Visualization Design - Mathematician’s Genealogy

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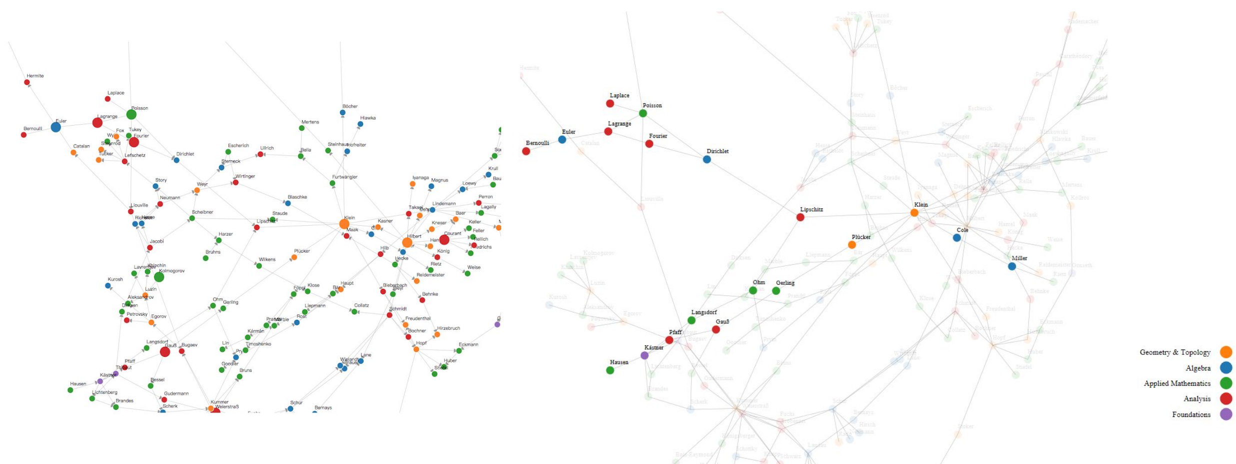
1 Tasks

- Browse connections and families of mathematicians
- Discover the trend of research field variations within a family
- Analyze the associativity of maths theorems by name
- Compare heat of different math fields
- Present categories of subfields in maths
- Browse the cross national connection of mathematicians in different ages along history
- Analyze the trend of globalization in maths study

2 Visualization Design



2.1 Force-Directed Graph for Mathematician’s Genealogy

2.1.1 Task Analysis & Design Rationale

In this phase, connections of mathematicians which assembled the genealogy of the community were presented. The task of this graph was to trace back to all the ancestors of mathematicians and their direct students, to analyze the trend of research field variations in a family and to help maths learners to understand the development of some maths theorems named after mathematicians by associating those theorems with other theorems established by advisors or students of those mathematicians.

The graph was implemented as a tool to visualize the connections and research field information. Tree was another important tool for genealogy visualization, but it cannot be applied here since some of mathematicians had more than one advisors. For instance, Klein has two advisors who can date back to Gauss and Euler, which are two important branches in maths. Hence, the graph here was a better design than a tree to present a more comprehensive information. On the node, different colors were used to present different research fields from which the trend of researches in families can be easily interpreted.

2.1.2 Visual Encoding Scheme

- Marks:
  - Points: a node represented a mathematician;
  - Connections: links among mathematicians;
  - Areas: a node occupied areas according to its importance;
- Channels:
  - Color(Hue): different research fields;
  - Size: the importance of mathematicians;
  - Position: locating a mathematician with his node;

2.1.3 Layout Design

A force-directed graph was implemented here to avoid too much crossings of edges and overlapping of nodes. Because the number of mathematicians were great, a strong repulsive force was applied in this layout. To make the graph more flexible, the layout enables users to drag nodes and zoom-in/out with mouse so that they can see the graph more clearly. Also, the size and color of nodes was used to represent the importance and research fields of mathematicians, and the width of links was used to represent the strength of connection between advisors and students.

Breadth-First-Search algorithm was implemented in the layout of animation. If one put the mouse on a node of mathematician, all of his ancestors and direct students would be highlighted. Since the number of advisors to a mathematician was uncertain, simply calling the parent of the node was useless, BFS algorithm was applied to visit all the ancestors.

On-click the node and a wikipedia page of corresponding mathematicians would pop-out. This interactive function in layout can provider more information for user to learn related maths theorems and papers of this mathematician.

2.2 Hierarchical Treemap for Volumes of Fields in Maths

2.2.1 Task Analysis & Design Rationale

In this view, different maths fields were visualized with a two-level hierarchical treemap. The task was to analyze the relationship among different research subjects inherited from the first view to browse basic information of specific fields and to discover the hottest fields in recent years so that the user can learn the latest trend of mathematical researches from the map.

A hierarchical treemap was implemented for these tasks with size of squares for number of mathematicians in certain field and color for the heat of field in 10 years. A treemap was applied because in squares there were enough area to present brief introduction on this field so that users can immediately know what the field was about. Otherwise, some user may not know what the meaning of “Analysis” in maths was by simply looking at the word. Also, the reason why a hierarchical treemap was applied as an improvement from traditional treemap was that there are about 100 sub-fields categories in the dataset. It was messy to present all of them in one flat treemap, and the hierarchical treemap can greatly reduce the number of squares in a single view making the visualization more organized. Based on these reason, the hierarchical treemap was a rational choice of this view.

2.2.2 Visual Encoding Scheme

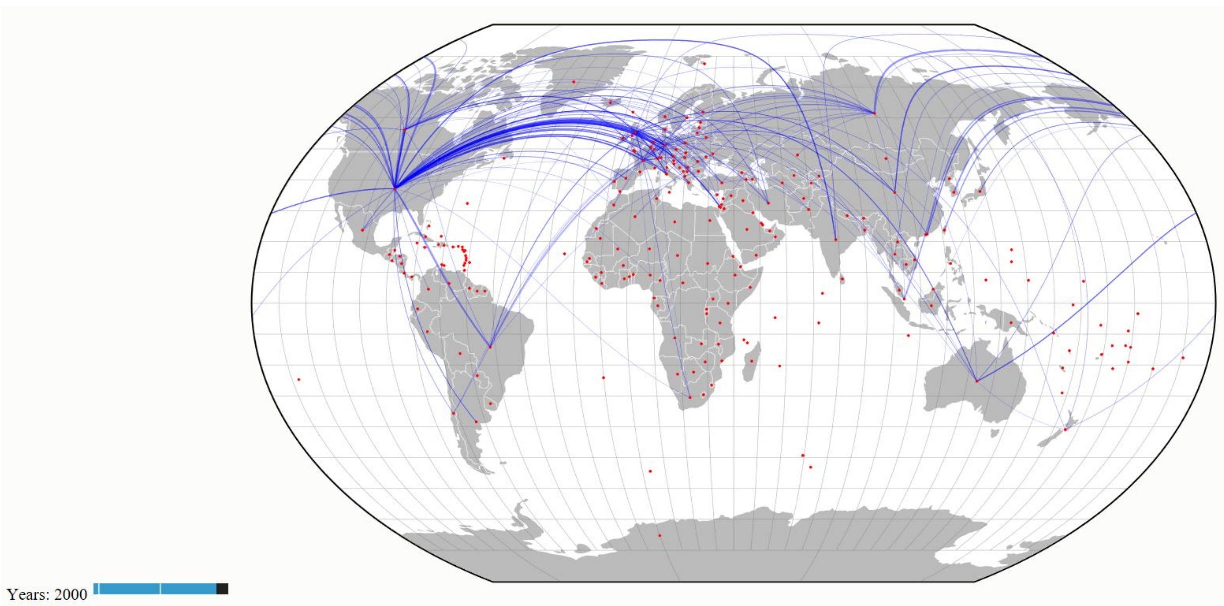
- Marks:
    - Containment: relationship between a field and its subfield;
    - Areas: squares for different research fields;
- Channels:
    - Color(Hue): heat of research fields: the redder, the hotter; the greener, less hot;
    - Size: the number of mathematicians in this field;

○ Position: locating a field with its square;

2.2.3 Layout Design

The dataset was transformed to a two-level tree including general fields and their sub-fields. In the first stage, each square represented a general field, and on-click either of them, it would show the treemap of the subfields. With this animation, treemap showed its properties of enclosure and helped user to learn the relationship among different fields. Also, the size of the squares showed the number of mathematicians in that field; the color showed the heat of fields, according to the ratio between the number of mathematicians in recent ten years in that field and the total number. Together with the texts on squares about the total number and descriptive information, this graph provided a comprehensive visualization on maths fields.

2.3 Temporal World Map for Cross-national Connections of Mathematicians



2.3.1 Task Analysis & Design Rationale

As a subtask of browsing the connection among mathematicians and analyzing the development of maths, this graph would like to compare the scale of cross-national communication in different ages (1800s, 1850s, 1900s. 1950s and 2000s) and analyze the trend of globalization of maths researches and trends of development in specific countries.

In this view, a spatial-temporal design was implemented because the task was to compare information of different time. The nationalities can be abstracted as GPS locations on the map. Hence, it was reasonable to design follow a spatial-temporal problem on a world map which a time axis to flip between different ages.

2.3.2 Visual Encoding Scheme

- Marks:
    - Lines: time axis
    - Points: nationalities of mathematicians;
    - Areas: location of different countries;
    - Connection: the number of connections in maths among different countries
- Channels:
    - Size: the stroke width represents the strength of connection between two counties;
    - Position:the location of countries;

2.3.3 Layout Design

The spatial-temporal design was implemented in an interactive layout. The view showed the connections of mathematicians between two countries. The scale of communication between two countries was quantified by the sum of the number of students in country A being supervised by advisors in country B and the number of students in country B being supervised by advisors in country A. The large scale communications were, the wider the connection lines would be. Then this layout projected these connections onto a world map and represented them in a spatial visualization, providing users a more direct observation on these countries then simply using a abstract graph.

The layout to present the temporal information was a drag slider on which user can choose the year range to visualize. On this time axis, five equally split year-range was presented to show the development of globalization in maths study, and highlighted several centers of maths education and researches in different ages.