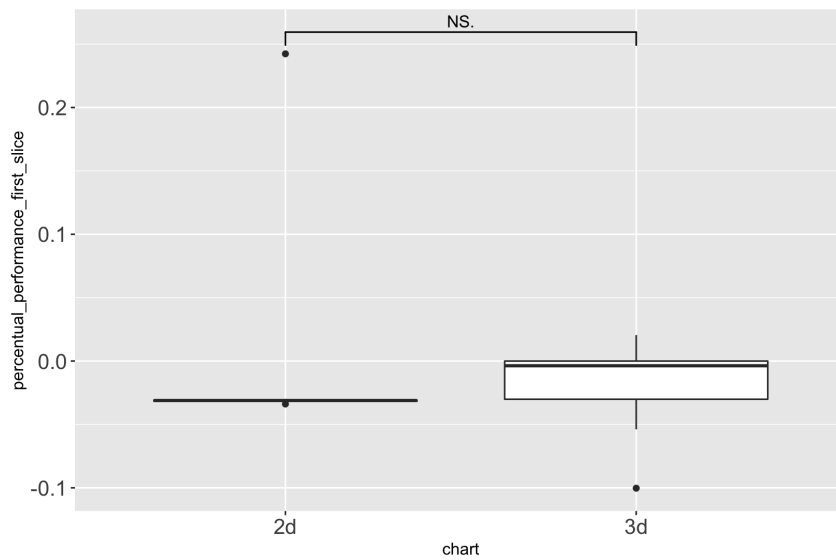
Figure 5.5 – First 6 interactions per chart type without outliers
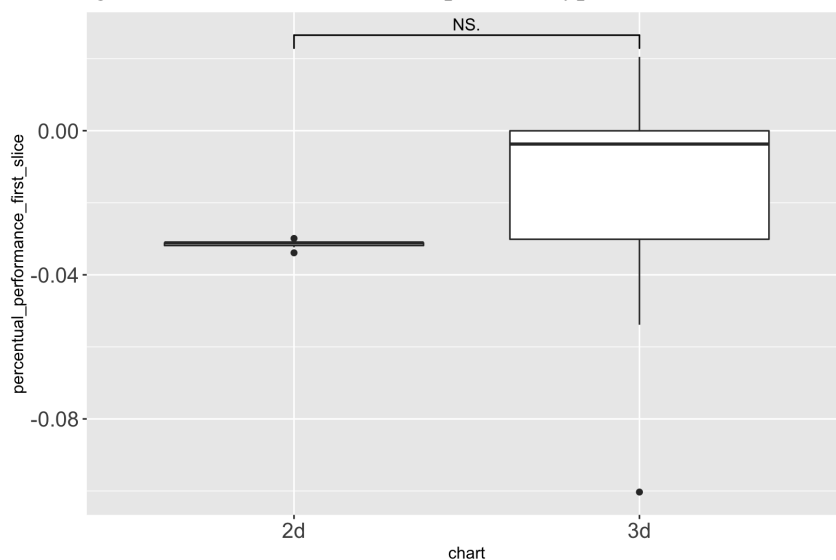
significance, we also analyzed the comparison per chart type (2D or 3D) performance separately. The initial and the remaining operations executed in the 3D chart follow a normal distribution with Shapiro-Wilk returning p-value > 0.05 (initial p = 0.05186591 and remaining p = 0.2182025). We then applied Student's t-test and found a significant difference (p = 0.01593) for the means -1.96% and -9.83% for the initial and remaining operations (Fig. 5.7).

The comparison between 2D initial and remaining operations was verified with Shapiro-Wilk as well, and we cannot assume a normal distribution. Kruskal-Wallis was applied, but no significance was found with p-value > 0.05 (p = 0.3208) and medians of -3.11% for the first and -14.80% for the last parts (Fig. 5.8).

The analysis of the 3D condition before and after provided a significant differ-

Figure 5.6 – The remaining interactions per chart type
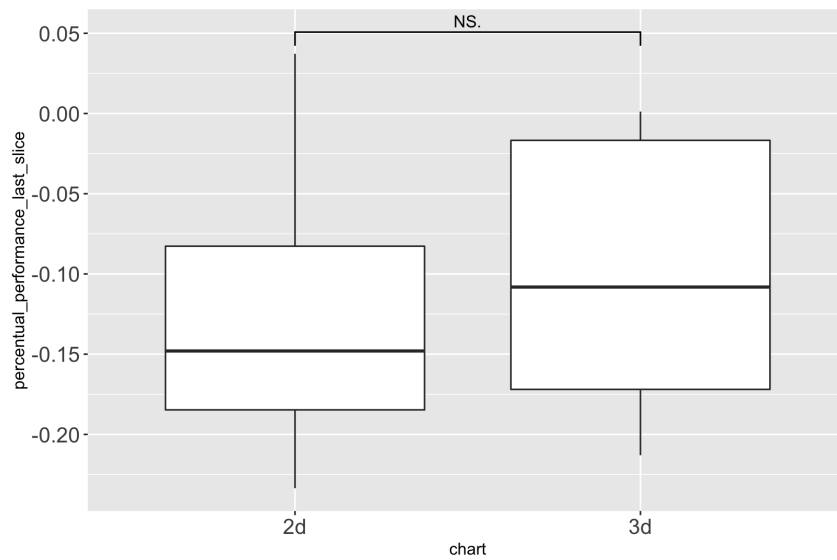
Figure 5.7 – First 6 and remaining interactions of 3D chart performance
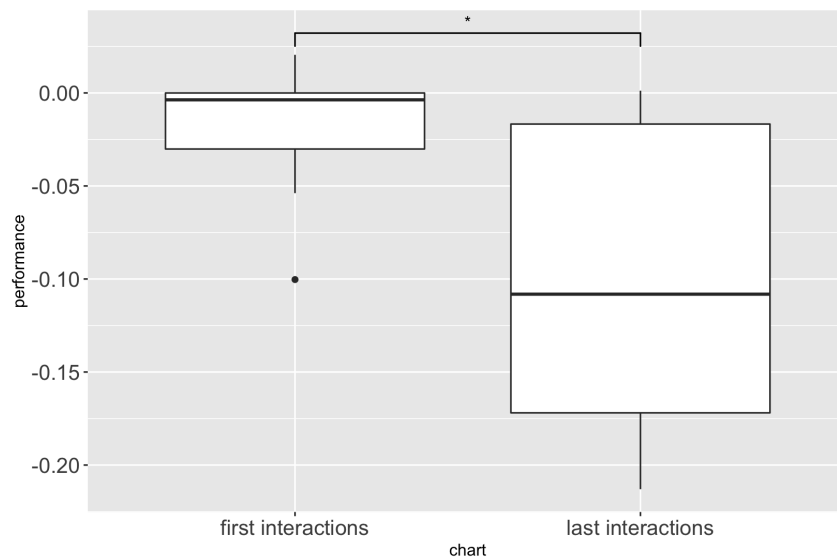
ence, but the same analysis for the 2D condition could not reach significance. Even if in both cases there is a degradation of the performance measured along time, a significant difference for the 3D condition could mean that the 3D interface has a higher mental load to keep track of the used strategy. We analyze workload in the following section.

5.4 Workload and usability

The workload was measured using the NASA-TLX ((HART; STAVELAND, 1988)) questions. The general collected average score was 40.25974, the specific charts score was 42.17687 for 3D and 36.90476 for 2D charts (Fig. 5.9). Notice that we removed

Figure 5.8 – First 6 and remaining interactions of 2D chart performance
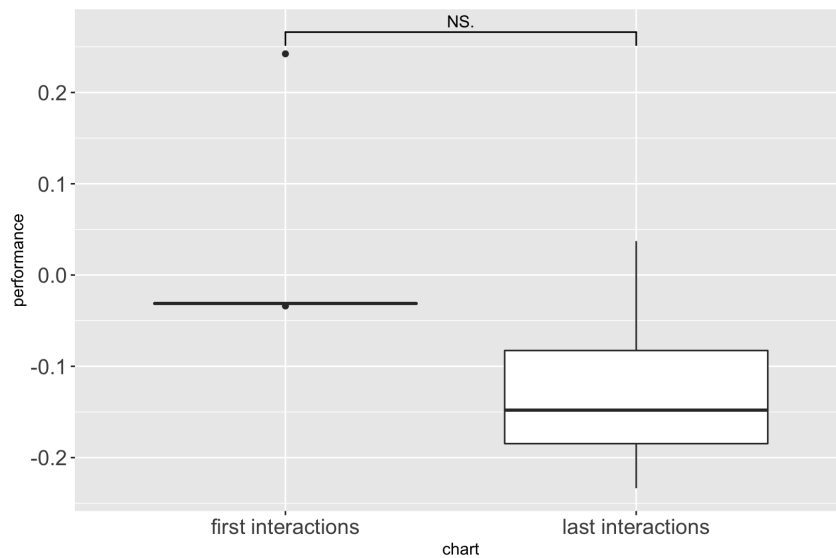
the zero values responses from the analysis as they mean that user did not respond to the questionnaire. Divided into factors, the effort declared by users are close to the mean (line in red) (Fig. 5.10 and Fig. 5.11), except for the insecure in Fig. 5.11 for 3D chart.

Figure 5.9 – Workload per chart
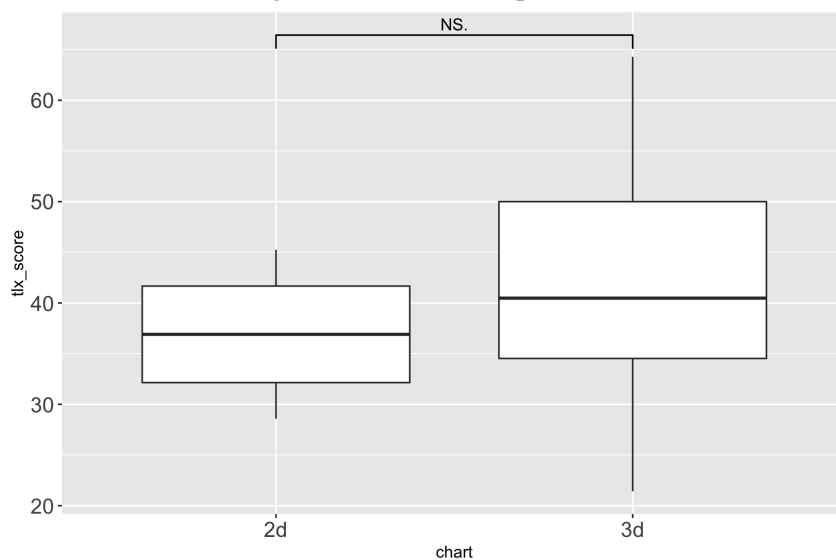
System Usability Score (SUS, Jordan et al. (1996)) mean for the 2D chart interface was slightly higher than 3D, being 64.375 and 54.28571 respectively. The 2D chart is above the 35% percentile and 3D is above the 15% of the SUS model (Fig. 5.12). The low scores obtained are quite surprising for interfaces that are relatively simple. We believe that instead of evaluating the interface, the participants considered their difficulty in deciding about buy/sell/hold options while responding the SUS questions.

Figure 5.10 – Workload per factor for 2D chart

TLX for 2D chart
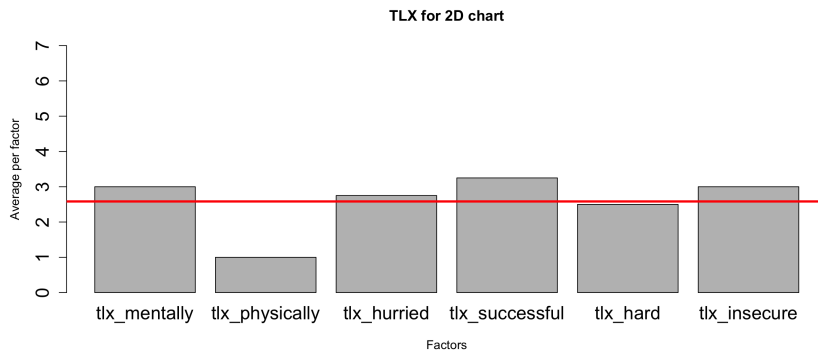
Figure 5.11 – Workload per factor for 3D chart

TLX for 3D chart
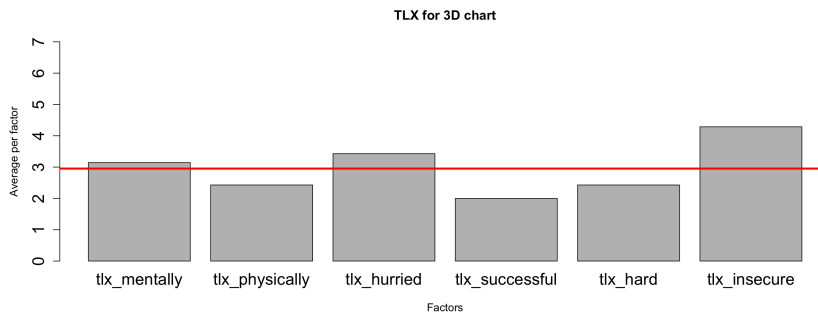
Figure 5.12 – SUS score per chart
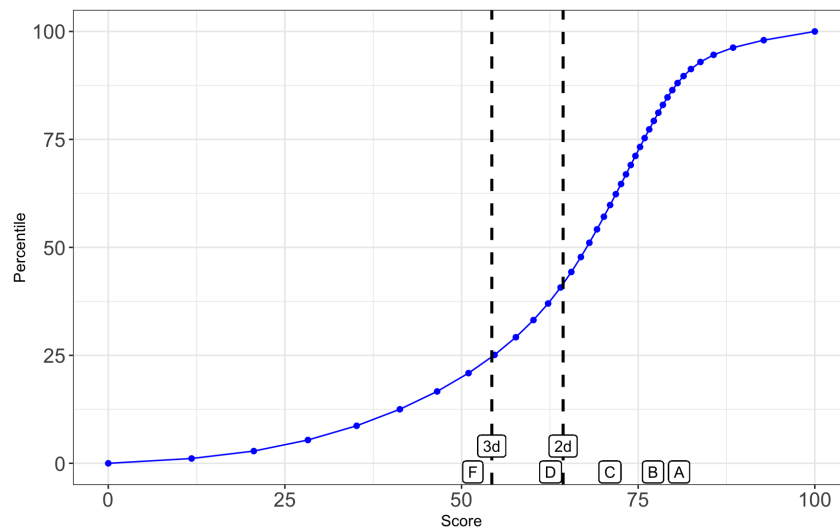
5.5 General discussion

As none of the participants reported experience with cryptocurrencies nor trading, there is a higher chance that their trading decisions have been made without using any solid strategy. It is being reflected in the medians of returns for both chart types. Only 4 of the individuals had positive return. and the range was from 0.17% to 6.06% which corroborates with the self-declared experience. The attention question about the timeframe was considered irrelevant for the study because the same analysis could have been made using other timeframes having the same result since in this chart is not possible to change it. All the collected data were used to make the analysis even when the given answer was wrong due to the small amount of participants and their experience level.

The workload reported is low in general except by the last question that asks how insecure, discouraged, irritated, stressed, and annoyed the participant were that had a higher value of response. This could also reinforce the fact that no experienced trader was tested, but this answer could be ambiguous due to users being referring to the task and not to the interface.

The usability score for the 3D chart can indicate that the interface can be improved making iterations with experienced users to understand the features that could help to have a higher return of the investment also endorsed by the decrease of performance rate in the remaining operations.

6 CONCLUSION

A novel design was proposed to use the third dimension in a trading environment to aggregate price information from other assets. An experiment was developed with the goal of verifying users' performance of this design against the traditional 2D charts. However, the results did not show a significant effect between interfaces. We believe that the effect would be significant if tested with a different population that includes experienced traders.

The objective was to propose an alternative to the commonly used chart in the trading platforms presenting multiple asset price variations in 3D. This was accomplished and is one of the contributions of this work. A second contribution is an experimental protocol for comparative evaluation with a standard 2D interface. A study was carried out with volunteers for evaluation using the proposed protocol. One of the advantages is that it can be used to compare the differences between conditions remotely, with the system hosted on a third-party platform for global access on the web.

Notwithstanding the sample size and composition were not enough to prove the initial hypothesis, the visualization technique can be applied with more participants with the proposed experimental methodology. The use of 3D visualization for trading in cryptocurrency markets can be a good choice to compare the trends of different assets without using a split-screen or multiple monitors, avoiding switching the context of observation if a strategy is well constructed.

The fact that no experienced people participated in the test indicates that there are not many that had effectively made such type of activity. A good interface could assist more inexperienced people to start trading. Maybe interfaces that can provide a piece of better educational information about the possible decisions based on curated material while showing conservative strategies to reduce the barrier of risk to starting trading.

We can still improve the 3D interface by adding visual indicators such as moving averages to visualize the possible trends, or signaling formed candlesticks patterns to user compare them between the other assets on the side and decide the one that is more convenient. Another visual technique that could be applied is displaying which was the optimal path for the past market data for future decisions to be more informed resulting in higher returns.

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APPENDIX A — FORMS USED IN THE EXPERIMENT

Figure A.1 – Agreement

Agreement

You are being invited to participate of this experiment with the purpose of understanding the performance in crypto coin trading using the present visualization method.

Participating in this experiment you will allow the research to better understanding the profile and performance of people interested to trade cryptocurrencies for profit. You can refuse to participate at any given point without harm or any penalty. The participation up to the "Thank you!" screen means you agreed the data provided for the experiment to be fully used in this study. You can contact experiment.yr7gmx@bumpmail.io for more information about.

Confidentiality: All performed actions recorded during the course of this experiment does not include personal data of the participant (e.g.: email, phone numbers, names, gender, race, color, religion, etc). The only data recorded are: Questions answers, market operations and the timestamp they were executed.

Risks: No lawful penalty is applied to this experiment. No money is used to perform any actions.

Benefits: Participating in this experiment will not bring any benefit to the participant. However, we hope it show us relevant information about the applicability of the present visualization method.

Payment: The participant will not be charged by any means on participating nor going to receive any payment for it.

Considering all the items above, you agree participating the experiment.

Agree

Figure A.2 – Profile questions

Pre-experiment questions

Which interaction device you are using?

○ Touchpad

○ Mouse

How many hours do you use computer/laptop a day?

○ Don't use

○ Less than 1 hour

○ Less than 4 hours

○ Less than 9 hours

○ More

How long have you been operating cryptocurrencies?

○ Never operated

○ Less than 6 months

○ Less than 1 year

○ More than 1 year

How frequently do you make operations on cryptocurrencies?

○ Never

○ Once a year

○ Once a month

○ Once a week

○ Once a day

○ Many times a day

Send Answers

Figure A.3 – Understanding questions

Understanding_questions

Which value is used to calculate performance?

○ Don't know

○ high

○ open

○ close

○ low

Which period each candlestick was representing?

○ Don't know

○ 1 hour

○ 4 hours

○ 1 day

○ 1 week

Next

Figure A.4 – TLX

Effort on using the graphical interface

How mentally demanding was the task?

Very low   Very high

How physically demanding was the task?

Very low   Very high
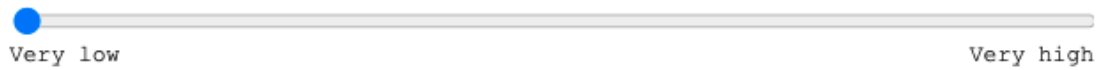
How hurried or rushed was the pace of the task?

Very low   Very high

How successful were you in accomplishing what you were asked to do?

Very low   Very high

How hard did you have to work to accomplish your level of performance?

Very low   Very high
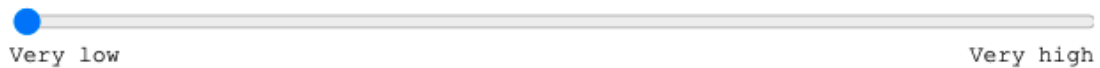
How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very low   Very high

Next

Figure A.5 – SUS

Graphical interface usability

I think that I would like to use this system frequently.

Strongly disagree   Strongly agree

I found the system unnecessarily complex.

Strongly disagree   Strongly agree

I thought the system was easy to use.

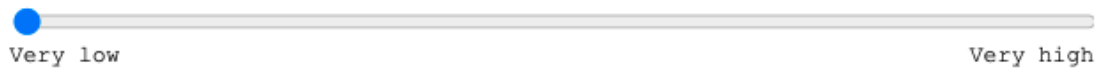Strongly disagree   Strongly agree

I think that I would need the support of a technical person to be able to use this system.

Strongly disagree   Strongly agree

I found the various functions in this system were well integrated.

Strongly disagree   Strongly agree

Next

Figure A.6 – SUS

Graphical interface usability

I thought there was too much inconsistency in this system.

Strongly disagree   Strongly agree

I would imagine that most people would learn to use this system very quickly.

Strongly disagree   Strongly agree

I found the system very cumbersome to use.

Strongly disagree   Strongly agree

I felt very confident using the system.

Strongly disagree   Strongly agree

I needed to learn a lot of things before I could get going with this system.

Strongly disagree   Strongly agree

Finish