Bitcoin Blockchain Transactions Visualization

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***Abstract*— Blockchains were originally used to support the Bitcoin cryptocurrency and now entire software ecosystems are being supported by blockchains. Despite their widespread use, not much is known about how peers in the bitcoin blockchain network use the system. We present visualizations to help in identifying some patterns in the usage of bitcoin blockchain supported technologies. In this paper, we observe the bitcoin transaction continent-wise via a visualization of the locations from where peers in the bitcoin blockchain network were making their transactions, using WebGL technology. We analyzed regional bitcoin blockchain usage patterns by observing their clusters formation over time. We also presented a pattern of how the value of the bitcoin changes over time.**

Keywords— Bitcoin; Blockchain evolution; Visualization; WebGL; JavaScript; R

I. INTRODUCTION

The advancement in software and hardware technologies have led to the development of intelligent computing, RFID, wearable sensor devices, secured VOIP, cryptocurrencies and blockchain and many products which fulfill the changing needs of the people [1]. As the world is becoming increasingly aware of innovative use cases with crypto tokens, the importance of the blockchain is growing dramatically. Since large amounts of data can be found everywhere, there is a risk that that data is being manipulated. One example of this can be found in the music industry where millions of artists are not paid properly [2] simply because the data trail takes too long to follow. Having music licensing details along with consumer access requests placed on a blockchain with smart contracts to handle changes in licensing is a potential solution to this logistical nightmare. Blockchain can also be used to help manage other data sets such as researchers' data as demonstrated in [3].

Bitcoins are where the blockchain had its beginnings. Bitcoin was invented due to a rising distrust in the current handling of currencies [4]. Satoshi felt that a centralized entity, being responsible for all of the currencies was not a good idea after the fallout from the 2008 financial crisis. This is the way things are with traditional banks. We hand all of our money to the bank and they control everything about our money. This method needed to be decentralized, so the blockchain was invented, and with it came the first digital currency, named as bitcoin. The bitcoin was also the first currency to be encrypted as all interactions with the blockchain occur over public key encryption.

The blockchain data comes from a decentralized peer to peer network. This network acts as a public ledger of all transactions taking place within the network. Any transaction that occurs within the blockchain can be verified by not only the node in the network through a process called mining, but also by the full nodes that don't mine. The decentralized and secure nature of the blockchain makes cryptocurrencies a tempting alternative to the centralized nature of traditional banks.

There is a huge potential for blockchain and its associated applications such as bitcoin to be used in an increasing amount of new ways while getting so much information. Finding methods for visualizing blockchain, bitcoin etc. to pick out patterns is becoming pertinent to uncovering how people use these large volumes of data. In order to build these visualizations, many technologies had to be put together. In this paper, we have tried to see the bitcoin transactions continent wise though the bitcoin blockchain visualization. There are few virtual globe visualizations already created such as [5] [6]. A repository of blockchain transactions was taken from the API available on the legitimate website, "blockchain.info". The IP address taken from it represents the IP of the first node to rely the transaction to the service node. Without any knowledge of the bitcoin communication network topology, there is no reason to believe that it corresponds to the node of the IP creating the transaction. However, deploying a network listener could solve this issue. Also, the scope of this paper is to observe the density of bitcoin transactions continent-wise. Here, we have presented our approach using the WebGL and jQuery so as to develop the front end interface while JSON and WebSocket have been used to extract information from an online repository of bitcoin blockchain transactions. The R programming language has also been used to analyze particular aspects of the blockchain data including currency exchange values for the bitcoin.

Each block found in "blockchain.info" repository has several pieces of information attached to it including the number of transactions captured by that block, when the last transaction took place, how many blocks are in that particular blockchain, and a difficulty associated with verifying that block's correctness. The mining nodes can claim a reward for verifying the block. This reward comes in the form of a fractional number of bitcoins. This creates an incentive for peers on the network to spend computational resources to earn currency. The last piece of information of interest to us is the IP address of the peer issuing the transaction. Each transaction from the repository can be visualized onto a rendering of the earth by mapping these IP addresses to the appropriate coordinates.

The visualization presented here can be viewed in any standard web browser (i.e. Google Chrome, Mozilla Firefox, Safari, Opera, and Microsoft Edge). We have presented a 3D rendering of the Earth with every new transaction that occurred in the blockchain. We analyzed the formation of transaction clusters over time in order to form speculations about regional blockchain usage patterns continent-wise. Furthermore, an interesting pattern regarding how the value of the bitcoin changes over time has been presented. Since blockchain based cryptocurrencies can be produced by spending computational resources to verify the correctness of a transaction, we suspect its value over time to follow different patterns than typical currencies which are produced in a more centralized manner being printed at particular locations. Another graph visualization allows viewing the fluctuations in differing granularities to spot micro level patterns in the prices.

The rest of the paper is organized as follow: In section II, we present an overview of tools and Bitcoin blockchain. A brief analysis of the existing visualization schemes of the bitcoin blockchain is presented in section III. In section IV, we present procedures, and then provide the results and their analysis in section V. Finally, we conclude the paper in section VI.

II. Overview

An extensive amount of web technologies were used in developing these visualizations. We present an overview of all the technologies used in our visualizations to help the reader understand how they may extend our work in the future. We also briefly discuss the many ways blockchains are starting to be extended beyond bitcoin. Finally, we discuss how our visualizations were pieced together in the end product.

A. R Libraries

The R programming language was used to perform statistical operations on bitcoin data. R Studio was used to manage R libraries along with the R runtime. The dygraphs library [7] was used for creating plots while igraph [8] was used for analyzing graph data gathered about the blockchain. Also, the Rbitcoin library was used to compare the value of the bitcoin with other standard currencies.

When going through large datasets it helps to have tools which support effortless exploration. The dygraphs package in R was built from a JavaScript library to do just that. The dygraphs has been used to create many visualizations [9].

Large connected networks lend themselves to being represented by extremely large data structures. The iGraph library allows for efficient computation of large graphs.

As with all currencies, computing its value is a complicated endeavor. For that reason, we used the Rbitcoin package to handle all calculations related to the bitcoin.

B. Web Technologies

WebGL is a JavaScript library which is used to display 2D and 3D graphics on any browser. More specifically WebGL is a specification [10] which is implemented by all the major web browsers. One of its strengths is that it exposes hardware accelerated graphics to web programmers. This means that through simplified commands, complicated rendering techniques can be used to create detailed visualizations [11]. It also allows for the creation of beautiful browser-based video games that run smoothly [12]. The visualization in this paper does not need such complicated features, but if the visualization were ever to grow in complexity, the graphics pipeline would allow for massive increases in scale.

JSON, short for JavaScript Object Notation [13], is a data format which can be easily exchanged between programming languages. It is because of this language independence, JSON has achieved the popularity among the developers. It is a standard through which most Application Programming Interfaces (APIs) are built to communicate with jQuery, as another JavaScript library which makes accessing JSON data simpler.

C. Blockchain Implementations

The secure and decentralized nature of blockchain has inspired researchers to extend the blockchain to be usable in other contexts. The users can use exchange platforms or local exchanges to exchange their fiat currencies into Bitcoins that includes (a) to withdraw money from recently introduced Bitcoin ATMs, (b) to store Bitcoins in an online wallet, (c) to use payment services in transactions with online merchants, (d) to pay with Bitcoins in local shops or bars, (e) to gamble with Bitcoins on various gaming platforms, (f) to incorporate transactions in a block, called mining and (g) to thus verifying the transactions and publish it to the network via the blockchain [14].

The blockchain may have originally been designed for supporting transactions of bitcoins, however, the same design can easily be changed to support all kinds of other transactions. One such use is to redesign the way transactions occur in the tourism industry and the incentives the users receive for trading their user data [15]. The current infrastructure of the internet lends itself to being compromised by a single entity. The security provided by blockchains has led to the creation of custom blockchains like Ethereum [16]. Ethereum modifies the blockchain even further to add smart contracts. These smart contracts improve security even further. Smart contracts are the scripting languages stored on the blockchain which all the connected nodes in the network have a copy of. This allows programmers to build applications for smart devices/ metaproducts on top of Ethereum blockchain [17]. One of these programs includes the Ethereum wallet which uses Ether as a currency like bitcoin. The difference between these currencies is that smart contracts can allow for different reward schemes and they are built on top of different blockchain networks.

D. Globe Visualization

A legitimate website found at https://blockchain.info hosts all the bitcoin blockchain transactions. As transactions are posted to the blockchain, the website posts the block data. This website has provided WebSocket API which sends JSON representations of these block transactions to a data stream for other applications to listen for these blocks and transactions in real time. This website also provides tutorials on how to make the API work for several other applications like C#, Node, Ruby, and Python.

Every time a peer in the blockchain starts a transaction, the WebSocket API sends to our application all the data from that repository as a JSON object. In order to extract data from each JSON described block, we used jQuery. Once we extracted all the data we needed using jQuery, those data gets stored in a cookie. This data then gets posted to our application alongside the globe. As each data comes in, it gets added to a list of recent transactions.

In fact, once a new cube gets placed onto the globe, the previous cube gets removed from it. This happened because we could only store one JSON object at a time. In order for our application to render every cube, we needed to store all our data inside cookies. The block data was then placed into cookies. Once a new transaction is detected by our application, it gets placed into a cookie. All the blocks stored in the browser's cookies get rendered as cubes. The limitation of the local storage made the system display only the lookup IP after the threshold value. So our application only shows a limited number of transaction data on the screen which in our case was at least 163719, and that it refreshes the whole page in every 24 hours after keeping the log of all the recent values. Summary data is also shown alongside the recent transactions. All this data helps users to understand where the blocks are coming from so that they can also observe patterns themselves.

We used the IP address from the most recently posted transaction block to determine a geographic coordinate to place a cube. Using WebGL, the application rotates the globe to the coordinate that was calculated from the IP address and places a yellow cube into that spot. For the cubes to accumulate, things became a little bit trickier.

III. Bitcoin Blockchain Visualization

Since the blockchain is part of a peer to peer network, it is possible to construct visualizations with all the peers in the network and the transactions that get placed on the public ledger of the blockchain. Various blockchain graph visualizations have been created with different approaches [18]. Several visualizations about the bitcoin were developed by Fergal Reid and Martin Harrigan [19] to address the issue of anonymity within the blockchain. Meiklejohn et al. produced a graph by performing heuristic clustering on the addresses of peers within the network [20]. This was done to gain insight into the economic structure of the bitcoin currency. The full graph of bitcoin transactions [21] was analyzed by Ron and Shamir. These analyses looked to study the behaviors of the peers in the network finding that a large amount of the transactions were similar to a single large transaction, which was made in November 2010. A similar analysis was recently performed on the network produced in the first four years of Bitcoin's existence [14]. They found several regional differences relating to adoption and business distribution. McGinn et al. in [22] analyzed the wealth of bitcoin transaction activities in order to explore algorithmic behaviors exhibited by the peers within the bitcoin network.

In this paper, we observed continent wise bitcoin blockchain transactions via globe visualization. We have also presented a graph, which was built using the dygraph package and other useful packages for R which we explain in the next section.

IV. Method

We first developed a web app to visualize the bitcoin blockchain transactions. The web app uses the open data from different WebSocket and APIs. Furthermore, we have also used R to extract some of the useful information from the bitcoin blockchain transaction via data wrangling and to manipulate and plot those data using different transparent packages for R.

A. Web app

We used WebGL as we wanted to have a JavaScript API to put real-time interactive 3D earth in any compatible web browser without the use of plugins. There is a JavaScript 3D Library called three.js that makes WebGL simpler. We used 'globe.js' to visually represent all the live Bitcoin Blockchain transaction in a single web browser. The real-time WebGL 'globe.js' is very interactive with mouse scroll and mouse drags features and it makes it easy to add custom shapes such as smaller blocks to the globe at different coordinates [23]. Besides, there is a provision for easy API for adding elements on the globe while it's running. The transactions which get initiated within the latest block and relayed through different computers in the world are mapped into the interactive globe.

To develop the web app, we created a simple HTML page with some scripts in it. We used a WebSocket from blockchain.info. The WebSocket sets one TCP connection and it's a two-way path connected between the client and the server. The client can send many messages but not the request, to the server and so can the server, but no one is basically responsible to each other. The first thing that we did was to create a connection to the WebSocket as:

```
var btcs = new WebSocket('wss://ws.blockchain.info/inv');
```

After that, we used an API command called 'onopen' from the WebSocket by referencing our previous variable. Then the 'send' command was used to send the message to the WebSocket server about what sort of message we wanted to do. Here we used the message in JSON for subscribing to all the notifications for all new bitcoin transactions as:

```
    btcs.onopen = function(){
btcs.send(JSON.stringify({"op":"unconfirmed_sub"}));
}
```

This process created a continuous flow of messages from the WebSocket into our system and thereby we could set what to do with each information from the messages. We created a response variable to hold the data from the JSON format data. The first thing we did was to get the "relayed by" information so that we could store the data into cookies by modifying the 'localStorage' object in JavaScript. We performed the operation by directly using setItem() and getItem() methods. We further extracted the time, amount and address fields. Since the amount is in Satoshi, we converted that in BTC by dividing it with 100000000.

```
btcs.onmessage = function(onmsg){
var response = JSON.parse(onmsg.data);
var relay = response.x.relayed_by;
localStorage.setItem('relay',relay);
```

```
var time = response.x.time;
var amount = response.x.out[0].value;
var conAmount = amount / 100000000;
var address = response.x.out[0].addr;
$('#message').prepend("<p     style='color:yellow;'>
      "+"("+sn+") "+" Address= "+address+ "
       TIME="+time +"    Relayed_by="+relay+"
       Amount="+conAmount+"BTC    "+  "</p>");}
```

We added jQuery for appending values to the top of the list, HTML content division elements (divs) by referencing the URL from code.jquery.com as:

```
<script src="http://code.jquery.com/jquery-3.3.1.min.js"
                integrity ="sha256-
FgpCb/KJQlLNfOu91ta32o/NMZxltwRo8QtmkMRdA
                u8=" crossorigin="anonymous">
```

The next thing was to provide another div alongside to show the live bitcoin transaction data from the new unconfirmed block as:

```
$.getJSON("http://btc.blockr.io/api/v1/block/info/last",
function(blocks) {
        var latesblocknb = blocks.data.nb;
        var latesthash = blocks.data.hash;
        var fee = blocks.data.fee;
        var time_utc = blocks.data.time_utc;
        var nbtx = blocks.data.nb_txs;
        var lastblocknb = blocks.data.prev_block_nb;
        var status = blocks.data.status;
        $('#Nmessage').prepend("<p style='color:white;'>"
        +"Latesblock= "+ "<a href=https://blockchain.info
         data-direction='reverse'>"+latesblocknb+"</a>"+"
         Status(valid/not_valid)="+status+ "
          LatestHash="+latesthash +"  Time_utc="
          +time_utc+"Number_of_transactions="+nbtx
          +" Total_Fee="+fee+"</p>");
        });
```

The final task was to create the div for the globe and to map latitude and longitude of the different nodes from the bitcoin blockchain transactions into the globe. We used getItem() method for the localStorage object to retrieve the IP addresses and displayed them in the console and converted into corresponding coordinates in the form of latitude and longitude.

```
var div = document.getElementById('globe');
var urls = { earth: 'img/world.jpg',
             bump: 'img/bump.jpg',
             specular: 'img/specular.jpg', }
var globe = new Globe(div, urls);
globe.init();
 var trackIss = function() {
      var ip_cord=localStorage.getItem('relay');
      console.log(ip_cord);
```

```
        {$.getJSON("http://freegeoip.net/json/"+ip_cord,
function(coords) {
        var latitude = coords.latitude;
         var longitude = coords.longitude;
                if(!latitude && !longitude){
                 latitude = 52.13;
                   longitude = -106.67;
                 }
               }}}
```

The loopback IP address value of 127.0.0.1 when obtained, was mapped into the coordinates of Saskatoon as it is just the "localhost", used to establish a connection to the same computer being used by the end-user. With the loopback construct, we assumed our computer would become capable of networking so as to build the IP stack on the machine. Finally, we created and rendered the object on the globe.

```
      var data = {
      color: 'yellow',
      size: 5,
      lat: latitude,
      lon: longitude,
     };
     globe.center(data);
     setTimeout(function() {
     globe.addBlock(data);
     , 300);
```

B. Statistical Analysis with R

Furthermore, we used the bitstamp exchange for getting the exchange value for Bitcoin to USD. Rbitcoin library package is used for this purpose.

```
library(Rbitcoin)
wait <- antiddos(market = 'bitstamp', antispam_interval
 = 5, verbose = 1)
```

The antiddos method allows having the query interval of 1 per 10 seconds. We plotted the time series of the latest exchange value for BTC to USD using the aggregated values. We used Rbitcoin.plot for this purpose; however, another method rbtc.plot may also be used to plot the values. Similarly [24], [25] have provided different ways to query and access the bitcoin blockchain with R using libraries such as dygraphs and iGraph.

```
trades <- market.api.process('bitstamp',c('BTC','USD'),
            'trades')
Rbitcoin.plot(trades,col=red, xport.args=list(format="png",
            width=8*480, height=8*480, units = "px",
            pointsize = 58)))
```

The corresponding output is shown in figure 1. It shows how the value of bitcoin is now fluctuating around 10,140 USD.

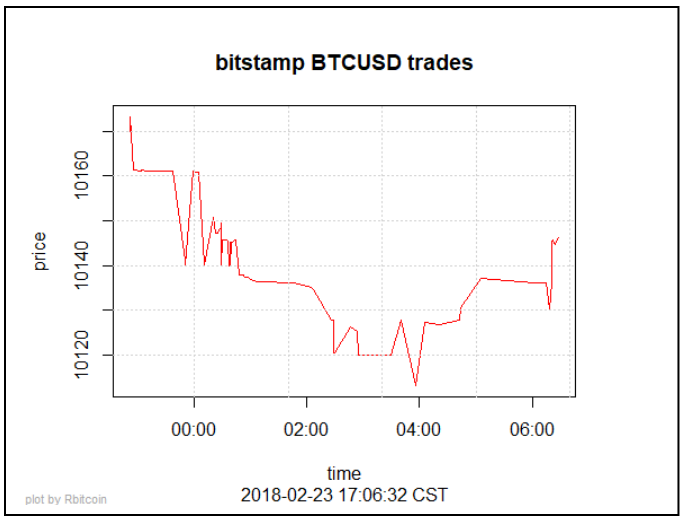

Fig. 1. Visualizing BTCUSD trades

V. RESULTS AND ANALYSIS

A snapshot of the final appearance of our web app in the google chrome browser is shown in figure 2. The web app appears to be interactive with the real-time data mapped into different coordinates within the globe. There is a zoom feature which allows one to change the earth size with the scroll of the mouse. Besides, other two HTML content division elements provide all the relevant information from the live bitcoin blockchain transaction in a stable manner. The values of the address, time, relayed-by, and amount for each transaction are shown in one div. Another div presents the data of the UTC time, the latest block, and its status, hash value, number of transactions and total fees. The console window, from the developer tool, presents the IP addresses to be mapped into the globe. We observed the clusters of blocks continent-wise across the globe for a period of 1 day and continued the same to get 15 samples. We found an average of 190,000 confirmed bitcoin transactions with an average block size of 0.7 MB every day. The observation showed that the largest number of transactions was from Europe and then from North America. Asia has few transactions and even fewer transactions were found to be from Australia and South America.

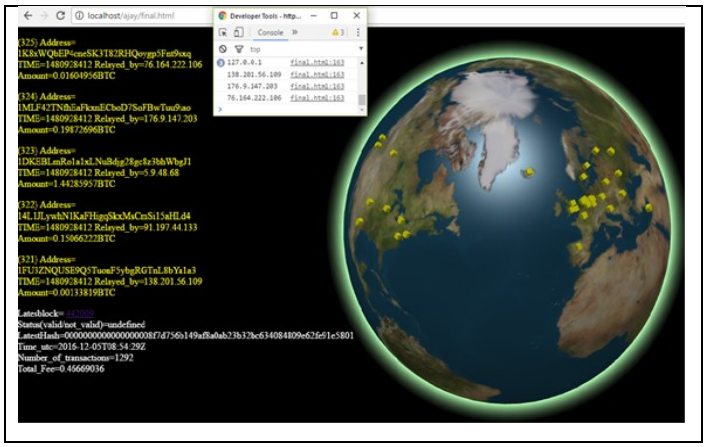

Fig. 2. Visualizing live bitcoin blockchain transactions

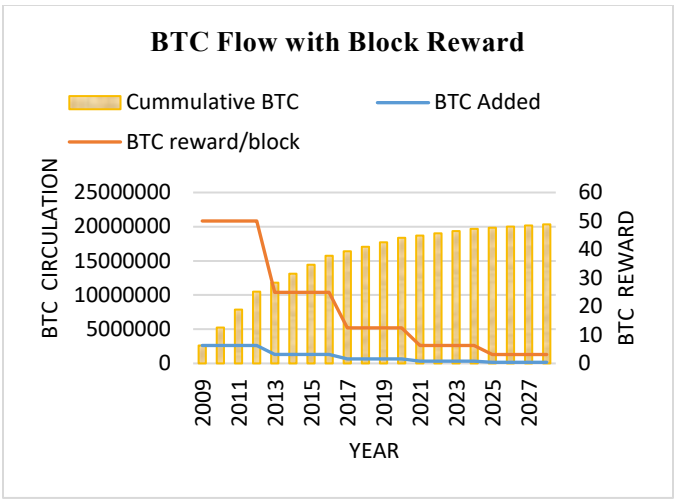

Fig. 3. Visualizing BTC block reward

Africa was the least involved in the bitcoin blockchain transaction. In Africa, very few people have recently started mining cryptocurrencies including bitcoin. Also, the extortionate bitcoin price is mainly because locals in Africa have not fully commenced using cryptocurrency/ crypto tokens in their local businesses. Recently, only fewer have started experimenting with the implementation of tokens as coupons, rewards or club's membership for their customer.

Furthermore, we also analyzed the trend of fluctuation of the bitcoin. In 2017, Bitcoin's value rose from 1,000 USD and reached almost 20,000 USD on December 17 before dropping sporadically down to around 10,000 USD. Looking at these past values and trend, it might take between 1.6 to 1.75 times the total duration of the decline for the complete bitcoin recovery. The price of bitcoin has always been changing drastically since it was released in 2009. "Regulators and policymakers have also been following Bitcoin and cryptocurrencies, raising the occasional eyebrow as they evaluate their risks and benefits and how to regulate this little-understood technology" [26].

Figure 3 presents the flow of bitcoin cryptocurrencies with the mining rewards as defined by Satoshi [4]. As proposed in the Satoshi's paper, this mining reward rule can only be changed with an agreement within the Bitcoin network. As per his paper, starting with the year 2009, only 2,625,000 bitcoins were made available each year and after four years, the BTC supply was brought down to 1,312,500. The block reward to the miners started at 50 BTC in the very first block in 2009 and it lasts for 4 years. Basically, an increase in the BTC price was thought to offset the block reward halving. It has been observed that, as the mining reward dropped to half, the BTC value later climbed up. Generally, the block reward halving also decreases supply, which as a result might have caused the BTC price to increase with time.

VI. CONCLUSION

Bitcoin is the first cryptocurrency using the blockchain technology, invented due to a rising distrust in the current handling of currencies. With the potential for blockchain to be

undertaken in different use cases while getting so much of information out of it, finding methods for its proper visualization to observe patterns is needed to uncover how researchers play with those large data set. It is very much required to put many technologies together in order to build those visualizations.

A repository of all the bitcoin blockchain transactions can be accessed from the APIs and WebSockets available in the legitimate website "blockchain.info". In the paper, we provided a brief analysis of the existing visualization schemes of the bitcoin blockchain and presented bitcoin transactions' density continent wise via one visualization with its complete development processes, which is based upon HTML, WebGL and scripts, WebSocket and APIs. We visualized where peers in the bitcoin blockchain network were making their transactions from, by allowing a cube to be placed at the originating location on the virtual 3D globe. The densities of these cube clusters show how actively a particular region contributes to this particular blockchain. Another interesting pattern is how the value of the bitcoin changes over time. For this, we used R to extract some important information in order to analyze particular aspects of the bitcoin blockchain transactions including currency exchange values. Our analysis shows that the largest number of transactions were from Europe and the least from Africa. The currency exchange pattern shows that the value for the bitstampUSD buys jumped in value by more than 1,300 percent in the year 2017, hitting a record peak of almost 20,000 USD before plunging by 70 percent and now again it exhibits the gradual upward trend. Our future work will be focused on the analysis of the cluster of cubes on the globe over a longer period of time in order to form speculations about regional blockchain usage patterns.

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