A Design Study of Visualizing Historical Book Movement

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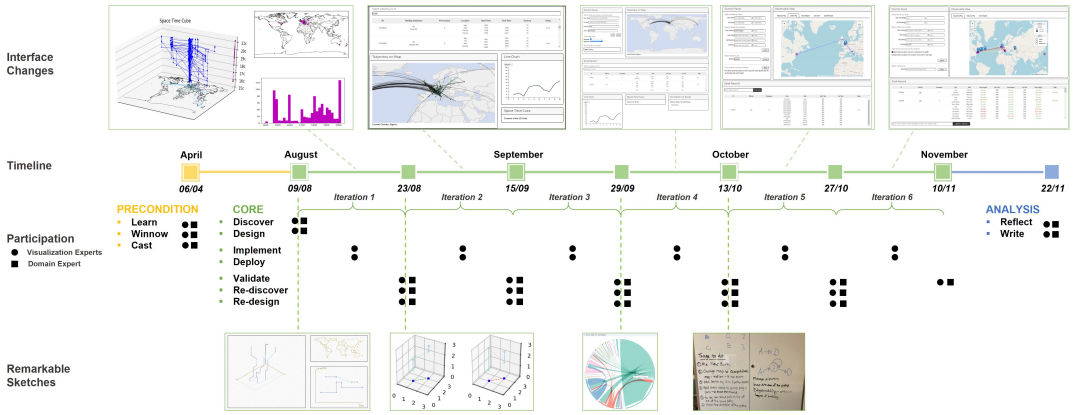

Figure 1: *The timeline of the iterative design process of the* BookTracker *using the 'Nine-Stage Framework' [SMM12].*

Abstract

Trading of 15th-century books is an area of great interest to historians. In this paper, we document the process behind an intensive design study and close collaboration with a domain expert on understanding crucial historical research questions, together with the result of the design study – BookTracker*, a tool for mining and visualizing circulation and movement of the 15th-century book trade. The main contribution includes a summary of insights from the design study and* BookTracker*, a web application supporting historians in: (i) query-based search of user-defined path sequences, and (ii) analysis of the movement of the resulting user-defined path sequences through multiple visualization techniques. We discuss and summarize the value and logistics of conducting this design study, which could become generalizable lessons for the visualization design methodology.*

1. Introduction

Visualizing 15th-century book movement is an interesting and challenging problem. In a time when there are no FedEx, Amazon, or an easy mode of transportation, thousands of books moved across continents, spanning over centuries, and to finally where they are now. These books bear witness to their movement in their manuscript annotations, decoration, and binding styles, and to be able to capture their movements in terms of both spatial and temporal factors could unveil answers to research questions for historians. Tracking the movement of a version of a book in the era of big data may be simple, but for historical books, it is not straightforward. Thanks to the 15cBOOKTRADE [Don21] and the MEI [CER15], which integrates databases related to historical manuscripts, we can obtain historical book data with complete provenance records. The access and availability of such records is an invaluable resource for historians, however available analytical tools do not cater well for this type of data where both spatial and temporal dimensions are crucial. This challenge forms the motivation behind our design study.

The main contribution of our design study is *BookTracker* – an application supporting historians in: (i) query-based search of user-defined path sequences; and (ii) analysis of the movement of the resulting user-defined path sequences. We approach the development through a seven-month iterative design process with a domain expert, following the 'Nine-Stage Framework' [SMM12]. In this paper, we document our design study, summarizing and visualizing the differences between our practice and the 'Nine-Stage Framework'. We report on the insights obtained from conducting the design study in the humanities domain, to make them generalizable lessons for the visualization design methodology.

The remainder of this paper is organized as follows: In Section 2, we introduce domain background and data of the project. In Section 3, we discuss related work in spatio-temporal visualization, design studies in humanities, and related projects on historical data and book trade. In Section 4, we describe the iterative design process of *BookTracker*. In Section 5, we summarize the findings and logistics of conducting a design study with an intensive collaboration with a historian. In Section 6, we discuss our conclusions.

2. Domain Background and Data

15cBOOKTRADE [Don21] assesses the impact of the first 50 years of the European printing revolution (1450-1500) on the development of European society transitioning from the medieval to the early modern period. It uses 15th-century printed books, half a million of which still survive today in libraries mainly in Europe and the United States, as historical evidence. The evidence allows scholars to reconstruct the history of each book, its 'life', or

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provenance, from the time it was printed, to the time it enters the current holding [Don13]. MEI [CER15] is a result of 15cBOOKTRADE, which integrates pieces of 15^{th}-century book records into one database, and represents the movement of books over their 500 years as blocks of provenance. MEI has been developed to provide a physical representation of the circulation of books throughout the centuries. It gathers evidence of the distribution, sale, acquisition, and use of thousands of surviving 15^{th}-century printed books. MEI is hosted and maintained by the Consortium of European Research Libraries (CERL). The 15cBOOKTRADE supported redevelopment of the data structure which made MEI capable of holding the records which it is poised to collect, as well as fully interoperable with the other digital applications of the data and with the other digital resources for the study of incunabula, ISTC, and GW.

Our domain expert is the Secretary of CERL, and also the Principal Investigator of the 15cBOOKTRADE, and the creator of the MEI. Based on her experience, she recommended us a set of data in the MEI that may have research value to them. Therefore, *BookTracker* is developed using MEI [CER15] records entered for the Polonsky Foundation Dante Project. An illustrated copy census of all the 173 surviving copies of the first Florentine edition of Dante's Commedia, printed in 1481. This edition was chosen as it was complete.

3. Related Work

3.1. Map-Based Visualizations on Spatio-Temporal Data

The COVID-19 pandemic has boosted research on visualizing trajectories with the need for virus traceability [LLZ*20, SE21]. Research has been done to trace the dynamic movement of vehicles [SGB19, HZM*15] or the movement of population migration [RVN*17, SH05, LD16] through a map-based visualization. Evaluation and comparisons were made between the 3D and 2D models by Kjiellin et al. [KPSL08]. Kraak [Kra03] and Tominski et al. [TSAA12] demonstrated that 3D models such as space-time cube and stacking-based visualizations are preferred for visualizing geographical temporal features and displaying multiple paths. Previous works on visualizations of spatio-temporal data [SE21, AAG00, SZM14] were also reviewed and explored.

3.2. Design Studies in the Humanities Domain

Sedlmair et al. [SMM12] presented the 'Nine-Stage Framework' which provides guidelines for conducting a design study. Lam et al. [LTM17] introduced methods for bridging goals and tasks in a design study, providing guidelines to obtain reflections from the conduct of a design study. Munzner [Mun09] summarized a nested model for the design and validation of visualizations. Bradley et al. [BEAC*18] and Benito et al. [BSS20] gave a general introduction of visualization for the digital humanities. Lam et al. [LBI*11] reviewed studies in information visualization and carried out seven scenarios as a conclusion. The challenge of evaluation was summarized by Plaisant [Pla04]. Lamqaddam et al. [LMA*20] presented a framework to help reduce the semantic distance of visualization in the humanities. We also reviewed papers that conduct design studies in but not limited to the humanities domains [HMSA08, HQG*17, ARLC*13, ZCD18, NGCL18, BISM14, EBJ*21].

3.3. Historical Data and Book Trade Related Projects

Driven by the digitization of cultural heritage (CH) collections, projects such as HathiTrust [HAT21] have emerged. Windhager et al. [WFS*19] conducted a survey on visualization approaches to CH collections. Previous works that shared common interests with historical book analysis were reviewed. Both Peripleo [SIBdSC16] and ArtVis [DMTS14] presented the spatio-temporal historical data through a scatterplot-based visualization without showing a sequential path. Visualizations of the Republic of Letters [CGS*09, EFC*17] managed to present the circulation of correspondence, but focused more on presenting the total number of letter exchanges rather than the story of a single record. Regarding historical book trade, 'The Atlas of Early Printing' [PHS21] is a tool that presents the spread of printing and typography, and trade routes. 15cVISUALIZATION attempted to present the movement of each book using Cartesian diagrams. But it is no longer available.

4. Iterative Design Process

We carried out a design study with intensive collaboration with a domain expert for seven months. Comparing with other methodologies, the 'Nine-Stage Framework' [SMM12] presented more comprehensive guidelines from the precondition stage to the analysis stage in a design study. The iterative dynamics process was consistent with the intensive collaboration with the domain expert as we envisioned. As it can be generalized to multiple domains, we intended to explore what is noteworthy when applying it to the design study in humanities. Therefore, our design study was conducted based on the 'Nine-Stage Framework' with six iterations of the core phase. Meetings were held biweekly to discuss with the domain expert the prototype for inward facing validation and evaluation. In the seven months, we have conducted nine formal discussion meetings with our domain expert where each meeting lasted no less than an hour. In addition to formal discussions, there were countless email exchanges. Through this constant communication, we hoped to bridge the understanding gap between us and the domain expert. We recorded in detail the development history of *BookTracker* – from its inception to its present stage – and at each stage of our project, the corresponding phases in the 'Nine-Stage Framework' are marked. Figure 1 showed the history of the project, as well as the changes in the interface after each iteration.

4.1. The Precondition Phase

Our project began in April 2021, when we approached our domain expert about a collaboration using MEI [CER15]. The integration of MEI promoted by our collaborator has brought opportunities to their research area. But such a large amount of data also caused problems to them. From our discussion, we determined these domain goals and tasks for *BookTracker*: 1) to show the movement of a single book; 2) to show the movement of a group of books; 3) to quantity and visualize the early distribution of books; and 4) a static visualization of where the books were in history and today.

4.2. The Core Phase

In each iteration, every two meetings denoted a cycle node of *discover–design–implement–deploy*. At each meeting, our domain

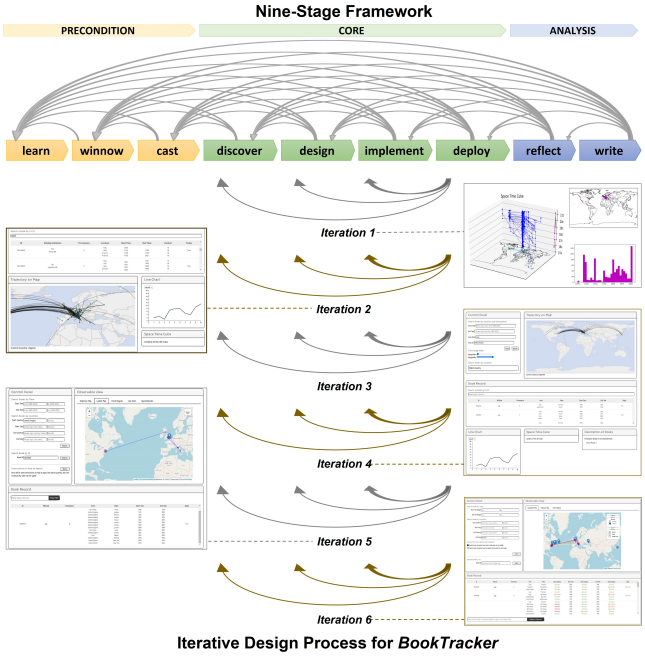

Figure 2: *The recursive validation described in [SMM12] and the iterative process in our design study displayed for comparison. Interface changes in each epoch of iterations are visualized (full resolution image available in Supplementary Material).*

expert evaluated the prototype, and together we continuously revised the task abstraction, the visualization design, and the data retrieval method. The changes reflected in *BookTracker*'s interface were recorded in Figure 1 in chronological order.

Iteration 1 After the initial meeting, the domain background, data, and tasks were established. Based on the characteristics of spatio-temporal data, our visualization experts proposed to start with the Space-Time Cube [Kra03]. Together with the domain expert, we scratched a multi-view interface with the main observation view of a Space-Time Cube. Later, a rotatable Space-Time Cube was presented for evaluation. The feedback received was that the 3D model was difficult to understand and more focus was needed on the movement of the books in their geographical location. The time axis in the Space-Time Cube was confusing: " *I found the Space-Time Cube did not provide such clarity. At first glance, I could not understand what I needed to understand from it. In theory, it allows a manifestation of both space and time, but in reality, it is difficult to 'look' at the two dimensions as they unravel in the Space-Time Cube.* " The domain expert emphasized the need of visualizing the geographic movement of books rather than their temporal features. Based on the feedback, we changed our approach to the 2D map, visualizing temporal features through the sequential path.

Iteration 2 After a re-discover and re-design, a 2D Trajectory Map was implemented. This caused a complete change in the interface. Compared to the 3D Space-Time Cube, the domain expert preferred the 2D Trajectory Map for its clarity and ease of understanding. During the evaluation, the domain expert suggested a new domain task of visualizing the import and export of books in various places without considering the temporality of the provenance. From here, the visualization experts decided to test out the Chord Diagram [RLBD20] as a possible solution.

Iteration 3 The Chord Diagram was implemented in this iteration. The domain expert was able to see the potentials of this visual design in answering certain historical questions, such as: "*How many books were used in Italy in the 15th-century later moved to the UK / US?*" However, the Chord Diagram was hard to integrate with the existing prototype as its focus was not aligned with the identified goals. Based on this, both sides agreed to leave the problem for future work. So far, the main visualization and the domain tasks have been finalized. The visualization experts began the design of the Control Panel and the retrieval of book records from the database.

Iteration 4 A significant change of the interface was the Control Panel where four main components were used to filter records with provenance satisfying a specific search query: a start time with a location pair and an end time with a location pair. The domain expert was full of praise of the Control Panel as before they did not have a tool that could accurately retrieve all eligible book records using a time and location pair. We integrated the Control Panel with the temporal nature of the data in *BookTracker*. Although the design of the Control Panel was an improvement, there was still inaccuracy in the data retrieval algorithm. The domain expert also emphasized the importance of using a detailed geopolitical map.

Iteration 5 The database retrieval was changed where the time range is used for searching. By indicating the time range for the start and end points, certain groups of records would be filtered. This improvement was useful in analyzing a specific domain problem that was discussed previously: " *Which books left Italy during the period 1700-1900? This is a period with historical events causing closing down religious libraries in Italy and a massive number of books being sold.* " The base map was also changed to Leaflet due to its geopolitical naming capability. At this stage, all the domain tasks can be satisfied, but the prototype was still lacking usability and interactivity. During testing, the domain expert reiterated the significance of distribution and circulation of books and suggested that the tool would be more useful if we could filter arbitrary continuous provenances in book records, rather than the whole circulation. To achieve this, major changes were needed in the data retrieval algorithms. After an intense brainstorming with the domain expert, the best searching algorithm was decided.

Iteration 6 Interactive designs were added and a new searching algorithm was implemented. Although there were many changes to the back-end, only one button was added. Upon receiving good feedback, *BookTracker* was then deployed at `https://booktracker-v1-11192021.herokuapp.com/`.

4.3. The Analysis Phase

We reviewed the whole design study process and summarized all the meeting notes. We visualized our execution process and compared it with the 'Nine-Stage Framework' [SMM12] in Figure 2. We also had an in-depth exchange with the domain expert, asking about her feelings about the collaboration, as well as the bottlenecks and difficulties encountered. Based on this evidence, we summarized insights that could be generalized for similar projects.

5. Reflection

5.1. Notes From the Domain Expert

As a historian, our domain expert thinks this is a satisfying and rewarding collaboration. We quote her narrative here: "*I was very satisfied with the collaborative experience with the team of computer scientists/data visualization researchers. I have some experience in collaborating with engineers, and I have always found it a very stimulating and rewarding experience.*" She mentioned that the experience of talking to engineers, like the experience of talking to the general public, has been enhancing her ability to explain her research. She thinks that one of her qualities, developed over time in a collaborative and interdisciplinary environment, is to be able to clearly explain the type of data and the objectives of her research. In her opinion, "digital humanities" as a term of reference cannot be embodied by individuals but must be understood as the close collaboration of experienced humanities scholars and scientists of different specialization, dictated by the final common goal. In this collaboration and dialogue, clarity is an essential quality.

Reviewing the seven months collaboration, she found the hardest point was to explain that in the visualization of the book movement, the important part is not the trajectory from the printing place to its current location, but what happens in the middle, the journey. The identification of the data about the journey is valuable but at times difficult to pinpoint due to uncertainty or missing information, these data however make MEI unique. Our domain expert is also very satisfied with the output *BookTracker*: "*The* BookTracker *successfully captures and quantifies the amount of movement (something the database captures but does not quantify numerically). The visualization on a scalable map is very clear.*"

5.2. Notes From Computer Scientists

Over the seven months of collaboration, we finalized *BookTracker* as an application which would meet the requirements identified either at the beginning or raised/redefined during the iterative process. We traversed several challenges to reach the current results. Those tough times prompted important adjustments to *BookTracker* in both the front-end and the back-end implementations.

The first adjustment took place soon after we obtained the data. We initially consider both spatial and temporal dimensions of the data holistically. Starting from the historians' interest in inspecting trajectories we suggested a Space-Time cube. The proposal however met resistance from the domain expert who found the 3D visual layout unfamiliar, difficult to understand, and not being able to digest both time and map in a single visualization. We soon realized that we had overestimated the historians' acceptance of novel visualizations. They are relatively more conservative and with a preference towards adding interactivity to more traditional visualizations. Our design was then converted from the original Space-Time Cube to a 2D geopolitical map. Therefore, when proposing Chord Diagram and Edge Bundling to our domain expert, we spent longer time paving the way. Although still leaning towards traditional methods, her acceptance of novelty had gradually increased.

We iterated at the design of the Control Panel and the record retrieval algorithm due to: 1) the different interpretations of terminologies between us and the domain expert which caused some misunderstandings; and 2) during the testing phases the domain expert would make new discoveries which in turn generated new demands. The 'Nine-Stage Framework' plays a high level role in guiding and instructing our design study. We show our design process in Figures 1 and 2. Compared with the structure of 'Nine-Stage Framework', our validation process is not as evenly distributed. Our process has six iterations in the core phase (Figure 2), which lead to a denser cluster of iterations than the other two phases.

5.3. Summary of Insights

Insight 1 The historians tend to be conservative. Their attitude towards novelty may affect the evaluation result on a new approach. We recommend familiarising the domain experts with novel visual layouts through several design iterations rather than presenting them directly. Slowing down the pace to raise their acceptance gradually. This will expand the possibility of having new attempts in the cross-disciplinary cooperation. The propensity of domain experts towards exploring novel visualizations will provide possibilities for the development of new techniques in various domains.

Insight 2 It is important to maintain regular, frequent, and uninterrupted exchanges and communication with domain experts. The full understanding of both parties can prevent some useless work from happening, but also save time and manpower costs.

Insight 3 New domain-relevant tasks, raised by domain experts during the testing of the tool, should be encouraged. These are likely to become new entry points of communication or new features of the tool, helping the integration of visualization technology within the specialists' domain. Real data should also be used whenever possible during development, for domain experts to experience the advantages of using visualization with their specific data across each validation and testing iteration.

Insight 4 Guidelines for conducting design studies with different natures should be adjusted according to their characteristics. Unnecessary loops of iterations should be dropped, and the number of iterations and validations in important stages need to be increased.

6. Conclusions and Future Work

This paper presents a design study on the development of *BookTracker*, an application aimed at supporting historians in mining and visualizing the circulation and movement of the 15^{th}-century book trade. *BookTracker* is the result of a close collaboration with a domain expert for over seven months. The main contribution of this paper is twofold. Firstly, a summary of insights gathered from the collaboration and a design study following the 'Nine-Stage Framework' [SMM12]. Secondly, the *BookTracker* application, enabling historians to: (i) search for path sequences based on user-defined queries; (ii) analyze the movement of the resulting path sequences through multiple visualization techniques. The future work will be: (i) testing the prototype and conducting systematic evaluation with a wider user base for more generalizable insights; (ii) focusing on the contribution of new visualizations, exploring more advanced techniques to reduce visual clutter, such as Edge-Bundling.

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