

AlmaWorld: Data Visualization to Support International Research Collaborations

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ABSTRACT

Monitoring and evaluating research activities and their results can be intended as initiatives devoted to support universities and research institutes policymakers and governments while enhancing international relationships with colleagues from foreign affiliations. In this context, the integration of data coming from multiple and different sources, as well as the adoption of data visualization techniques can play a strategic role, letting the users browse official and reliable data by means of proper and effective user interface and interaction mechanisms. In this paper, we present AlmaWorld, a web application designed and developed to map the international co-authorships of the professors and the researchers of the University of Bologna, by exploiting two dimensions: the spatial and the temporal ones. The paper presents the approaches we have adopted in the design phase and a prototype we have developed.

CCS CONCEPTS

• **Human-centered computing** → Heat maps; **Information visualization**; *Web-based interaction*; • **Applied computing** → Digital libraries and archives;

KEYWORDS

Data visualization, user-centered design, academic research

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1 INTRODUCTION

Mapping, monitoring, and evaluating research activities and products are supported by the availability of publications repositories and scholarly databases. Such a kind of tools (e.g., Scopus, Web of Science) can provide bibliometric information and information about the authorship of the stored publications. Analyzing these data can provide information about the level of the research production of researchers and professors, in terms of quality and quantity.

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Moreover, other kinds of evaluations and findings can be obtained and discussed, for instance in terms of networks represented by the collaborations among authors coming from different subjects area or among authors affiliated to different universities and institutions or among authors coming from different countries [2, 17, 27]. This would allow to monitor and analyze international relationships in research activities.

International relationships can emerge by mapping and evaluating formal didactical activities (such as Erasmus+, and other exchange programmes), personnel mobility initiatives and programmes, research projects (national and international ones). Since the official nature of this kind of collaborations, it is easy for universities and institutes policymakers and governments mapping and monitoring the international relationships emerged among their departments and centers and other departments and centers from other countries. On the contrary, it is not so trivial having an idea about the amount of more simple and less official collaborations among single research or professor and their foreign colleagues. Such research activities can be witnessed by publications of their findings and results, reported in papers published in conference proceedings or in articles published in scientific journals. These publications are gathered and stored in repositories and scholarly databases, that often offered proper APIs to access and exploit their data, guaranteeing the trustworthiness and the official nature of the collected data [20].

In this paper, we present AlmaWorld, a system based on Web scraping mechanisms and on data visualization techniques, we have designed and developed to monitor and interact with data about international collaborations among researches. The dataset is built by integrating data collected from different sources (i.e., different repositories and scholarly databases). In particular, a prototype has been studied and implemented, by taking into account all the professors and researchers of the University of Bologna, fed and updated by means of Web scraping mechanisms, while it integrates datasets coming from Scopus and Web of Science thank to the APIs they make available. The paper describes the approaches we have adopted to collect data about the international relationships, on the basis of co-authorships with colleagues coming from foreign affiliation, and to design and develop a web application that lets users browse the data. In particular, we have adopted user-centered design methodologies [6, 7, 24] and data visualization techniques [14, 15, 23] so as to provide the information by exploiting two specific dimensions: the spatial [13] and the temporal ones.

The remainder of this paper is organized as follows. Section II presents main related work, focusing on projects about the representation of spatio-temporal data with data visualization techniques. Section 3 describes our approach and the data sources. Section IV

provides an overview of our system, while Section V presents the main functionalities of a prototype we developed. Finally, Section V concludes the paper with some final remarks and future work.

2 BACKGROUND AND RELATED WORK

The representation of spatio-temporal data with Data Visualization techniques has been faced under different perspectives according to the context of study examined. Some previous projects present similarities regarding the solution adopted, but they are based on completely different topics, while others offer exciting ideas which are not applicable to the domain analyzed.

An interesting idea derives from the project by Shapiro and Pearman [26], which uses the dynamic visualization environment, called Interaction Geography Slicer (IGS), to support the analysis and public discussion about the New York City's Stop & Frisk Program. This work represents the number of frisks carried out against suspected citizens, based on a spatial and temporal subdivision of data, characterized by the geographical area of citizen's origin. Therefore, there is a dual view showing in a first geographic map of the New York's city the spatial subdivision of the data by category, while a second adjacent graph distributes these data in a time-line with a characteristic of density. The problem of visualization is relevant, as data on international relations could also be represented in this way. However, the categorical subdivision is off topic with respect to the project's requirements since it is not required to display the data in a fractional way by associating a color to each department.

The work of Boyandin et al. [3], Flowstrates, defines an interactive visualization approach based on the use of heat maps. The goal is to represent existing flows of entities between two locations over time. In this case is shown the amount of people's flows entering and leaving certain countries in a certain year, associating a different color gradient based on the quantity. The origin and destination of the flows are shown in two different maps separated by a central graph, which shows the time filter always using color gradients. Considering a single representation instead of the flow, this visualization can be compared to that of the AlmaWorld project, where the temporal component is represented by a textual filter.

In the medical context, there are several projects that present patients' temporal data through graphs, to ensure a better management of cares by the doctors. TimeSpan, by Loorak et al. [11], is an exploratory visualization tool representing the temporal aspects of the stroke therapy process. The dataset used presents multidimensional data in addition to the temporal data, which are grouped in a single view from the complex comprehension in case the application domain is not known. The visualization includes histograms and line graphs that could be used individually for AlmaWorld, but the overall context is so peculiar that this complete visualization can't be used in different fields.

Other works that can be compared with the project examined come from the urban area context, showing data about several aspects in terms of spatial and temporal dimensions, enriched by gamification elements to better involve users [12, 19, 21, 22, 25]. SURV [10] is a framework for creating interactive maps and dynamic visualizations, realized with HTML, CSS, and JavaScript libraries. The general nature of the system allows to represent any type of spatio-temporal data, through animations in a heat map. In

the example, GPS data of taxicabs are shown, but the system could also be exploited so as to report data about international relationships. The component that is currently missing in AlmaWorld is the one related to the animations, which could still be considered by displaying the sequence of several years' subsequent collaboration. TelCoVis [28] is an interactive visual analysis system based on telco data to explore co-occurrence in human mobility, as people who visit an urban location at the same time. One of the proposed visualizations shows a heat map about mobility in the nearby of the points of interest, allowing analysts to identify interesting patterns. Although in this case the data have a different domain, the analogy with our work can be found considering professors and researchers who collaborate with an institutional entity (spatial feature) in a certain year (temporal feature). Voila [5] is a visual analysis system for detecting anomalies in spatio-temporal data. The system uses a heat map that focuses the user's attention on the regions of interest, by means of visual color signals. This work is based on a specific use case where a security agent exploits the system with the aim of detecting accidents in the urban scenario and then intervening accordingly. In a different context, AlmaWorld also allows administrative employees to make decisions, following the visualization of the amount of international relations in certain countries rather than others.

Regarding the context of study under consideration, e.g. the international collaborations of a university (in terms of international co-authorship), this topic has been already considered first by Rodríguez et al. [17] and then by Toral et al. [27] in 2011. Although the solutions adopted to show the results were different, these projects mainly consisted in the analysis of the relations held by the Spanish and the English universities respectively. The affinity with our work is mainly based on the analysis of the impact of universities' external collaborations while supporting and increasing the internationalization of scientific production. The differences are related to the data set considered and how the results were represented. In our work, we only consider the publications of the University of Bologna that give rise to international relations, therefore in which there is at least one author affiliated to the University of Bologna and one to a foreign (i.e., non-Italian) university, while these works retrieved the publications with co-authors coming from all the universities, also other national entities. On the one hand, from this point of view, AlmaWorld seems more peculiar, while, on the other hand, it does not limit the publications to a certain temporal interval, nor it does consider the only Web Of Science database. At the current state, only Scopus publications are considered, but the integration of publications from Web of Science is under development. Finally, in such projects, the results are not shown by means of a heat map (based on the countries or regional entities, just like in [13]), but through a graph. Here, each node represents a university or institution and the edges a collaboration between them, while the size of the node determines the amount of the collaborations carried out.

The work of Asiwal et al. [2] is similar to AlmaWorld, since it considers the collaborations of researchers from a single university. Instead of showing international relations, the goal of this work is to support looking for partners for new collaboration. For this reason, it has not been considered the geographic aspect and the affiliation of the co-authors, but only their research areas that in

AlmaWorld are represented by the filters by department or area. As for the previously described projects, the representation is done by graph (weighed and not), visualizations which are not suitable for our case, because it does not take into account the spatial and geographic dimension. With a goal similar to the encouragement of international relations, the project by Park et al. [18] wants to evaluate the relations between China and Korea in 2014, followed by the government program to stimulate relations between the two states. The work involved the publications in the Web of Science and the result was visualized by means of a graph.

In summary, the work presented in this article is based on previous research and it integrates a study context not widely developed, using a resolution that has been found to be predominant in other research areas for the visualization of spatio-temporal data. Furthermore, the existing structure allows us to consider a future development that handles multi-source data, thus defining a problem that has not yet been evaluated.

3 APPROACH AND DATA SOURCES

Our approach is based on the analysis of all the scientific publications authored by professors and researchers of the University of Bologna together with colleagues affiliated with foreign universities. In this way, it is possible to extrapolate interesting information about international relationships, such as the amount of foreign relationships with different research professionals and academic professors, the countries and, cities where more collaborations take place, how much every single professor collaborates with foreign researchers, and the number of collaborations of a specific department.

Since the information has to be irrefutable, our dataset has to be retrieved from reliable and certified sources. For this reason, we considered different scholarly databases. First of all, we evaluated Web of Science and Scopus, two of the most well-known and widely used reference databases in the scientific community. Web of Science¹ (previously known as Web of Knowledge), is maintained by Clarivate Analytics. It is built on the top of multiple databases that reference cross-disciplinary researches. It provides free and premium APIs. In the premium version, it is possible to retrieve information about publications. Web of Science has been the only scholarly database until the introduction of Scopus, in 2004.

Scopus² is the Elsevier's abstract and citation database. It was born thanks to the Elsevier's two years collaboration with librarians and researchers from all over the globe [4]. It provides free APIs that allow to collect data about publications, authors, and their relative affiliations.

We also considered scholarly databases of two of the most important technology companies in the world, Google, and Microsoft that have developed respectively Google Scholar and Microsoft Academic. Google Scholar³, released in 2004, is a free web search engine that allows to access the full text or only the meta-data of scholarly literature. A recent study [8] highlights how it is constantly expanding its coverage, but it is still difficult to use as a sole

bibliometric source since it lacks quality control and clear indexing guidelines. Thus, it does not provide official APIs.

Microsoft Academic⁴ is a free web search engine for academic publications and literature. Such a system, launched in 2016, replaces its predecessor Microsoft Academic Search, since its development ended in 2012. It provided the Academic Knowledge APIs that allow information retrieval through the use of REST endpoints. Harzing and Alakangas, in their study [9], compared the publications and citations coverage of Microsoft Academic with respect to the three previous systems mentioned above and they concluded that this last one is undeniably growing and it is quite mature to play a role in the field of research evaluation.

The last data source we have taken into account in our analysis is Dimensions [1], a scholarly database developed by Digital Science in collaboration with other research organizations. It collects data about publications, categorized as articles, proceedings, chapters, monographs, and preprints. Moreover, it also gathers information about grants, patents, and clinical trials data. It provides also a freemium API, called DimensionsMetricsAPI, but it allows also to get data only about a specific publication and its relative metrics.

In the first prototype of the system we have designed and developed, we have decided to retrieve data from two different data sources, Scopus and Web of Science. Among the main factors that have driven our choice, there are the maturity of such scholarly databases, their main role in the research evaluation and the availability of standard APIs they provide.

The main steps at the basis of our approach are:

- Get the list of all the professors and researchers of the University of Bologna.
- For each professor, get the list of his/her publications co-authored with one colleague affiliated to a foreign institute.
- Collect and visualize such information in a web application letting the user browse and monitor them, considering both temporal and geographic dimensions.

4 SYSTEM OVERVIEW

This section presents an overview of our system architecture. The main components of our system are shown in Figure 1.

A first and central component in such an architecture is represented by a script that collects data from the University of Bologna web site and from the publications sources we have identified (Scopus and Web of Science). This represents a data collector fed by the data of professors and researchers of the University of Bologna listed in the address book that can be browsed in the official web site and by the data that can be provided by means of the Scopus and Web of Science APIs. This means that data can be kept up to date, by running our script everyday, considering the data already collected and downloading only the new one, in terms of new University of Bologna personnel and in terms of new publications.

It is worth mentioning that the University of Bologna does not provide an API to collect information about affiliated professors and researchers. Hence, we have created an ad-hoc script to gather such kinds of information from the address book website of the University, by means of web scraping techniques. On the other side, both Scopus and Web of Science provide proper APIs to collect

¹<http://www.webofknowledge.com/>

²<https://www.scopus.com>

³<https://scholar.google.it/>

⁴<https://labs.cognitive.microsoft.com/en-us/project-academic-knowledge>

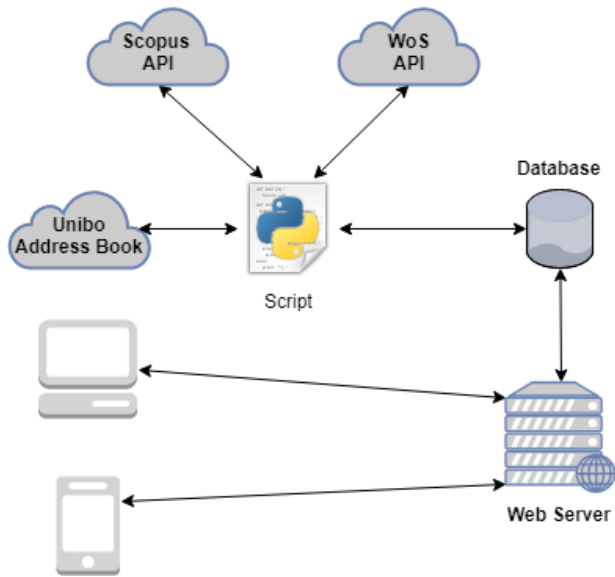


Figure 1: AlmaWorld System Architecture

information about publications. All the collected data about authors and publications are stored in a database. Since they have a well-defined structure we chose to use a relational database, instead of a noSQL one (just like MongoDB, as an example).

On the server side, our web application can let the users browse the data about the publications of the professors and the researchers of the University of Bologna, by exploiting data visualization techniques. We have designed and developed such a web application on the basis of the responsive design principles (so that the web pages are rendered in a suitable way, regardless of the device type and the screen size), by applying a user-centered design, involving target users in focus groups and experience prototyping activities during the design phase [16].

We adopted a user-centered design approach in order to detect in the early stage of the project which visualizations could be effective and useful. We involved possible target users of such system, in particular the Vice Rector for International Relations of the University of Bologna and her staff, together with personnel from the International Relations Division. We took advantage of different Human Computer Interaction techniques, such as mock-ups, focus groups, and interviews. At the end of the design phase, we decided to mainly exploit two different visualizations: (i) a heat map, to visualize data by exploiting and highlighting the spatial dimension (see an example in Figure 2); in this kind of visualization, in order to analyze both the spatial and temporal dimension together, the web application interaction system is equipped with a filter on the year of the publications; (ii) histograms and pie charts, to better show the temporal dimension (see an example in Figure 3); in particular, it will be used to show the number of scientific contributions published by a specific professor or researcher over time.

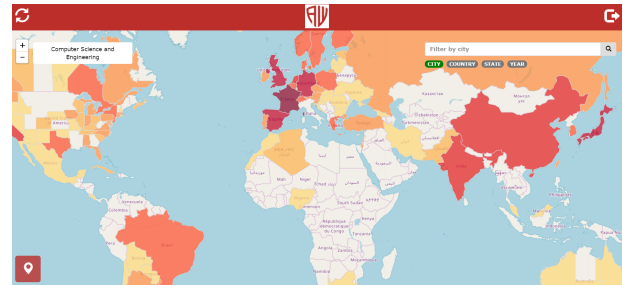


Figure 2: Heat Map, a screenshot of our AlmaWorld prototype

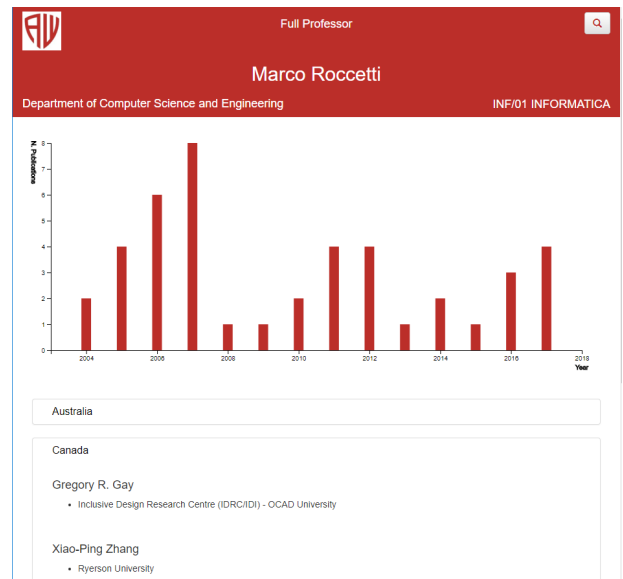


Figure 3: Author's international co-authorship over time: a screenshot of our AlmaWorld prototype

5 ALMAWORLD PROTOTYPE

This section is devoted to the description of details related to the implementation of our AlmaWorld prototype.

We developed a first prototype of AlmaWorld that has been deployed on a Linux server. The script that collects the data and adds them in the database has been developed in Python. In particular, we exploited the *Requests*⁵ to handle HTTP requests and *Beautiful Soup*⁶ (a Python library that allows to manage HTTP response not as plain text but replicating the DOM structure). We chose MySQL as the relational DBMS. The script is in charge of cleaning and integrating data collected from the APIs of Scopus and Web of Science before inserting them into the database.

With regard to the web application, we adopted the LAMP stack. We used CakePHP⁷, a PHP framework that offers a flexible database

⁵<http://docs.python-requests.org/en/master/>

⁶<https://www.crummy.com/software/BeautifulSoup/bs4/doc/>

⁷<https://cakephp.org/>

access layer and a powerful scaffolding system, supporting developers while building both small and complex systems. We exploited the use of Bootstrap as front-end library and of several Javascript libraries that include Leaflet⁸ (for the heat map development) and D3⁹ (for data visualizations and charts).

The main functionalities provided by the system, and the related visualizations, are the following ones:

- Search the international relationships maintained by a specific professor or researcher of the University of Bologna through his/her name and surname. The web application shows a histogram of the number of the publications with at least co-author with an international affiliation, per year, together with the list of foreign co-authors group by country, as reported in Figure 3.
- Monitor the amount of international collaborations in a political map. The web application shows a heat map in which the color of the different countries (and states or provinces for some specific countries, such as Australia, Canada, and USA) has a different gradient based on the number of publications. It is possible to apply filters in order to select a specific department (among all the departments of the University of Bologna) or research area (among scientific, technological, medical, humanistic, and social ones), country, state or province, city, or year. A screenshot of the heat map, showing data filtered on the basis of the Computer Science and Engineering department is depicted in Figure 2.
- Search the international relationships in a given country, state/province, or city. By clicking on a country or on a state/province, the web application shows all the universities or research centers of the co-authors placed there. Then, by clicking on the "Details of all relations" link, a pop-up appears. It shows the list of professors and researchers of the University of Bologna who has authored publications together with colleagues with affiliations in such a city or country. For each one of them, details are reported, such as name, last name, and affiliation. On this results visualization, some filters allow to group such information in different ways, such as by Foreign affiliation. Thus, it is possible to export the visualized information in a PDF file, by clicking on the button in the left-bottom of the page. Figure 4 depicts a screenshot of an example of such results visualization, showing researchers and professors having co-authored publications with colleagues from Boelter Hall - Los Angeles (hosting the University of California, Los Angeles, UCLA).
- Visualize the international relationships in the city where the user is currently. To activate this function, the user has to click on the button in the left-bottom of the page when the map is shown, as visible in Figure 5. The user's position is geo-localized through the use of Google Maps APIs. Then, it is possible to see the list of all the institutes closed to the user's position, hosting at least one of the co-authors of any professor or researcher of the University of Bologna.

Currently, we have conducted some usability tests by involving some target users, with the aim of evaluating the effectiveness of

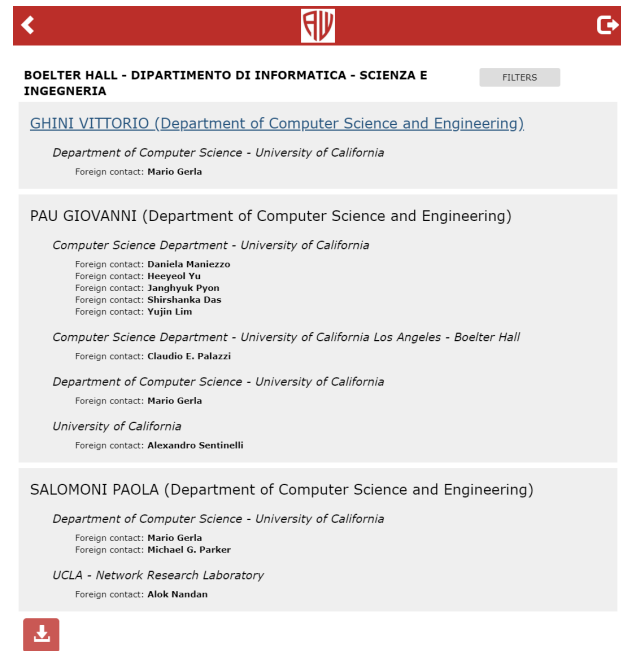


Figure 4: A results visualization of relationships with colleagues affiliated in Universities and research institutes placed the city of Boelter Hall - Los Angeles

the interface and of the interaction mechanisms we have developed, showing the feasibility of our approach and the appreciation from the testers. A more extensive evaluation campaign should be planned and conducted so as to assess the effectiveness of the data visualization strategies we have applied in our prototype. A long-term evaluation will concretely prove if monitoring activities by means of our system would really support stakeholders and policymakers in improving and promoting international relationships and collaborations.

6 CONCLUSION

This paper presents AlmaWorld, a web application prototype which aims to support policymakers in monitoring and promoting international relationships and collaborations among scientific and academic researchers. We have designed and developed a prototype on the basis of the data of researchers and professors of the University of Bologna, allowing users to browse among their international relationships, gotten from well-known publications repositories Scopus and Web of Science, according to their co-authorship.

Several future works can be envisaged. An interesting one is the integration of dataset coming from other repositories, such as PubMed, Google Scholar, and Microsoft Academic. Another one is devoted to the investigation of a feasible solution which could effectively include data related to researches in the fields of humanities. In fact, Scopus and Web of Science mainly store publications related to scientific, medical, and technological areas of research. In this sense, our prototype underrates the international relationships among researchers and professors in humanities and social sciences.

⁸<https://leafletjs.com/>

⁹<https://d3js.org/>

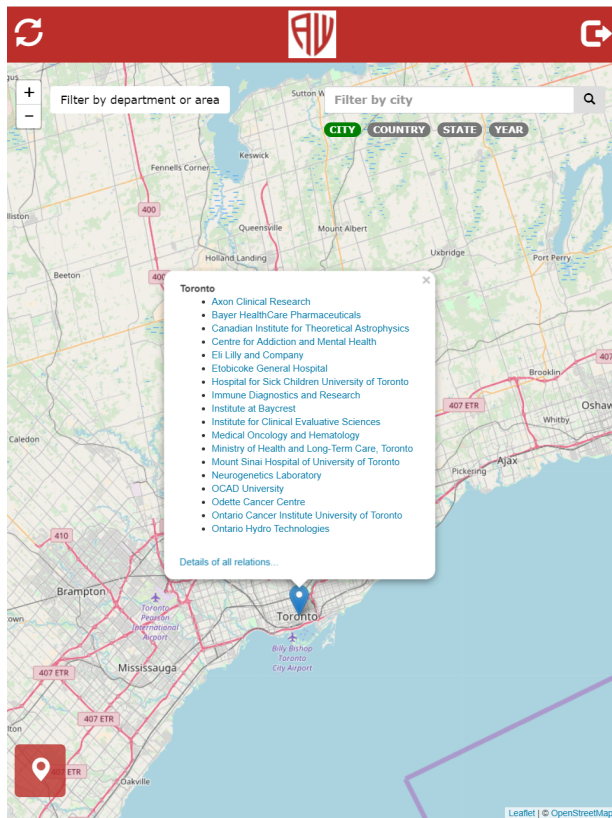


Figure 5: A screenshot of an example of user's position functionality

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