Implementation and evaluation of a Flow Map Demonstrator for analyzing work commuting flows between Norway and Sweden

Quan Ho, Hai-Phong Nguyen, Mikael Jern

Statistics visualization facilitating methods from the geovisual analytics research domain has recently gained interest. Global, national and even sub-national statistics foundations have started to migrate from tabular representations to interactive web-enabled visualization that show trends. Flow map statistics, however, visualizing quantities of trade, transport or migration is still rare. This paper covers spatial interactions for a wide variety of realized movements of people such as commuting and migration between an origin and a destination. This type of flow data can be visually expressed by directed weighted arrows over a geographic space. For a small number and properly distributed regions directed arrow symbols can be an attractive means of visualization. Cartographic flow maps showing official statistics related to a larger number of sub-national regions (e.g. counties and municipalities) are still problematic and often skewed and detailed which leads to cluttered flows where important details are obscured. In this paper, we introduce an interactive flow map demonstrator that effectively can explore reasonable large spatio-temporal and multivariate statistical flow datasets using bidirectional flow arrows where both in- and outflows can be clearly shown. The choropleth map with overlaid weighted (size) flow arrows is linked to an interactive histogram view that gives a detailed representation of all flow data using focus & context (figure 1). The specific applied research task is to gain knowledge exploring possible opportunities for sustainable development in the southern border regions between the long national borders of Sweden and Norway. The geographic area is mostly sparsely populated mountain and forest regions but in the south, however, there are the most densely populated regions in both Sweden and in Norway and represents an important area with a tradition of cooperation and cross-border movement in both directions. The objective is to evaluate social systems and environments with a potential to identify growth in economic, social and environmental development. Norwegians pursue recreation and leisure activities in the attractive coastal and inland areas of the nearby Swedish border region. On the other hand, the Swedes living in the border region mostly commute to Norway to work. Web-enabled tools are introduced to support visualizing and animation aimed at measuring economic, social and environmental developments and to engage policy makers, statisticians and also the citizens. Early results from evaluations made by analytics experts confirm a lot of interest and awareness among the local politicians and could have an effect on future regional development.

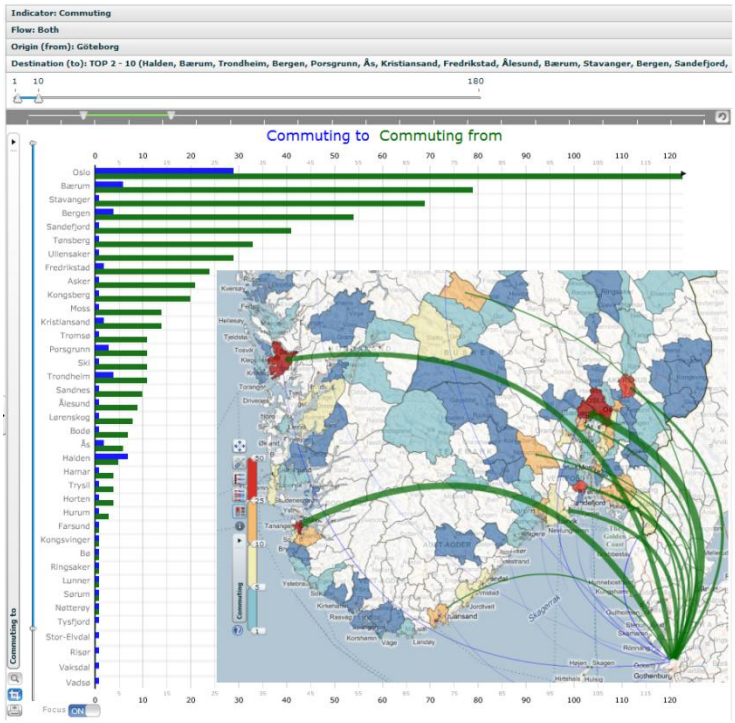

Fig. 1. Commuting from Gothenburg Sweden to municipalities in Norway. The weighted thickness of arrows represent to the total number of people. The coloured regions in the map represent the number of people commuting to this municipality from an origin. The dynamic histogram shows both commuting TO (blue) and FROM (green) Gothenburg and more clearly indicates that people in Gothenburg prefer to commute to Norway. The arrow representing the largest number of people that commutes between Gothenburg and Oslo is here removed using a dynamic query slider controlling “destination to top” which helps to avoid clutter in the display. The interaction matrix describes commuting from 290 regions in Sweden to 423 regions in Norway with potentially 122,670 flows.

The objective of our research has been to develop and evaluate a flow map demonstrator that supports:

- visualization and exploration of flow data in suitable and efficient ways
- a strong requirement from our statistics partners that tools are web-enabled through Flash
- interaction with reasonable large volume of spatio-temporal and multivariate flow interaction table with high performance
- animation to show flow time series
- different background map layers, e.g. Google map or Bing map, for identifying the name of a geographic location
- a high level of user interaction controls answering various questions about flow data such as:
  - What are the dominating flows (or the trend of movement) in a certain year?
  - Which are the top municipalities in Norway to which people living in Swedish border municipalities tend to commute or migrate?
  - What is the net migration i.e. the difference between in- and outflow?
  - How do flows vary over time?

- *Quan Ho is with Linkoping University, E-Mail: ho.van.quan@itn.liu.se.*
- *Hai-Phong Nguyen is with Linkoping University, E-Mail: haing604@student.liu.se.*
- *Mikael Jern is with Linkoping University, E-Mail: mikael.jern @itn.liu.se.*

In this paper, we propose the following solutions to the above objectives and requirements from our statistics partners providing flow data and evaluation. To visualize flow data, one of our main approaches is to use directed weighted arrows. The arrows are plotted on a map, where each flow starts and ends in suitable calculated positions (origin and destination) placed inside the regions. To avoid a cluttered visualization with overlapping arrows in densely populated areas with many small regions, several methods are proposed and evaluated including arrows plotted as quadratic Bezier curves instead of straight lines (figure 2). The curvatures of arrows are computed so that arrows are less overlapped and more readable. Users are allowed to manually adjust the curvature of arrows to reduce overlapping further. Another approach is dynamic scaling of the arrow thickness representing the number of people moving from the origin to the destination. Overlapping is also reduced using a range slider that dynamically filters less important flows and focus on flows of particular interest. This feature also supports users searching for an answer to questions such as "what are the dominating movements in general" or "what are the top movements with the origin placed in Stockholm" by filtering out other flows and showing only flows that meet querying conditions (figure 3).

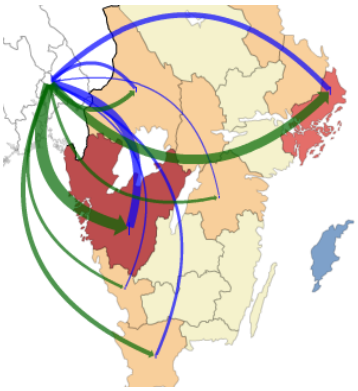

Fig. 2. Arrows drawn as quadratic Bezier curves

The second approach for visualizing flow data is to assign a colour to each region representing the number of people commuting to or from a region. This approach is appropriate to explore flows originating from a single region (figure 1), where each flow corresponds to a destination and therefore can be visualized by colouring the polygon representing that destination.

Visualisation of flow time series is another important objective of our research and two approaches are proposed. The first approach is to use time chart glyphs such as bar or line charts (figure 4). Similar to the coloured polygon approach, this approach is applied when users want to explore flows originating from a single region. Given a selected origin, each time chart glyph represents time series data of a flow starting from the selected region and flow to any of the other regions or its inverse flow. Glyphs are positioned inside polygon through an algorithm which is implemented based the erosion idea for finding a good centre point of a polygon. A trend glyph is also being evaluated where the size of the glyph represents the average amount of people moving and the glyph slope shows the trend of the movement - increasing or decreasing.

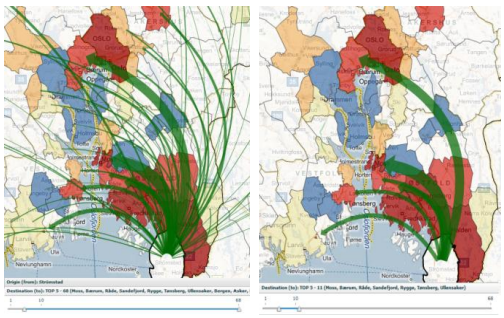

Fig. 3. Reducing cluttering by using a dynamic filtering slider

Our second approach for visualizing flow time series is through simultaneous animation of arrows, coloured regions and histogram. This time-linked animation views approach can be started and stopped at any time step and the animation speed can be also controlled to allow users to be able to observe changes easily.

A dynamic and highly interactive histogram based on a focus & context approach to handle a large number of regions gives a better overview of the magnitude and order of all regions with associate commuting. Flows are ordered according to their values. Dynamic filtering sliders allow users to be able to focus on a range of flows and/or a range of values.

To support the communicating of gained knowledge, the demonstrator integrates a story telling mechanism which allows users to capture their discoveries and share them with others.

The domain experts from both Swedish and Norwegian authorities summarize in their preliminary evaluation comments that gained insight and knowledge based on this interactive flow map case study identifies more efficiently work commuting statistics across the border and the potential political and economical consequences compared to previous used static flow mapping applications. This could help advance more interest in interactive flow map visualization for a better understanding of both commuting and migration between sub-national regions and across national borders.

A special thanks to Kjell Rennesund at Ostfold Fylke in Norway and Johnny Sehlin Sweden Statistics and OECD for providing statistics data and geographic regions together with evaluation and enthusiasm.

Two case studies of the flow map corresponding to two different datasets can be seen at
http://vitagate.itn.liu.se/GAV/flowmap/FlowMapNordicCounties
http://vitagate.itn.liu.se/GAV/flowmap/FlowMapNordicMunicipalities

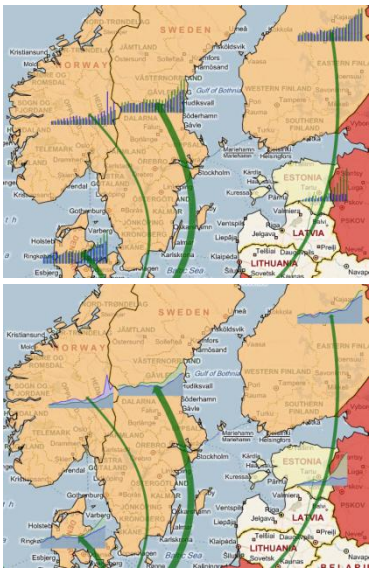

Fig. 4. Time chart glyphs visualizing flow time series: (top) bar chart glyphs, (bottom) line chart