Enhanced Family Tree: Evolving Research and Expression

Best Paper Award

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ABSTRACT

Enhanced Family Tree reimagines the possibilities of family trees with an evolving series of exhibits. The authors' works combine genealogical data, visualization, 3D technologies and interactivity to explore and display ancient genealogical relationships. Their new approach may reveal questionable relationships in genealogical records. Moreover, the authors' use of an organic metaphor of a "tree" can be further extended to increase public understanding and engagement. The audience's questions arising from this project show increased curiosity and nuanced questioning about their own family origins and development.

The work we describe in this article began from our search for massive family trees and evolved into better presenting them to the public. As more genealogical data is being made public and data visualization technology continues to improve, so does the prospect of visualizing ancient relationships. We believe that the possibilities of these family trees, to convey information to both researchers and the public, have not been fully realized.

The structure of a family tree is used in many cultures to represent family relationships by means of a node-link diagram. However, in visualization research, some have been skeptical about the ability of node-link diagrams to show readable maps of many data points: "We expected the readability of node-link diagrams to deteriorate when the size of the graph and its link density increase. This hypothesis was confirmed for the seven tasks we selected" [1].

As thousands of family members are densely packed into a diagram, the structure becomes complex to the point of not being able to see the relationships between individual family members. Some researchers have looked beyond family trees to other, newer forms of visualization [2]. However, our work suggests new approaches to effectively visualize large-scale genealogical data with family trees. Furthermore, one visualization approach we developed has an additional advantage for researchers: It can lead to discovery of questionable points in the data, as seen in the case study of Wang Ruan below.

Trees can be used for artistic expression of large-scale genealogical data. At SIGGRAPH 2007, Korean artist Jin Wan Park mapped his own family tree, or *jokbo*, a project that he said "has some functional features but does not have a clear purpose except expression itself" [3]. Park further claimed his work "can be seen as a successful application of techniques for the intuitive understanding of large datasets." The author sought an intuitive visual metaphor, creating a work that is "visually similar to an 'annual ring' of a tree, a representation which entirely makes sense."

We see further opportunities for intuition to be used for expression so that the public can rapidly understand the meaning of genealogical data. A comparative study contrasting the more mechanical node-link diagram with an organic tree design reveals that while the organic design was "the most appealing and intuitive for casual users," the node-link diagram could "better present complex relations" [4]. Our work unites the strengths of the two approaches, furthering the traditionally used node-link diagram with visual metaphors including branching, growth and leaves. By furthering the near-universal metaphor for family relationships in an organic way, we are able to help people intuitively use their previous experience of trees to discover family relations in an aesthetically pleasing form.

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Enhanced Historical Research

As we began our search for massive family trees, we asked ourselves, where could we find reliable census data? There is no centralized collection of information on ancient families in China. Fortunately, one historian's long-term contribution helped us. Early in his career, Robert M. Hartwell, a professor from the University of Chicago, began compiling large datasets of Chinese historical data. Hartwell, aided by his wife and many students, expanded the project and, upon his death in 1996, the database was bequeathed to the Harvard-Yenching Institute. Now known as the China Biographical Database (CBDB), the project contains historical materials, literary works, official documents and other forms of records on historical citizens in ancient China. The bulk of the records focus on people in the seventh to nineteenth centuries and, as of April 2019, includes 427,000 people [5]. A collaborator of Hartwell has noted, "Hartwell's aim was to take advantage of precisely those kinds of reliable data that the Chinese historical record provides in such abundance" [6]. Early on we decided to keep all of the original data, including the errors, so that historians could gain an accurate view of the state of the data. (Our data processing methods are described in a previous publication [7].) Hartwell's contribution gave us abundant and reliable data. We would have the chance to explore ancient history in a massive forest of family trees.

While the previous research we had encountered was skeptical of the ability of family trees to display large-scale data, we found an effective workaround by using the Reingold-Tilford algorithm, which can display dense hierarchical information in a tidy way. Each individual with the same surname is displayed by a node, with a link between nodes indicating a parent-child relationship. Generations of family members begin from the oldest at the bottom, with branches that stretch up to the newer descendants. The resulting visualization gives the overview of the Zhang family tree shown in Fig. 1. In this figure, we can observe data concentrated in several historical eras, particularly the Tang, Song, Ming and Qing dynasties. Other families in the CBDB mostly follow this trend, usually with an information gap between the dynasties.

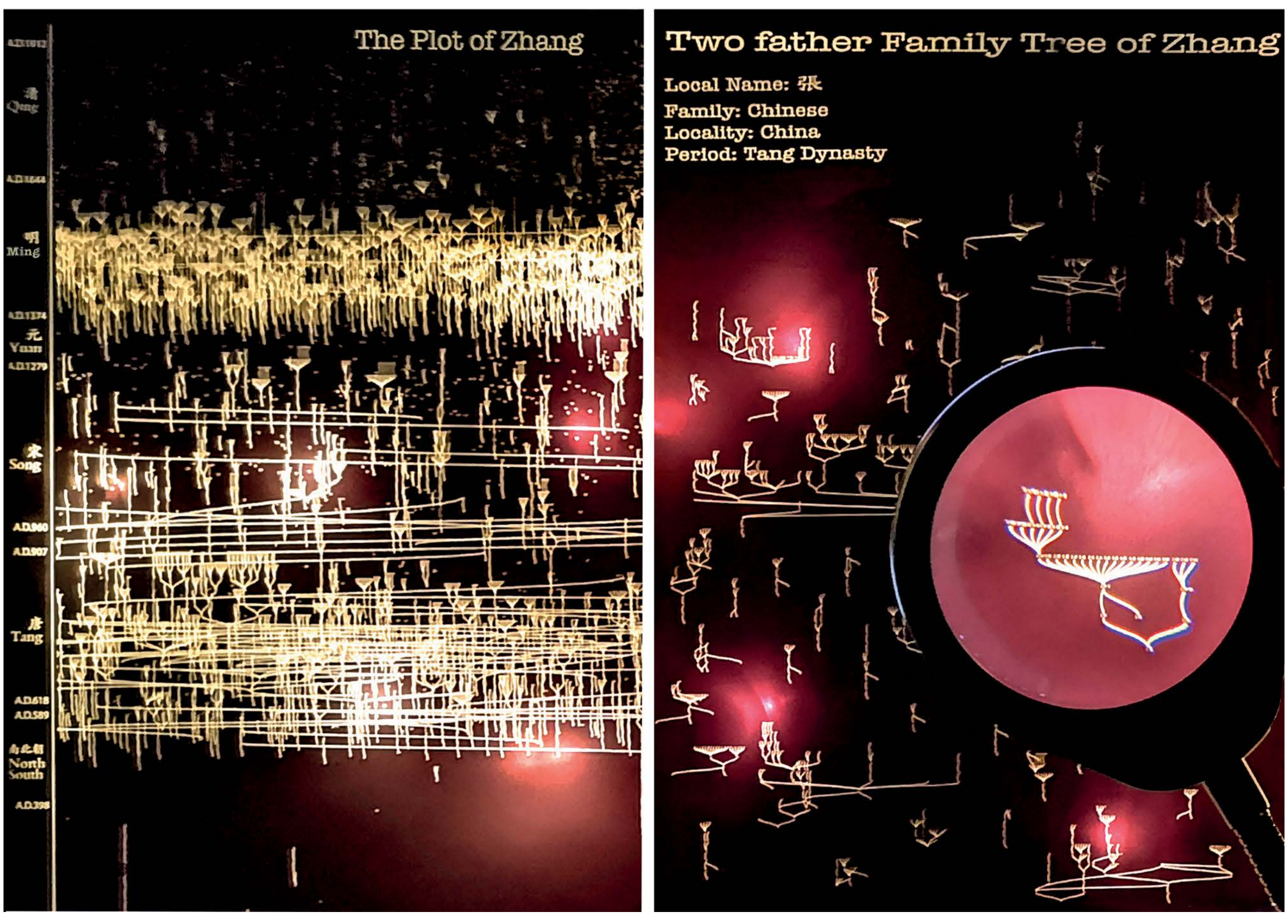

Fig. 1. (left) Overview of the Zhang family tree. (right) "One child with multiple fathers" as it appears in the Zhang family tree. Installation at the IEEE VIS 2018 Arts Program, Berlin. 60 × 30 cm. (© Fan Xiang. Photo © Yi Liu, 2018.)

The result of our visualization was far from what we expected. We can observe that the Zhang family name does not form a whole tree, but rather is a small forest of family trees. There were no large-scale family trees to be seen, and especially problematic were the messy horizontal lines that cluttered the view. Upon investigation, we discovered that the majority of the disorderly lines from the Tang and Song dynasties were caused by a biologically impossible phenomenon, "one child, multiple fathers" circumstances. That is to say that the Reingold-Tilford algorithm was insufficient for the data. The algorithm works by having each parent node horizontally centered between its child nodes. When multiple fathers for one child are present, one or more of the fathers cannot be horizontally balanced; instead, longer lines connect those fathers to the child from a distance. Lines connecting two distant families are formed, producing long horizontal lines across the screen. This disorderly line phenomenon also occurs in the *jokbo* example, but the artist, Jin Wan Park, does not explain it in depth. We observed that cases of "one child, multiple fathers" appeared for all of the last names of families we investigated. What could have caused this impossible phenomenon?

Looking at case studies, we found that there are many different "one child, multiple fathers" situations. Sometimes multiple people in one family tree are entirely grafted into another family. Occasionally multiple fathers have similar names. In other cases, the multiple fathers share the same names. We guessed that the original documents had recording errors, or that there were errors in data entry. We found the Reingold-Tilford algorithm inappropriate for the flawed CBDB data. However, from our investigation, we find that the Reingold-Tilford algorithm exposes the errors in the data, as its visualizations allow us to see quite clearly the flawed information that had been buried in the database. Our visualization technique might provide evidence of controversial relationships that historians were previously unaware of.

Applied Case Study

Using the technique described in the previous section, we also exposed errors in the Wang family tree. We found reason to question the lineage of Wang Ruan, a poet in the Southern Song dynasty. We then used historical documentation to examine the reason for the "one child, many fathers" family trees. Wang Ruan's father, grandfathers and ancestors were people of distinction. Wang Ruan was proud of his ancestors and often wrote of his family in poetry [8]. By examining his poetry, we found evidence for our skepticism about his lineage: In an earlier article, we describe documents about his paternal ancestors, as well as the identity of his siblings, that conflict with one another [9]. However, doubts about Wang Ruan's family ancestry have never been mentioned by scholars. When Wang Ruan's family tree is compared with further historical information, historians may be able to develop a new understanding of Wang Ruan and his works. We think that this visualization method combined with a comparison of literature could be usefully applied to further historical research.

Evolving Exhibition Design

Interest in history is not limited to historians. The near-universal appearance of family trees in genealogy books across cultures lends credence to the supposition that family trees are intuitively understandable to public audiences. We kept asking ourselves how the visual metaphor of a tree could be extended to enhance perception of genealogical information. In the first generation of our project (described below), we used an herbarium as our metaphor; we then extended the trees into 3D (in the second and third generations); and finally, in the fourth generation, we enhanced the metaphor by using motion and growth in an immersive environment. After each exhibition, the reactions of different audiences inspired us to improve the next generation.

Generation 1: Graphic Display as an Exposure on X-ray Film

In the IEEE VIS 2018 Arts Program, we exhibited family trees as X-ray film plots with backlighting. We intended on giving the audience a clinical and detached feeling, and by displaying the visualizations on X-ray film we hoped that the audience would have a sense of viewing the exposed insides of family histories. By presenting the trees on 2D plates, and adjusting the spacing of the branches manually so their structure could be more accurately understood, the family trees seemed exhibited in a kind of herbarium.

Generation 2: 3D Trees in Crystal Cubes for Hand-Held Observation

One intuitively understandable feature of physical trees, which we saw as having potential to enhance accessibility, is that they exist in three dimensions. Our approach to 3D tree generation was inspired by the visualization research work Cone Tree. Cone Tree presented large-scale information hierarchies "in 3D to maximize effective use of available screen space" [10]. However, we found that the generated trees with straight branches had little similarity to living objects.

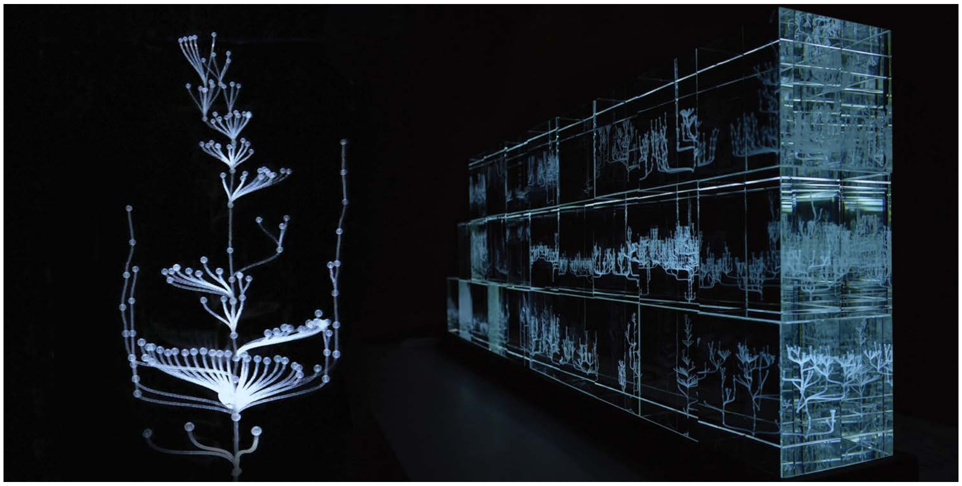

Fig. 2. (left) Detail of the Ming dynasty royal family in laser-etched crystal cubes, 10 × 10 × 10 cm. (right) Crystal cubes of family trees. (© Fan Xiang. Photo © Yi Liu, 2019.)

In terms of visual appearance, our previous visuals had been generated computationally and their appearance was too mechanical to be appealing to public audiences. We chose to add rhythmic displacement to the nodes in the horizontal direction, to keep an accurate depiction of the data in the Z index while also bending the branches. The resulting visualization appears to be more of a tree-like object. In Fig. 2 we see that the stretching branches give the impression of constant tension and energy. The shapes of the family trees often revealed dramatic stories. The royal family tree of the Ming dynasty has very short branches, which look as if they were manually trimmed (Fig. 2, left). In fact, they may have been. At the base of the tree we can the see many children branching out from Zhu Yuan Zhang, the first emperor of the Ming dynasty. However, most of the branches have no continuation; this may raise questions for the audience, as it did for us. "Was the shape caused by internal fighting?" "Was there a large step-down of the descendants in social status?" "Did the descendants have no children?" We can contrast this with the Song dynasty family tree, which has a more natural appearance of abundant and full branches (Fig. 3).

Generation 3: 3D-Rendering Experiments and Discoveries

For the Art and Science International Exhibition at the National Museum of China, we created various styles of family trees with rendering software. In the process of rendering, we often contemplated the large-scale family trees we had discovered. The largest tree was a family of the last name Hu that included 7,615 individuals in 44 generations over 1,031 years (903–1935 CE). While we had correctly expected the royal trees to be of gigantic proportion, we were surprised at how large some of the nonroyal families were. Their tree shapes often told a dramatic history. Once the 24 large-scale family trees we found had been rendered, we saw that many of the nonroyal families had impressive long-term expansions (Fig. 4). We asked ourselves, "How could this family have survived so many years? Why did they flourish for so long and then suddenly disappear?"

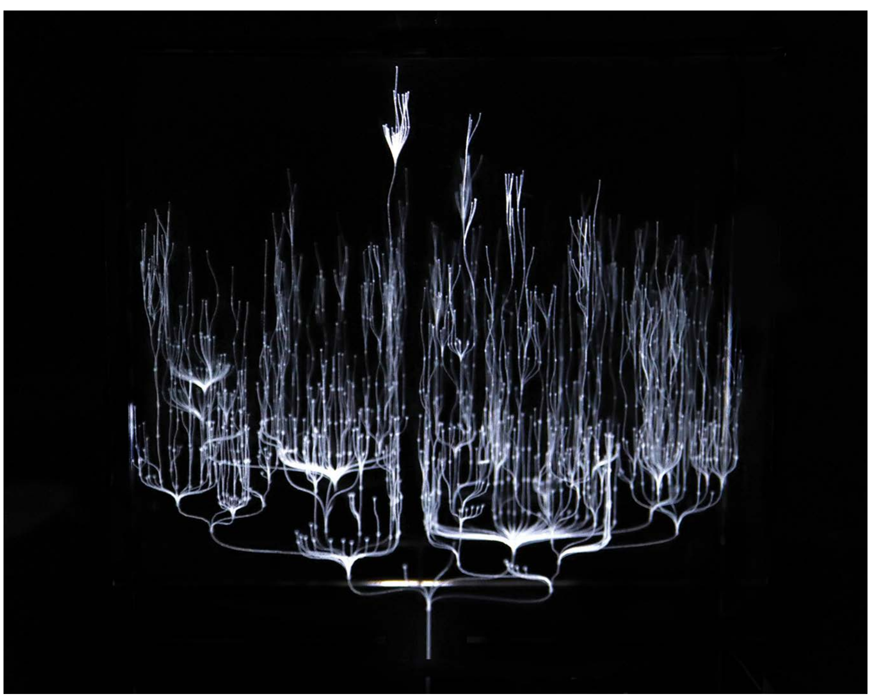

Fig. 3. The Song dynasty royal family in laser-etched crystal, 20 × 20 × 10 cm. (© Fan Xiang. Photo © Yi Liu, 2019.)

As we observed the visualizations from a distance, many questions came to mind. For instance, when observing the shape of Wang Qian's tree (Fig. 5) we asked ourselves "why was there a short spurt of growth?" This "short-lived" tree consisted of 312 individuals over 383 years. We again look to family history literature to answer our questions.

In historical records we found that the family included many high-ranking officials, all the way until the final descendants. It is not hard to imagine how a politically powerful family could have had a sudden downfall at the end of

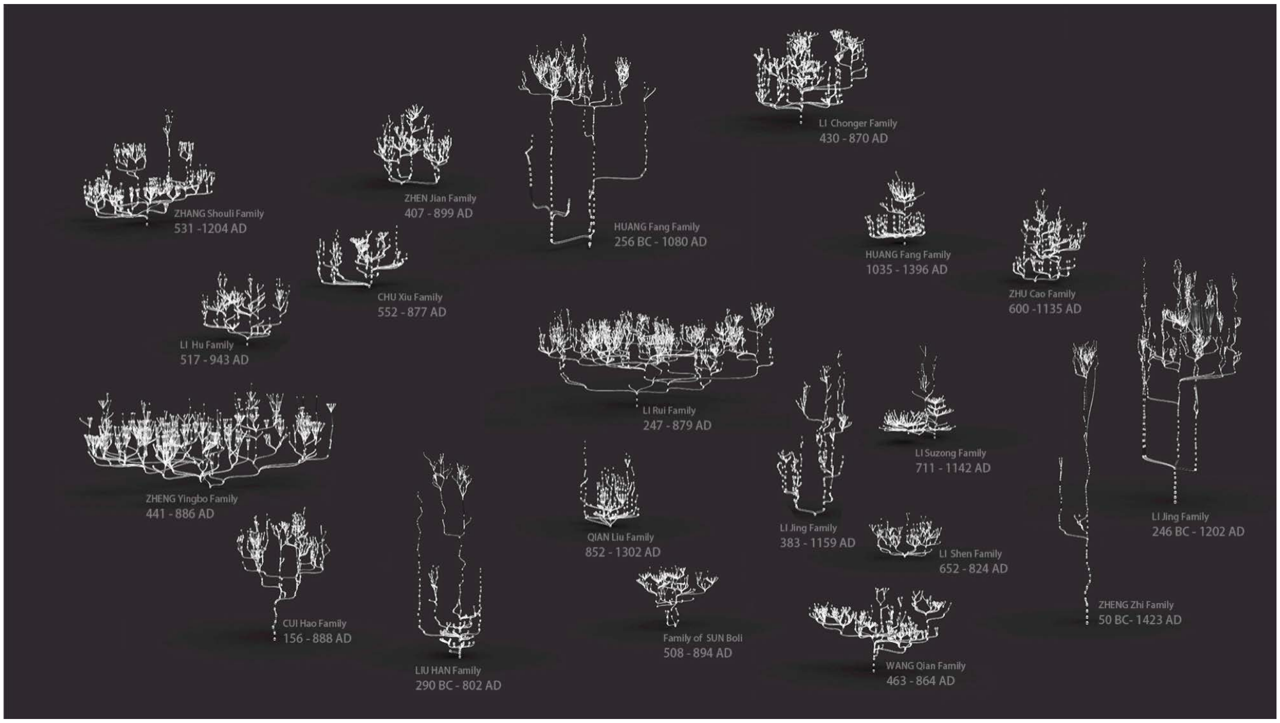

Fig. 4. Twenty large-scale nonroyal families rendered in Maya. (© 2019 Fan Xiang)

a dynasty. Stepping back and observing the Wang Qian family among the many longer-lived family trees (Fig. 4), how has our awareness of time in family histories changed?

Generation 4: Interactive Family Tree Forest Installation

As a space for exploration, a forest is always suitable for storytelling. At the exhibition *Mirror & State*, in our installation *Ancient Chinese Family Forest* (Figs 6,7), we built a family forest using the Unity Gaming Engine, connected to the processed data from the CBDB. Upon entering the space, visitors saw the overview of a family forest, which was projected on a 40-foot-wide screen. They watched thousand-year-old family trees grow before their eyes.

Visitors could enter their last names into a tablet interface, which would then display all persons with family histories relating to their name. After the user chooses the name of a particular person on the tablet, the projected view on the wall shifts to that person's family tree and zooms to the node representing that person. Next, a family tree is generated that begins with the selected person and grows upwardly node by node to all of their descendants. In Fig. 6 we can see a visitor interacting with the tablet. Visitors could also control the angle and position of the visual projected on the wall with tablet-based navigation.

Engagement was further increased by a more intuitively understandable graphic; we furthered the visual metaphor of growth by having the

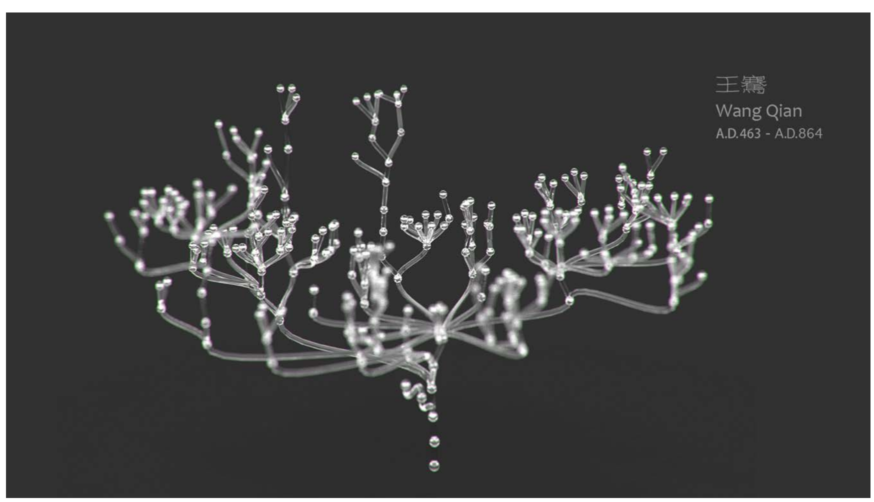

Fig. 5. The Wang Qian family tree rendered in Maya. (© Fan Xiang, 2019)

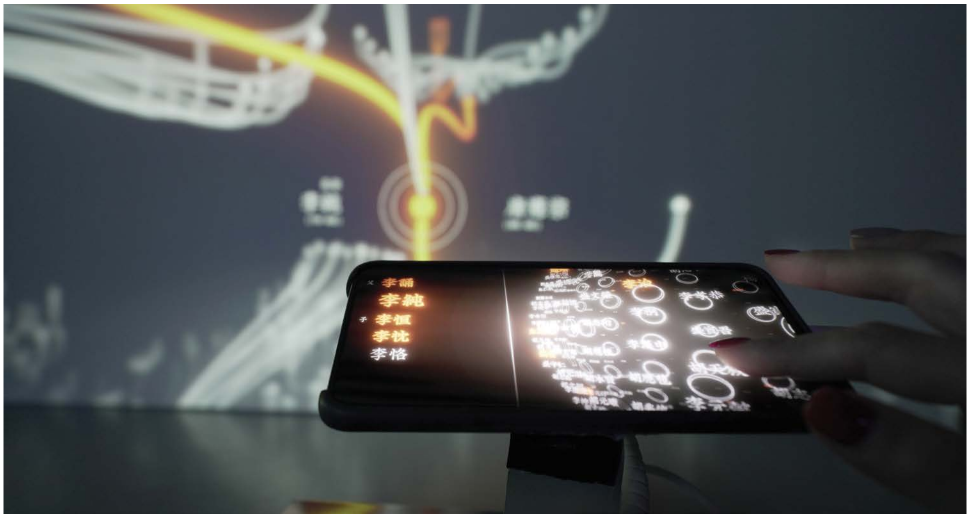

Fig. 6. The *Ancient Chinese Family Forest* installation interface in use at the *Mirror & State* exhibition, Beijing, 2019. (© Fan Xiang. Photo © Yi Liu, 2019.)

3D trees expand as they near the present. Golden colors indicate royal lineage, adding intrigue to some data.

We found that our audience was more engaged with this generation of our work than previous generations' audiences had been. Parents talked about Chinese history with their kids, young people took souvenir photos and adults tried to find their families in the forest. We heard intriguing questions from viewers. "Can I find myself in the trees?" "Why can't I add a link on the trees for myself?" By observing the audience asking questions about the works, we were led not only to think about new design approaches, but also to the practical and ethical dilemmas of future works.

From the IEEE VIS 2018 Arts Program's X-ray film printing, to the Milan Triennial's Crystal Cubes, to the National Museum of China's 3D model rendering, to the *Mirror & State* exhibition, our representation of ancient family relationships has steadily evolved. And we continue to explore how it might evolve further in the future. For example, it

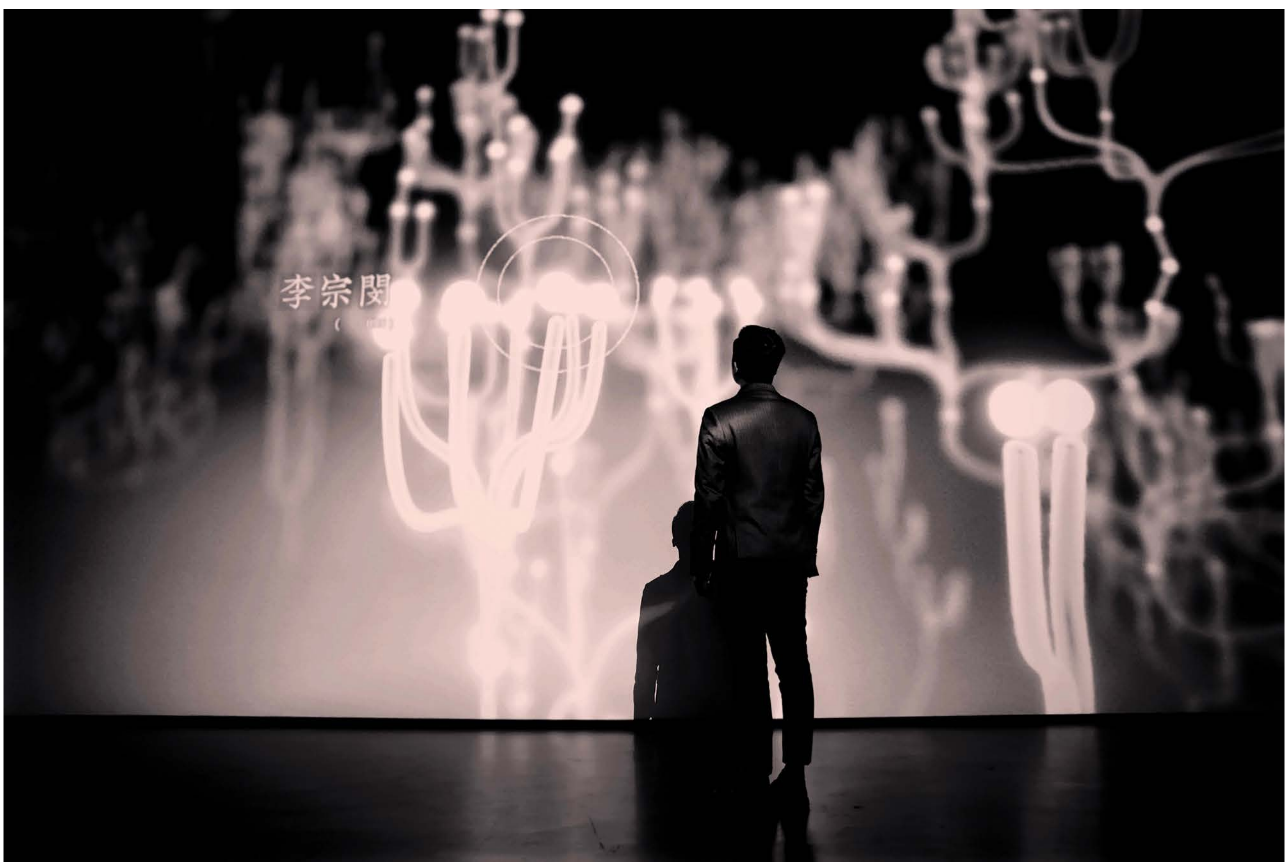

Fig. 7. The *Ancient Chinese Family Forest* installation wall space, 12 × 4 m, *Mirror & State* exhibition, Beijing, 2019. (© Fan Xiang. Photo © Yi Liu, 2019.)

would be possible to create a virtual family forest that would allow audiences to explore and trace back ancestries using virtual reality. And, beyond applying new technology or extending the data, we can further enhance the next generation of family trees by taking user feedback into consideration.

User Feedback

In response to our work, we received a variety of responses from viewers that expanded our sense of the possibilities of the family tree.

Harvard professor Peter Bol, the director of the CBDB, advised us to show individuals' social connections as well as their kinship connections. Social connections in ancient China were crucial, and the CBDB contains large quantities of social connection data.

One family historian/researcher from the Chinese Academy of Social Sciences asked if we could develop software that would allow them to detect controversial relationships in their database. This was a direct response to seeing the usefulness of applying the Reingold-Tilford algorithm to visualize conflicting information.

From the various visitors at our exhibitions, we received a broad range of questions. "Can you provide a service that lets me generate my family tree from my genealogy book?" In response to the crystal cube work, someone exclaimed, "How can an emperor have 20 kids?" We think these questions could foster an interest in history and, moreover, that a desire to find answers to these questions could be a motivation for historical study.

Conclusion

We have reported a progressive series of visualizations that we created to explore different ways complicated family histories could be communicated. Our project was iterated in many aspects: dimensions, material, scale, media and interaction. Each generation of the project led to different visual experiences and discoveries in the massive dataset of family histories. For historians, new forms of visualization may help them observe and discover questionable aspects of the data. More broadly, visualization that has an intriguing form can pique the interest of audiences so that historical lessons can be learned by a wider community. Our organic metaphor approach to expression could be further extended to create immersive narratives for museums and historians.

References and Notes

1. M. Ghoniem, J.D. Fekete and P. Castagliola, "On the Readability of Graphs Using Node-Link and Matrix-Based Representations: A Controlled Experiment and Statistical Analysis," *Information Visualization* **4**, No. 2, 114–135 (2005).
2. A. Bezerianos et al., "GeneaQuilts: A System for Exploring Large Genealogies," *IEEE Transactions on Visualization and Computer Graphics* **16**, No. 6, 1073–1081 (2010).
3. J.W. Park, "Information Aesthetics with Visual Genealogy Project," *Leonardo* **44**, No. 5, 464–465 (2011).
4. T. Fung, J. Chou and K. Ma, "A Design Study of Personal Bibliographic Data Visualization," *IEEE Pacific Visualization Symposium* (2016) pp. 244–248.
5. Harvard University, Academia Sinica and Peking University, "China Biographical Database Project": https://projects.iq.harvard .edu/cbdb (accessed 28 May 2019).
6. B. Peter, "The Late Robert M. Hartwell," *Chinese Historical Studies Ltd. Software Project* (1999): projects.iq.harvard.edu/files/cbdb /files/the_late_robert_m._hartwell_chinese_historical_studies_ltd._software_project.pdf (accessed 9 April 2020).
7. F. Xiang and S. Zhu, "中国家谱树的绘制实验报告 Experimental Report Visualizing Chinese Family Trees," 装饰 *Zhuangshi* **10** (2018) pp. 90–93.
8. K. Wang, "南宋诗人王阮生平事迹考 Investigation into the Southern Song Poet Wang Ruan's Life," 长江学术 *Yangtze River Academic* **2** (2009) pp. 137–144.
9. Xiang and Zhu [7] p. 92.
10. G.G. Robertson, J.D. Mackinlay and S.K. Card, "Cone Trees: Animated 3D Visualizations of Hierarchical Information," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (1991) pp. 189–194.