Fostering Collaboration in Science: Designing an Exploratory Time Travel Visualization

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Abstract. Finding important research papers according to a topic in the midst of an exponential growth of scientific publications is a significant challenge for researchers. Digital science libraries interfaces offer inadequate support for effective navigation and exploration, and fail to assist researchers in accurately articulating their queries with their specific interests, by typically offering a massive list of results as visual output. This problem arises not only in terms of interface design, but also in the domains of user experience and information visualization.

Collaboration is a key driver of science, and the collaborative behavior of sharing papers that is based on an individual curation process grounded on researchers' reading experience, can act as powerful social filtering system to find important papers. We present an exploratory visualization structure designed with the aim of mapping and supporting through a temporal perspective a curatorial behavior that already happens in social networks but without a visual communication logic. This article describes the design and implementation process of a temporal visualization structure in D3.js, and which combines a timeline, a node-link diagram, and a force-directed beeswarm algorithm. The findings present preliminary results and set the stage for further investigation into a "time travel" exploratory visualization. The article concludes with a reference to the visualization code, which can be accessed through the provided link.

Keywords: Interface Design · Information Visualization · Timelines

1 Introduction

Finding the most important research papers according to a specific topic in the midst of an exponential growth of scientific publications is a significant challenge, and the relevance of this topic has never been more critical. Evidence of this problematic was recently highlighted by researchers at the height of the Covid-19 pandemic, who had difficulty in tracking, handling and finding important papers [1]. The Association of Scientific, Technical and Medical Publishers (STM) in 2018 reported that three million scientific papers are published annually, meaning that eight thousand, two hundred and nineteen-point eighteen new research papers are published every day [2]. Currently this number must have been exceeded, however STM has not yet released a new update about the number of papers published annually.

A. L. Brooks (Ed.): ArtsIT 2023, LNICST 565, pp. 46–62, 2024.
https://doi.org/10.1007/978-3-031-55312-7_4

Despite the advanced search strategies (e.g., Boolean operators) offered by digital science libraries (e.g., filtering strategies, relevance metrics), the visual output still predominantly comprises an extensive list of results [3]. This can significantly burden cognitive processing, leading to information overload [4, 5], which, in turn, hinders the efficient discovery of results aligned with researchers' specific interests. As a response to the described problematic a recent solution based on social collaborative filtering, visualization and interface design has been proposed by [3, 6, 7]. [3] also points out that this collaborative filtering behavior already happens in social media, however, without a structured communication process. This work aims to make a contribution from a temporal perspective, taking into account the context/scenario described in [3], see Sect. 1.1 for a detailed explanation.

The exploratory visualization framework also must take into account a visual encoding strategy based on marks (e.g., dots, lines) and channels (e.g., size, position, angle, color, shape), but also an interaction strategy (e.g., overview plus details) that makes it possible to present and explore the characteristics of time as a dimension. Therefore, how can interactive and exploratory visualization be used to explore time-oriented data according to the describe context/scenario while considering the structure of time? To address this challenge, we propose Time Travel, an exploratory and interactive visualization structure implemented in D3.js that aims to map and support this collaborative filtering behavior through a temporal perspective. The proposed visualization structure combines a timeline, a node-link diagram, and a force-directed beeswarm algorithm that uses the concepts of forces [8], which is useful for representing distributions of nodes while avoiding overlaps. The visualization design and implementation will be discussed and presented in more detail in Sect. 3. The next section describes the context and scenario for a future usage of the Time Travel technique.

1.1 Future Usage Scenario for the Time Travel

This section provides a brief description of the scenario that shaped the conceptual basis for the Time Travel layout, and it also points out promising benefits in using this structure in a future exploratory interface for science [6].

User Experience (UX) methodologies are fundamental, because designing scenarios demands thoughtful evaluation of context-specific elements, given that the user experience is intrinsically connected with the context (e.g., user's goals, tasks, motivations). A scenario-based design methodology enables the proactive identification of challenges, pinpointing opportunities for enhancement, and the exploration of inventive solutions tailored to users' needs and expectations [9]. The Time Travel scenario is based on the context described in [3] and [7], regarding the collaborative and curatorial behavior that happens in the social dimension of science [10], more specifically in digital social networks. In this particular scenario, it is essential to provide a temporal perspective so that this sharing behavior can be framed on a temporal reference. The aim is to visualize trends, patterns, correlations, bursts, seasonality and set the stage for an analysis focused on the evolution of topics within communities, subareas of knowledge, among other types of analysis [11].

Science progresses continuously over time, which is demonstrated by the rates of variability of the attributes of different science entities [12]. Among other entities, the basic units of science analysis are papers, journals and researchers [12]. The focus of this paper lies on the relationship between these entities, researchers and papers, and the social processes of science, namely the collaborative sharing/filtering of papers [3], where researchers play a key role as curators of important scientific research/results. [3] shows evidences that this behavior also happens on social media (e.g., Twitter and Facebook), namely when the researcher asks for important papers on a specific topic from their peers, and the community is willing to help by responding to the request. These papers (or other documents), are usually stored on researchers' computers and the aim is to use these personal "databases" as a synthesis of important research. This synthesis is the result of a selection process based on the researchers' reading experience. From this point of view, the aim is to develop an interface to support and map a collaborative sharing/filtering behavior based on the curation process described above, however through a temporal perspective, as [3] presents a solution that is based on a relational perspective within a community around a specific knowledge subarea.

Information visualization (InfoVis) design process [13] plays a key role in translating abstract data into a visual language to provide effective cognitive processing [12]. The design of user-friendly interfaces and the improvement of the overall user experience depend fundamentally on user interface design and interaction methodologies. Providing a temporal perspective is essential for understanding the evolution of a subarea, or the evolution of topics. Network visualization aids in recognizing significant connections between the most widely shared pivotal papers and the researchers responsible for disseminating them.

The scenario described above set the stage for the design and implementation of the Time Travel. The next section provides a brief background on the topic of visualizing the temporal architecture of science; Sect. 2.1 presents a brief study and analysis on timelines, and Sect. 2.2 presents the state of the art. The remaining article is divided in the following sections: Sect. 3 outlines the procedure of designing and implementing the Time Travel InfoVis in D3.js, while Sect. 4 introduces preliminary results. The last section presents a brief discussion and future directions. The Observable link to access the dataset, visualization and code can be found at the end of the article.

2 Visualizing Time

Based on the current state of the art, this section presents a brief review of temporal visualizations in the context of science. However, and in order to understand temporal structures, we should first consider the data dimension: time.

Time holds significant value as a data dimension with its own unique attributes. It is found in various domains, including but not limited to medical records, business/finance, biographies, photo collections, history, planning, project management, traffic, mobility, and science, all are defined by temporal information [13, 14]. Time possesses an inherent structure that enhances its complexity, namely a hierarchical arrangement of granularities, from milliseconds to centuries, and it can be aggregated by astronomical time (e.g., hours, years) or cultural time (e.g., semesters). The higher the aggregation the lower the resolution [11]. It also encompasses diverse divisions and relations, one example is the relation between 60 min and one hour [11, 13, 14]. These elements are integrated into design systems (e.g., calendar), and it encompasses natural cycles (e.g., seasonal cycles such as annual temperatures) and recurring patterns such as seasons, as well as social cycles, that are frequently irregular in nature (e.g., school breaks), and trends (e.g., cyclical, seasonal, random) [13, 14]. Therefore, the time structure could be linear, cyclic and hierarchical (e.g., years, months, days).

Temporal data values depend on time and to analyze and visualize temporal data is important to considered a specific visualization framework and time resolution. Temporal analysis aim is to understand the inherent characteristics of events/phenomena mapped trough a sequence of observations, including patterns, trends (e.g., increasing and decreasing tendencies), seasonality, outliers, and bursts of activity [11].

Time-series data consists of a sequence of events and observations and can be categorized as discrete or as continuous [13]. Continuous data is where observations are recorded at regular time intervals, and discrete data is where events occur within milliseconds or extend over extensive periods such as years or centuries [11, 13, 14]. Temporal data can also be categorized as static, involving the examination of historical data, or dynamic, displaying the information flow of data streams like email or news updates [11]. Such example is the work of [15], which combines node link diagrams and circular treemaps to visualize the information flow of sharing behaviors. Another important work is from [16], which presents a summary of a set of important techniques for text data flow, focusing on social networks, more specifically in three areas that are related to the objective of the proposed exploratory visualization structure: events, topics and information dissemination. It also proposes an interactive visualization for depict and analyze anomalous information spreading in social media. It is fundamental to make a reference to the employed technique, specifically the greedy layout algorithm derived from an extended circle packing approach [17]. Other types of analysis to visualize time that should also be considered are: time zones, outliers and time slices [11, 14]. For a more comprehensive analysis, [14] provides an important survey about general time visualizations methods and techniques.

The following section presents the state of the art regarding time visualization in the context of science.

2.1 Temporal Structures in Science: State of the Art

The focus of this analysis is on interactive and exploratory visualizations of science trough a temporal perspective. This section references several important visualizations that make use of temporal structures (e.g., line graphs, stacked graphs, scatter plots, histograms, timelines). [12] provides important milestones in mapping science, from algorithms, visualizations, mapping strategies, tools and books, from 1930 to 2007. This work is used as a starting point for the present analysis. Thus, it is important to highlight the following works: PaperFinder (2004) explores and visualize the history of InfoVis, and it uses the time attribute for the x-axis ordering; The Timeline of 60 years of Anthrax Research Literature (2005) employs three methods to map and visualize a particular topic: a timeline, a technique for clustering papers by time, and the capability to visualize temporal changes within the topic [18]; HistCite visualization of DNA Development (2006), is a tool that automatically generates chronological tables and historiographies from Web of Science searches. The historiography presents documents of a chronological nature and interlinked by their citations [19]; The History Flow (2006)[1] shows the edit history of Wikipedia entries/topic on a timeline [20]; TextArc[2] Visualization of The History of Science (2006) provides a chronological order of the text from the book: *A History of Science* [12]; Science and technology outlook: 2005–2055 (2006) maps uncharted territory of science and technology (S&T) through a timeline from 2005 to 2055 [21]; BiblioViz (2006) is a bibliography visualization over time (Table View) [22]; The 113 Years of Physical Review: Using Flow Maps to Show Temporal and Topical Citation Patters (2007) captures the structure and evolution of physics between 1893 to 2005. The 389,899 documents are arranged in a two-dimensional time-topic reference system. It uses a temporal and topical PACS organization of papers. In the last third of the map, an overlaid layout depicts the citations from every Physical Review paper published in 2005 [23]; Mapping the Universe: Space, Time, and Discovery![3] (2007), time is captured as a time spiral and also maps the sequence of new themes that emerge over time [24]; EdgeMaps (2011), is a tool to visualize influence relations between philosophers using a network graph and a timeline [25]; Citeology (2012) it is an interactive visualization that displays the connections among research publications by analyzing their citations over time [26]; CitNetExplorer (2014), is a tool for analyzing and visualizing citation networks of scientific publications over time. Nodes/publications are displayed on a vertical timeline and colored according to a categorical attribute (e.g., knowledge area) [27];

There are also some interesting web visualizations that should be referenced, although not published in academic papers, such examples are: Science Paths (2015–2016) project,[4] allows the interactive and exploratory visualization of citations of over 10.000 scientists from seven different fields over time by using an histogram [28]; The project Celebrating 150 years of Nature papers[5] (2019) represents an interactive and exploratory reference tree where each ring of the tree represents a cascade of references, and where the papers are arranged in rings by year, grouped and colored by discipline [29]; Searching Covid19[6] (2020) uses the most prominent Covid-19 related search queries starting from January 20th, 2020, and it combines a timeline and a beeswarm [30].

An important work to be referenced, but outside the scope of this review is the work of [31]. The MuzLink uses a linear and chronological layout with three axes of beeswarm connected timelines[7]. However, it does not allow a "time travel" navigation (pan and zoom), because the layout presented is defined by specific time period according to the selected artist. A user study was also conducted to assess the effectiveness of MuzLink with positive feedback regarding the exploration and analysis of musical adaptations and artist relationships.

1 https://whitney.org/exhibitions/idea-line.
2 http://wbradfordpaley.com/live/#.
3 http://cluster.cis.drexel.edu/~cchen/projects/sdss/images/.
4 https://www.youtube.com/watch?v=qlnxM-ld4BU.
5 https://www.nature.com/immersive/d41586-019-03165-4/reftree-home.html.
6 https://searchingcovid19.com.
7 https://muzlink.witify.io/#/artist/1923.

Understanding and interpreting temporal data requires different visual and analytical techniques. In conclusion, this concise overview shows the predominant adoption of the timeline structure and also provides important clues and strategies for the visual coding of temporal data and nodes placement optimization such as the *beewswarm* algorithm.

2.2 Time Lines: Brief Analysis

The focus on this section is to provide a brief analysis and overview regarding linear timeline visualizations, that are designed to present a linear sequence of events [32].

The portrayal of time and time-oriented data through visual representations predates the computer era [14]. Drawing was the primary medium to communicate, and for centuries, timelines conveyed the chronological order of events (e.g., biographies, historical summaries, chronologies) [33–35]. According to [35] timelines are the most common graphical representation of historical time, thus allowing to create sequential and chronological narratives of historical events.

A time-series plot, also called a timeline, chronological or data-distribution plot, plots values over time, revealing the temporal distribution of a data set, such as the first and last time point, any absent values, outliers, values, trends, growths, peak latencies, and decay rates [11, 32, 34, 36]. The spatial layout features temporal intervals and spatial units (e.g., negative space) that indicate "uniform or non-uniform temporal intervals" [35]. A detailed timeline could provide information about the chronological occurrence of events, their duration, and potential overlaps among them. [34].

Succinctly, timelines describe the type, number and order in which events occurred [14], and it can be described as a chronological arrangement of events that provides a historical account [37]. Therefore, a timeline is a visual representation of a series of events in time, namely it represents temporal event sequence data.

[34] provides a design space classification specific to timelines, with the aim of balancing expressiveness and effectiveness. It divides the timeline design space into five categories, namely Linear, Radial, Grid, Spiral, and Arbitrary. It also presents an introduction and analysis of a design space for storytelling with timelines, and identifies three important dimensions for timeline design, namely representation, scale (chronological, relative, logarithmic, sequential, sequential plus intermediate duration), and layout (unified, faceted, segmented, faceted plus segmented). However, these guidelines focus on expressive storytelling and not on exploratory InfoVis. [36] presents a novel study comparing timeline shapes. It assesses how the shape of the timeline influences task performance and whether users have a preference regarding the shape. They found that participants are faster at reading information from linear timelines than from circles and spirals, and that linear shapes are more readable. They also found evidence that linear shapes allow timelines to be read faster than non-linear shapes. It also provides some design recommendations, such as using linear timelines for difficult tasks that requires complicated decision making. This study was conducted with a more limited number of timeline shapes compared to the study conducted by [34].

A more extensive analysis of timeline visualization structures is beyond the scope of this article.

3 Time Travel: Design and Implementation

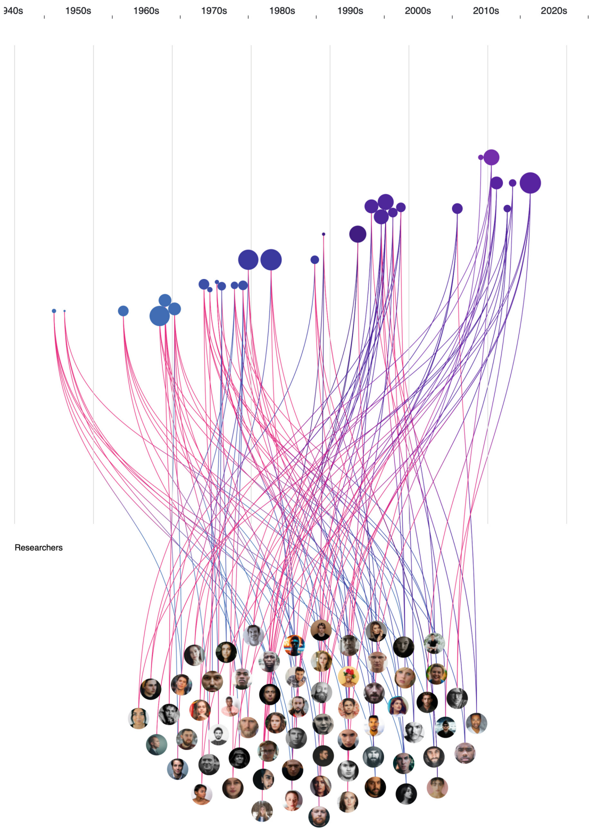

Fig. 1. Time Travel Prototype in D3.js: Clusters on

This section describes the design, implementation and interaction techniques (see Sect. 3.1) of the proposed exploratory Time Travel visualization prototype (see Fig. 1), which will be implemented in a future system/platform according to the scenario described in Sect. 1.1. The Time Travel exploratory visualization is an early-stage prototype and has been implemented in D3.js, an open-source JavaScript library for information visualization and manipulating documents based on data [38]. The visualization conceptualization aimed at supporting a "time travel" navigation was carried out through multiple iterations based on user experience and user interface design methodologies. These iterations have been supported by a focus group: with researchers, visualization, and interaction experts, where no sensitive data was collected. This approach provided guiding advice and evidences for the design of specific tasks, requirements, users profiles and personas, layout design, from early mockups (see Fig. 2) to an early-stage functional protype (see Fig. 1). The aim of Time Travel is to provide researchers with a temporal perspective on the most shared documents in a specific topic and subfield of knowledge (see Sect. 1.1).

The interface layout was divided into three main sections: the bottom section accommodates the researchers; the upper section provides the temporal reference (years and decades); and the middle section displays the shared papers (see Fig. 2). The curved edges/links provide the connections between researchers and papers or between papers and researchers.

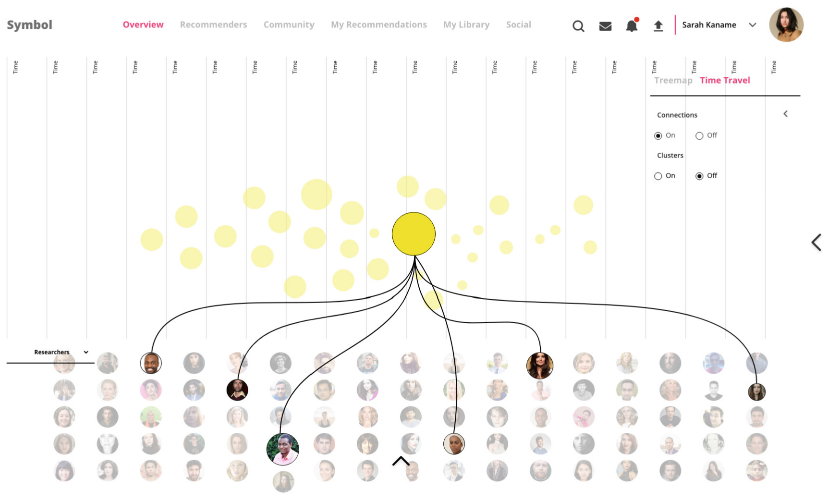

Fig. 2. Time Travel Layout Concept

In the visual encoding strategy, visual marks are used to represent data items, namely circles/nodes and links. Based on a visual abstraction process, the visual mark circle/node is used to represent papers and researchers. Circle size encodes a quantitative variable, namely the number of times a given paper is shared (see dataset), hues and color intensity encode topics, and position the temporal reference. In a future iteration, a weighting factor will be integrated as a quantitative variable, which will act as a constraint between the number of researchers and the number of papers shared. The aim is to avoid/mitigate the visual clutter that can occur as a result of visualizing a high number of links between these two entities. However, a discussion of the weighting factor is beyond the scope of this paper.

A dataset in JSON was fabricated based on the described scenario, where we can find three different entities, namely a standard user profile (personas design), a set of shared papers (scenario) and the links between researchers and papers (network). The entity name of researchers is `person`, the name of papers is `object` and the links between the entities is `links`. A set of attributes defines the three items (ordinal and quantitative variables). For more details, see the dummy dataset in the Observable page. The link can be found at the end of this article.

A beeswarm visualization structure works similarly to a histogram, except it allows individual data points to be displayed. When compared to histograms, beeswarm plots offer several advantages, namely to interpret dense regions by highlighting individual data points within a distribution instead of binning them [39]. Additionally, beeswarms are effective at visualizing data gaps and irregularities. The data is plotted along a singular axis, with points vertically displaced while maintaining their horizontal positions [39]. Each data point is represented by circles, and the data points are placed along the axis based on their corresponding values. Beeswarm charts present various benefits, including clarity by allowing clear observation of individual data points and their distribution, thus simplifying the identification of patterns and outliers [39]. They can also be used for categorical and quantitative data, which makes them versatile for various types of data analysis. For extensive datasets, employing additional techniques, such as grouping or filters, becomes essential as a mitigation strategy for dense layouts [39]. In contrast to simple scatter plots that illustrate the correlation between two numerical variables, beeswarms depict the distribution of an individual numeric measure across either a singular category or multiple categories [39]. Another feature, is to visualize different scales (linear and logarithmic), transitions between scales, and hue or size can add additional dimensions [39].

In the Time Travel layout, the points are nodes of a network, and the relative position of each circle/node is based on D3.js forces[8]. The position of the papers and researchers are defined by the implementation of two force-directed beeswarm algorithms[9], which employs a simulation of physical forces acting on nodes to achieve the intended arrangement without overlapping [39, 40]. The collision force `collide` uses nodes as circles with a given radius, and avoids nodes from overlapping. The `tick` function runs *n* iterations of a force simulation, and on each iteration of the simulation the "tick" function is executed. This function associates the nodes array with circle elements and then adjusts their positions according. The `forceX` and `forceY` induce the movement of elements towards designated position(s). The used forces are based on the following code:

```
//SimulationForce
var simulation = d3.forceSimulation(data.object)
.force('x', d3.forceX((d) => xScale(parseTime(d.date))))
.force('y', d3.forceY((d) => y(d.domain)))
.force('collide', d3.forceCollide(d => d.radius))
.on("tick", tick);
console.log(data)
var simulation1 = d3.forceSimulation(data.person)
.force('forceX', d3.forceX(width / 2).strength(3))
.force('forceY', d3.forceY(height2 + 250).strength(10))
.force('collide', d3.forceCollide(30).strength(1))
.on('tick', ticked)
//ForceSimulation Ticks
function tick() {
svg.selectAll('#circle1')
.attr('class', 'dataPoint')
.data(data.object)
.attr('cx', d => d.x)
```

[8] https://d3js.org/d3-force.

[9] https://observablehq.com/@harrystevens/force-directed-beeswarm.

```
.attr('cy', d => d.y);
}
function ticked() {
svg.selectAll('#circle2')
.data(data.person)
.attr('cx', d => d.x)
.attr('cy', d => d.y);
}
```

The data-driven concept implies that the dataset should have a specific structure [20], namely a relational dataset structure (network) in order to compute and draw the links between the papers and the researchers. As previously mentioned, the dataset network structure encompasses attributes. These attributes make it possible to establish links between `persons` and `objects`. The links have a target attribute and a source attribute, where the target corresponds to the `id` of specific `objects` and the source corresponds to the `id` of specific `persons`. In this way we have a pair of `person` and `object` (bi-partite network). Based on the `ids` of the `object` and `person` nodes, the x/y position of the node in the layout is determined, which is then used to create a vertical link (`path`) by using `d3.linkVertical()`.

Color was used to simplify category identification, and is based on Lch/HCL color space interpolation that is both intuitive and perceptually uniform [49]. The transformation from RGB to Lch/HCL interpolation space, was performed in the Leonardo color webtool[10], and the color scheme was generated in Coolors[11] webtool. A further discussion about the color topic is beyond the scope of the current article.

3.1 Interaction

The process of data interaction, exploration and visual analysis involves the active participation of the user. The aim is that the interaction techniques implemented allow users to effectively analyze and explore the data.

A linear arrangement is characterized by the progression of time moving in a straight line from the past to the future. However, the linear arrangement implemented starts on the most recently shared papers. The main objective is to align with the reasoning inherent in a systematic literature review procedure, in which a time period of five years from the present year is delimited. Thus, the position of the nodes is related to the year of publication of the papers, and the hue represents a specific topic taking into account a knowledge subarea. The timeline interactivity (zoom and pan) is based on code already implemented[12], and the aim is to navigate through the shared papers over a time reference. The panning function enables navigation both backward and forward along the timeline, while zooming provides the capability to focus on specific dates, such as moving between decades and years (see Fig. 3).

The interaction buttons allow users to select a set of functions, namely the grouping function, where nodes are arranged vertically according to specific topics and are

[10] https://leonardocolor.io/#.

[11] https://coolors.co.

[12] https://observablehq.com/@notanaccent/timeline.

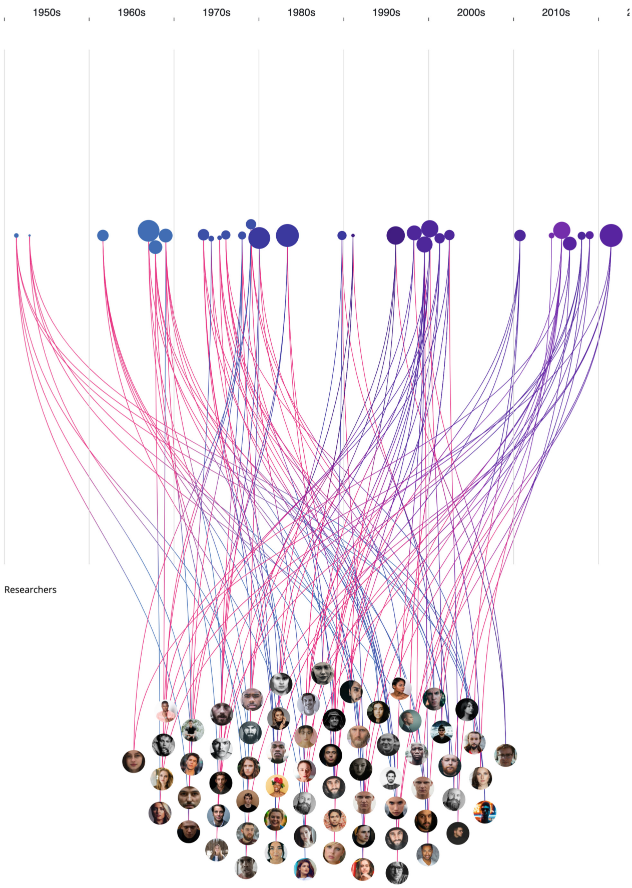

Fig. 3. Interaction Detail: Distribution on

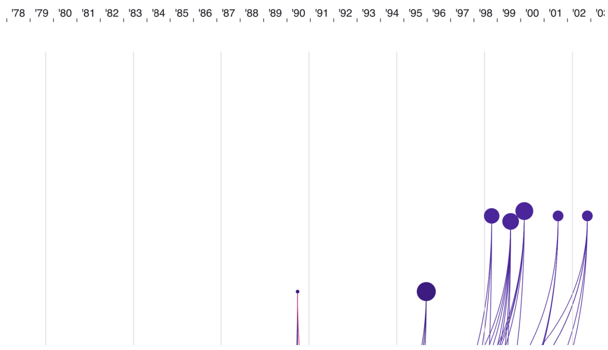

Fig. 4. Zoom and Pan Navigation

distributed over a time reference (see Fig. 4). The distribution button allows users to visualize the horizontal distribution of papers over a time reference (years) (see Fig. 5).

The connection button allows users to enable or disable links between researchers and papers (see Fig. 4). The color gradient aims to convey visual information about the researcher's knowledge domain and the paper's topic.

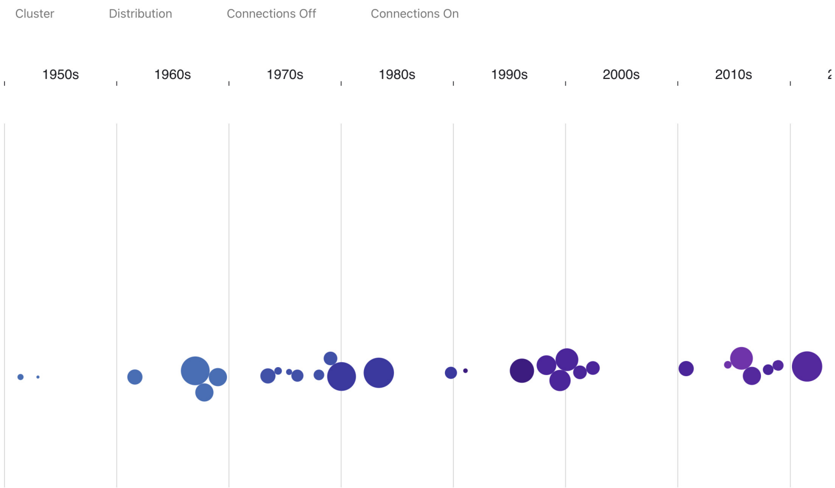

Fig. 5. Buttons: Distribution On

A mouseover event triggers a tooltip/infotip to display detailed information/ metadata related to papers (e.g., Date, Title, DOI among other metadata), and to the researchers (see Fig. 6 and Fig. 7). Another visual feature is the tooltips opacity that is used to prevent users from losing sight of the context (see Fig. 6 and Fig. 7). Opacity with a value of 0.85 was used to make the tooltip translucent.

Another interaction feature is the possibility to individually select researchers and therefore check details/metadata related to their profile (see Fig. 6). Another important technique is to visually " deactivate " the context to reduce visual clutter. This technique makes it possible to focus on a node and its respective links without letting users lose sight of the context, and thereby deliver a seamless and foreseeable user experience during transitions in the interface context. Opacity with a value of 0.85 was used, see Fig. 6.

It is important to note that the buttons (connections on, connections off, distribution and clusters) are not the final design, a new design will be proposed in a future iteration (Fig. 5).

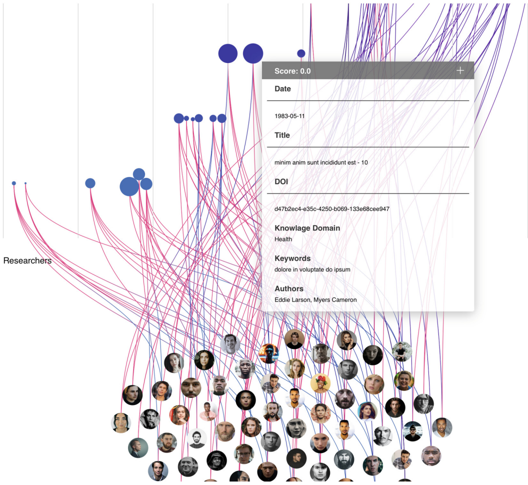

Fig. 6. Papers Metadata Tooltip

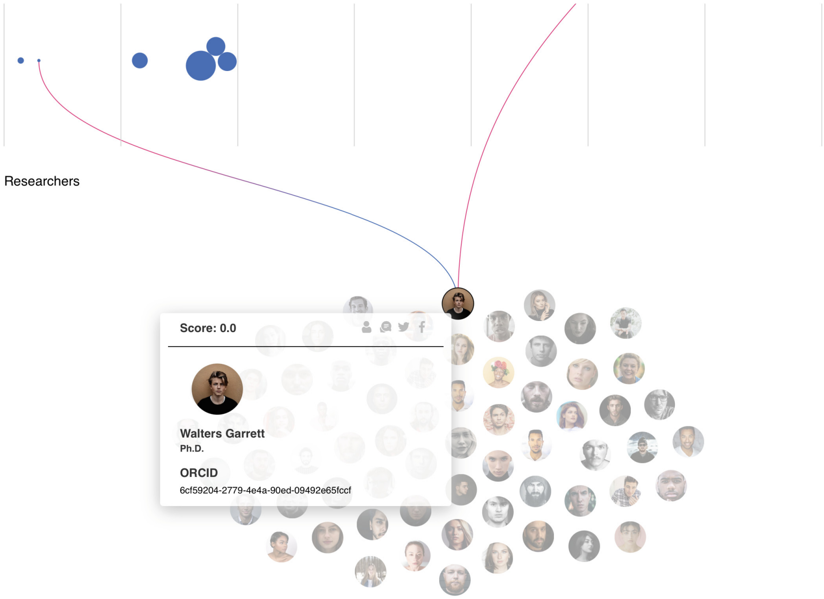

Fig. 7. Researchers Profile Metadata Tooltip

4 Preliminary Results

The main goal of this paper was to describe the designing and implementation of an interactive Time Travel visualization structure in D3.js, given a specific scenario. This section introduces initial findings, covering aspects such as user interface design, interaction techniques, algorithms and implementation strategies.

Section two provided important guidelines and points to some techniques and approaches for visualizing the temporal structure of science, namely the use of linear structures and some important algorithms, such as the beeswarm algorithm. In addition, it was concluded that timelines are a predominant structure used in almost all the projects previous presented. Based on the referenced works, linear representation proves to be the most suitable visual approach to assist the chronological placement of items in a sequential order.

The Time Travel layout strategy was devised through the blending of a timeline, a node-link diagram, and a force-directed beeswarm algorithm. (see Sect. 3). The connections among the nodes involved the transformation of the distribution points into a network of nodes (see dataset on the provided link) and also the work of [7]. The aim was to establish links between two different entities, namely researchers and papers. In order to avoid overlap between nodes, a force-directed beeswarm was used. [41] points out a drawback in this approach, which is its tendency to represent slightly incorrect values in the placement of nodes at the x position. However, this topic needs further exploration.

Succinctly, Time Travel can interactively and aesthetically accommodate a social cooperation behavior based on a curation process that is grounded in the researchers' reading experience through a temporal perspective. Interaction techniques allow users to interact and navigate, but also mitigate visual clutter. Examples of this are the use of buttons to activate or deactivate links, the use of zoom in and zoom out functionalities, as well as panning for linear navigation through sequences of events. While we have preliminary results, the aim is to reveal intriguing patterns of social sharing in a future iteration /increment of the propose visualization structure.

5 Discussion and Future Work

This paper presents a solution to the problem of science information overload. It proposes a temporal visualization that supports and maps a social filtering behavior that already happens on social platforms, but without a visual language and communication logic. Time Travel is an interactive and exploratory visualization that aims to support a collaborative and curatorial process based on the reading experience of researchers. The proposed visualization layout incorporates a set of visualization structures/algorithms, and the aim is to provide an effective visual interface to time exploration/navigation according to a specific scenario. Time Travel remains in its initial prototype stage, and some issues need to be addressed in forthcoming iterations. An existing issue relates to the interaction of zoom and pan and the automatic updating of node placement. Whenever a user engages in zooming or panning, the positions of nodes must be readjusted. This update can be carried out using either the buttons (distribution and cluster buttons) or by refreshing the page. It is through these buttons that the node positions and the aforementioned forces are recalculated. The second issue involves the hue gradient employed within the lines, which is reversed in certain links (See Fig. 3). The purpose of using a gradient between hues is to establish a perceptual connection between the researcher's sub-area of interest and the paper's topic. This issue will be addressed in a future iteration.

There is also room for further research on the proposed visualization, such as the integration of the edge bundling technique in order to reduce visual clutter when a larger number of links are presented. And, it is also important to conduct a user study/assessment based on performance and satisfaction metrics to understand how researchers interact and navigate. The study will be conducted with researchers playing 3 types of roles: beginner level (e.g., PhD students), intermediate level (e.g., postdoctoral researchers) and expert (e.g., established researchers and professors), in a total of 15 testers and according to a set of task scenarios, using the Think Aloud protocol.

As future work, it is intended to design and implement a time visualization perspective from an individual point of view, that is, from the selection of a specific researcher. The objective is to visualize a temporal perspective based on the papers shared by a selected researcher. A cyclic arrangement can be used to carry out other types of analysis, such as visualize time granularities allowing users to discover trends, or low frequency variations in the data, or bursts and other temporal dynamics of papers sharing/ information spreading.

The presented work represents a proof of principle and the current results are still at a preliminary stage, so more research is needed on the main points highlighted. The visualization and code can be found in the following link: https://observablehq.com/d/03f2b04695e9947a.

Acknowledgements. This work has been supported by FCT – Fundação para a Ciência e a Tecnologia within the R&D Units Project Scope: UIDB/00319/2020.

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