OrderBookVis: A Visualization Approach for Comparing Order Books from Centralized Crypto Exchanges

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***Abstract*—Trading for a currency pair on centralized crypto exchanges is organized via an order book, which collects all open buy and sell orders at any given time and thus forms the basis for price formation. Usually, the exchanges provide basic visualizations, which show the accumulated buy and sell volume in an animated 2D representation. However, this visualization does not allow the user to compare different order books, e.g., several order book snapshots. In this work, we present OrderBookVis, a 2.5D representation that shows a discrete set of order books comparatively. For this purpose, the individual snapshots are displayed as a 2D representation as usual and placed one after the other on a 2D reference plane. As possible use cases, we discuss the analysis of the temporal evolution of the order book for a fixed market and the comparison of different order books across multiple markets.**

***Index Terms*—2.5D Visualization, Centralized Exchanges, Order Book**

I. Introduction

When trading cryptocurrencies or derivatives based on them, buy and sell orders are gathered in an order book. At any time, the bid side (offers to buy) and the ask side (offers to sell) consist of several levels, sorted by price in descending or ascending order. In addition to the price, each level is specified by a volume, called size, which describes the tradable quantity for a level. A purchase/sale always requires a corresponding sale/purchase by a counterparty; if the size offered by a single level is not sufficient, the price is determined as a weighted average of the entries in the order book. Especially for large orders, this can lead to significant deviations. [1]. Figure 1 shows an excerpt from the first four levels of an order book.

The trading interfaces of the various exchange operators are essentially similar and are limited in their representations to basic 2D diagrams. The accumulated volumes are displayed in a so-called depth chart, i.e., two polygons that reflect the total volume for a price both for the bid and ask sides. Since the order book changes with each transaction, the Depth Chart is displayed in animated form. Although the visualization shows basic liquidity measures, e.g., the spread, a deep analysis is not possible. For example, it is not possible to track the development of an order book over time for a fixed market or to compare several order books, e.g., of a currency pair on different exchanges.

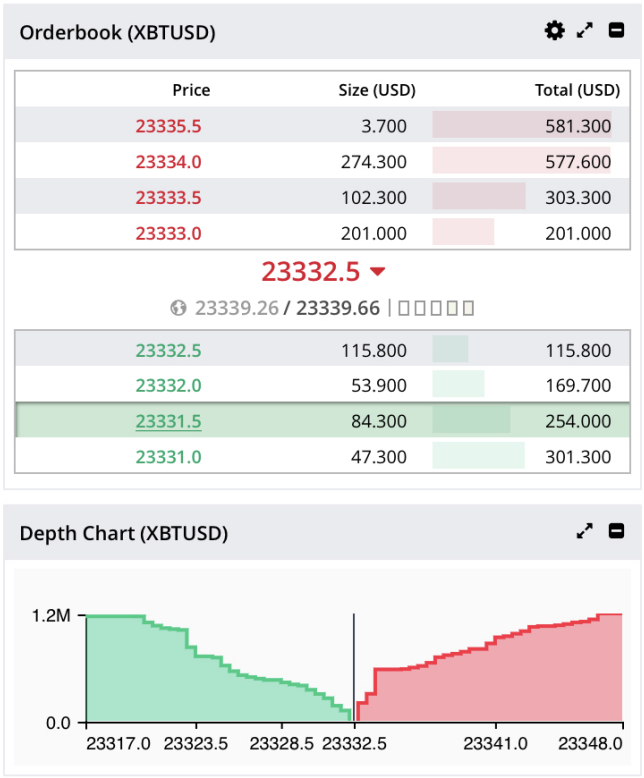

Fig. 1. Excerpt from the order book of the *XBTUSD* future contract from the exchange *Bitmex*. The first table shows the first four levels of the ask side, the second table the first four levels of the bid side. The total volume measured in USD is furthermore visualized as an bar chart in the third column. The Depth Chart shows the accumulated total volume at any price for both sides.

In this paper, we present *OrderBookVis*, an extension of the widely used depth charts with an additional dimension. The idea of OrderBookVis is to arrange single depth charts, i.e. snapshots of an order book, in juxtaposition to allow the comparison of a discrete set [2]. The resulting visualization

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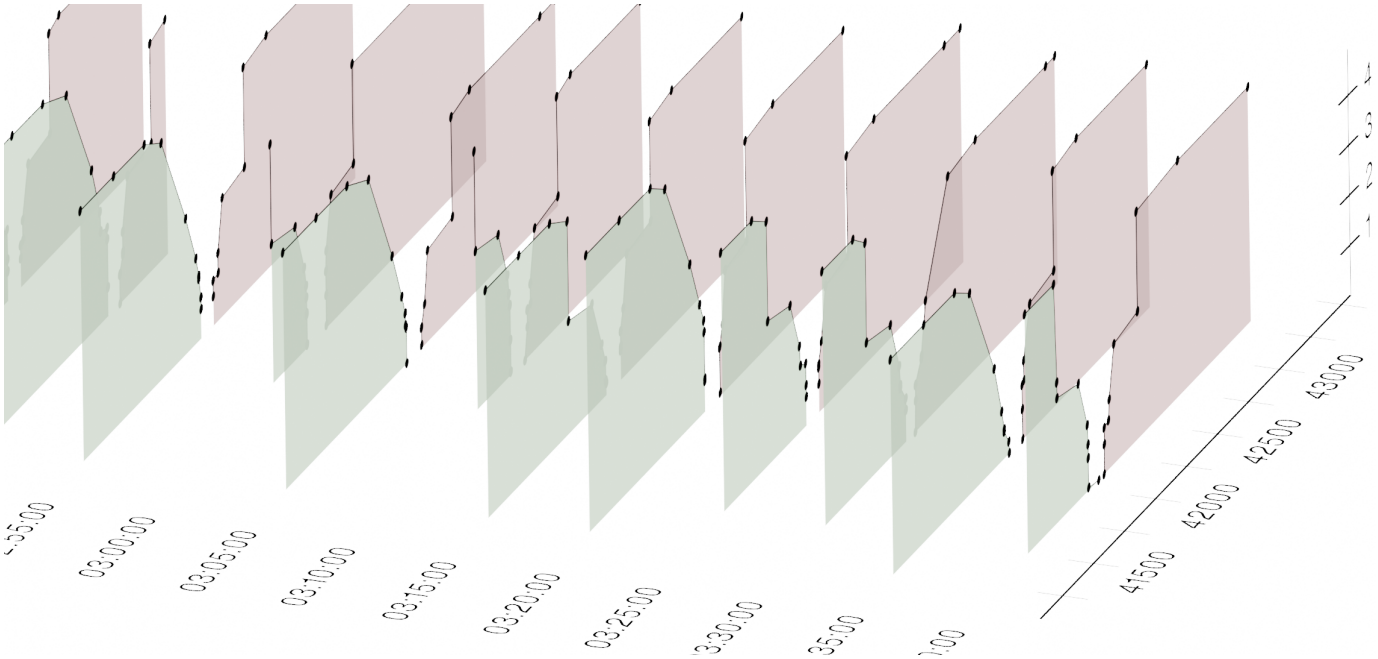

Fig. 2. Illustration of OrderBookVis for the currency pair BTC/USD on Binance. The individual slices represent the first ten levels for the bid and ask side as a depth chart for different points in time. The individual slices are arranged parallel to the shared price axis at equidistant intervals.

employs small multiples of individual 2D ridgeline plots on a 2D reference plane with graphical primitives embedded into the third dimension, i.e., its dimensionality can be systemized as $\mathcal{A}^3 \otimes \mathcal{R}^2$ [3], resulting in a 2.5D visualization. This idea originates from the ridgeline plot representation, but is extended by an additional height scale [4]. OrderBookVis allows the analysis of the temporal development of an order book, for example over a day. Alternatively, other categorical properties, such as the exchange, can be used as selection criteria for the order books. In this paper we focus on the visual mapping and the discussion of application scenarios.

The remainder of this paper is structured as follows. Section II presents previous work on visualizing data from the financial domain, in particular data related to cryptocurrencies. Our method together with some implementation details is detailed in Section III. We discuss two application scenarios in Section IV that show the benefit of our approach compared to existing techniques. Section V completes our exposition with conclusions and directions for future work.

II. Related Work

The visualization of financial data is an active research field targeting a variety of application domains [5]. A browsable survey of existing work is presented by Dumas et al. [6]. In our presentation of the related work, we focus on visualizations of order book data and aspects of cryptocurrencies, primarily *Bitcoin*.

The visualization of order book data is primarily done using depth charts. Other 2D visualizations have been proposed for showing selected aspects of an order book but have yet to be used by domain experts [7]. We, therefore, decided to extend the depth charts using a third dimension rather than developing another 2D variant. In doing so, we were inspired by the work of Brath and Matusiak [8]. Their approach *3Dify*, extrudes common 2D charts with time series data thus generating surfaces embedded in 3D. The authors applied their approach to histograms, scatterplots, and bar and line charts, but not on depth charts for order books. Unlike 3Dify, our approach focuses on discrete data rather than continuous time series.

Many visualization approaches that deal with cryptocurrency data examine market participants' transaction networks. Sun et al. presented *BitVis*, a 2D dashboard to capture the relationships of individual Bitcoin accounts [9]. For this purpose, data on transactions, such as price and volume, are displayed when an account is selected, which in turn is represented as a node in a social network graph. Through various interaction options, e.g., filtering or details-on-demand, BitVis supports regulators in monitoring financial crime. Zhong et al. presented *Silkviser*, a more detailed transaction data viewing tool [10]. Besides information regarding transactions and addresses, their data processing pipeline also analyses the underlying blockchain and single blocks, which are presented on four different pages. An alternative approach was proposed by Kinkeldey et al., whose technique allows the exploration of the transaction timeline for a set of filtered or clustered entities in the Bitcoin network [11]. A visualization framework for investigating the particular case of transactions between exchanges was proposed by Yue et al. [12].

Tovanich et al. developed *MiningVis*, a visual analytics tool for exploring the dynamics of the Bitcoin mining network [13]. Their approach combines various 2D visualizations for displaying statistics on the most active mining pools and news

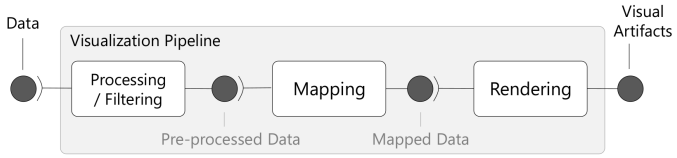

Fig. 3. Model of a visualization pipeline: First, the raw data is undertaken through pre-processing and filtering; second, the pre-processed data is mapped to a geometrical representation; third, the geometrical representation is rendered as an image [16].

related to Bitcoin. By different interaction techniques, a user can investigate different analytics tasks, e.g., identifying the significant miner's migration flow between mining pools.

Over the last decade, cryptocurrencies have gained much attention from professional and retail investors, as they provide high volatility. Conforti et al. developed a visual analytics tool, *CryptoComparator*, to support users in making investment decisions [14]. Their dashboard is designed to identify promising trends in the price movements and correlations between different cryptocurrencies by utilizing basic 2D charts. However, popular trading strategies that rely on trends have proven unsuccessful in other works [15].

III. Visualization

Our description of the visualization follows the stages of the visualization pipeline, as depicted in Figure 3. We first detail the processing stage to extract order book data from centralized crypto exchanges. We then describe the data mapping on geometric primitives and the layout. The rendering stage and its implementation details are presented at the end of this section.

A. Processing and Filtering

We retrieve the order book from the APIs of the exchanges. For our considerations, receiving a snapshot of an order book at selected points in time is sufficient via the corresponding REST APIs. For *Binance*, these are output as a *json* file. By merging multiple lines, we get a *ndjson* that collects the discrete set of order books. For professional trading, exchanges also provide the ability to request incremental updates. The development of such a system would be accompanied by a significant increase in complexity, which is why we refrain from doing so in our work.

B. Mapping

At the end of the first stage, we are given a discrete set of order books $\mathcal{D} = \{D_1, ..., D_n\}$ that can be grouped into slices according to one or a combination of categorical or numerical attributes, e.g., trading pair, timestamp, or exchange. Each element within $\mathcal{D}$ is therefore given by an order book snapshot at a given time for a specific market and can thus be displayed as a 2D depth chart. In a 2D depth chart, the ask and bid sides are displayed as polygons whose top line originates from the total volume for a given price. The sum of all volumes of the levels below the price gives the total volume for a price. The price is shown on the horizontal axis and the volume on the vertical one. Usually, the area of the ask side is displayed in red, and the area of the bid side in green.

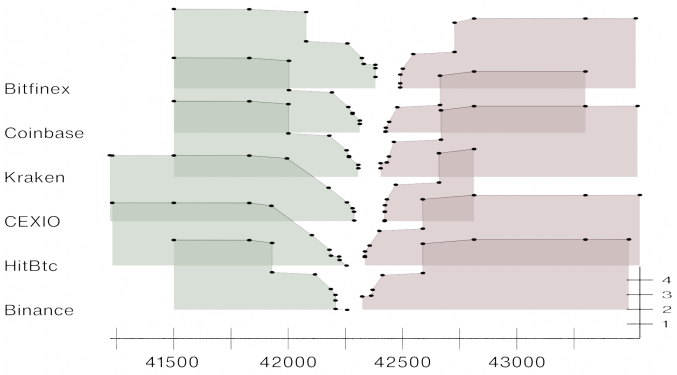

Fig. 4. Order book snapshots of the first ten levels for the currency pair BTC/USD of six different exchanges. The view allows an easy comparison of the best ask/bid across exchanges, as well as a comparison of market depth.

The individual depth charts are oriented on a shared price axis. The distances between the individual 2D charts can be chosen equidistantly, e.g., if they were chosen according to a nominal value, or might inherit a meaning themselves, such as time intervals.

C. Rendering and Interaction

The rendering is based on the software *Blender*, an open-source computer graphics software[1]. The data is read and transferred through a Python script to corresponding geometric primitives. Materials are assigned to each object, i.e., each surface, the axes, and the text, and with it, a shader. Blender's rendering engine (Cycles) creates the final image. Blender supports basic interaction options within the development environment, e.g., zoom or rotation.

IV. Application Scenarios

In the following, we discuss two use cases of OrderBookVis. First is the representation of the evolution of the order book for one market, followed by comparing order books across different exchanges.

A. Evolution of an Order Book

Figure 2 shows an example visualization for our first use case. Each slice shows the Depth Chart for a snapshot of the order book at five-minute intervals. In particular, two basic liquidity measures can be derived from each slice: the spread and the market depth. The spread is the difference between the best ask and best bid and is particularly relevant for small investors who only place small volumes. The height in the Depth Chart reflects the market depth for a price. The so-called "walls" are particularly interesting here, i.e., sudden increases in market depth. A wall forms a hurdle or support for the price development since a large size of a level would have to be cleared to move the price. From the figure, it can be derived that the reference price, i.e., the average price between the

[1] www.blender.org/

best ask and best bid, remains almost constant over the period shown. The spread also mostly stays the same. It is noticeable that between 3:10 and 3:15, a wall at level 6 arises from the placement of limit orders.

B. Comparison of Multiple Exchanges

In addition to time points, other categorical attributes can be used to select order books. Figure 4 shows an example of six order books describing the currency pair BTC/USD but from different exchanges. From the comparative representation, the trading venue with the best characteristics for placing an order can be directly identified. For example, a sale of small volumes is most favorable at Binance. Furthermore, large sell orders can be placed on Binance, Kraken, Coinbase, and Bitmex exchanges as they have walls as support. Furthermore, similarities can also be seen across the different marketplaces, such as walls at similar price levels on the ask side.

V. Conclusions

Visualizations can help users explore complex data interactively. In finance, simple 2D representations are usually used to visualize simple data, e.g., price movements using line charts. The order book is the central source of information for various use cases. Traders and investors need knowledge about the structure and dynamics of an order book to recognize market phases with high liquidity, in which trading is possible with minor price distortions. Furthermore, the order book enables the detection of prohibited market activities, e.g., wash trading, and is therefore also of interest to regulatory authorities. To support users in exploring order book dynamics, we present OrderBookVis, a 2.5D visualization for representing a discrete set of order books composed of several depth charts placed one after the other in a reference plane. OrderBookVis allows the comparison of several order book snapshots to analyze the evolution of a single order book. As another application, order books for one currency pair across different exchanges can be compared.

For future work, we plan to develop a scalable implementation using WebGL, enabling more interactions, e.g., details-on-demand. This will be presented in a dashboard together with other data visualizations, such as an analysis of relevant Twitter data. Subsequently, we plan to conduct a user study with professional investors whose activities focus on crypto exchanges.

Acknowledgment

Part of this research work is supported by a PhD grant from the HPI Research School for Service-Oriented Systems Engineering at the Hasso Plattner Institute for Digital Engineering, University of Potsdam. The funding is gratefully acknowledged.

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