An Innovative Approach to Studying Migration: Applying Functional Mapping to Examine Global Migration Trends

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Abstract

This study will utilize functional mapping, a technique often used in medical fields that the authors believe can be applied to the study of migration to provide decision makers with an informative view of the social, political, and economic issues shaping migration policy. Preliminary results of a study examining net migration data from 49 selected countries with the most migration either in or out has produced statistically significant results of migration patterns. The authors will apply the technique of functional mapping to collect, analyze, and assess migration data from both developed and developing nations in order to illustrate migration patterns. Through this study, it will be determined if migration patterns can be mathematically modeled as they occur around the globe based on functional mapping. Data for this study will be retrieved from United Nations Common Database and the global data base of the Development Research Centre on Migration, Globalization and Poverty (Migration DRC). Statistical information from this database includes International Net Migration data, which is available for 192 countries dating back to 1955 and is projected through 2050. Countries that have similar migration patterns will be viewed as close together in this functional map, while countries with different patterns are far apart, regardless of the physical distance between the countries. Therefore, functional mapping of migration patterns might have significant usefulness to policy makers.

Introduction

Using a technique that had previously been used to model the spread of disease, the authors show that global migration patterns can be mathematically modeled as they "spread" around the world revealing trends of population movement. This technique, known as multidimensional scaling (MDS) successfully models complex patterns in migration data around the globe using a "functional map." Countries that have similar immigration rates are close together in this functional map, and countries that have different rates are far apart, regardless of the physical proximity between the countries. A statistically significant ($p<0.001$) map was made of immigration and emigration rates in 49 countries selected from the United Nations Common Database (United Nations, 2007) and the global data base of the Development Research Centre on Migration, Globalisation and Poverty (Development, 2007).

Research Questions

In pursuing the study of migration, the authors investigated the following questions:

1. Can a statistically significant result be achieved using multi-dimensional scaling in the study of migration?

2. Can functional mapping be a useful technique in studying migration patterns?
3. If Yes to Question 2, how can data visualized by functional maps allow policy makers a means of easily interpreting complex mathematical models?
4. What problems (i.e. public health, security, and economics) within migration can patterns revealed by functional maps explain more clearly?

Multidimensional Scaling

The statistical technique of multidimensional scaling (MDS) provides a method to extract and to visualize underlying trends in migration data. MDS is a data-reduction technique, well-established in numerous disciplines, which has had great success in modeling disease outbreaks (Cliff, Haggett et al., 1995). The technique was chosen because of its flexibility and success in modeling complex data such as the spread of cancers throughout the body (Gray, Klasky et al., 1993; Gray, Woolgar et al., 2000; Gray, Vaidya et al., 2004). Here the technique is used to model the "spread" of migration throughout the world.

The researchers chose the statistical technique of multidimensional scaling (10, 11), as MDS "attempts to find the structure in a set of distance measures between objects … by assigning observations to specific locations in a conceptual space (usually two- or three-dimensional) such that distances between the points match the given dissimilarities as closely as possible. In many cases the dimensions of this conceptual space can be interpreted and used to further understand the data" (6).

Multidimensional scaling is a powerful data-reduction technique that plots immigration and emigration according to their functional distances—probabilities that two sites share a similar population flow. It is interesting when such a map does NOT resemble normal geography, as this indicates a predictable but complex pattern of spread—population change that skips physically adjacent sites to appear at distant but non-random sites (4).

Multidimensional scaling accepts a set of proximity measures as input (7). These data are off-diagonal half-matrices comparing all pairs of immigration and emigration. MDS produces a "map" such that inter-point distances in the map match the input data. The reverse process is easier to understand. For example, given a physical map of major tourist sites in Virginia, it would be easy to derive a matrix of distances between all possible pairs of sites on

this map. Such matrices of inter-point distances are often found on travel maps. MDS reverses this process—starting with input proximities and producing the map that best fits the matrix of input distances.

Functional Mapping

A functional map is a computer generated plot with points representing population in flow and different points representing the population out flow (emigration) and is constructed such that distances between all points in this plot are proportional to the prevalence of migration. Functional maps are a data-reduction strategy, allowing the data to explain what is important. Functional maps offer several advantages over traditional tabulations including:

1. Statistically significant solutions;
2. Succinct visual summaries of the underlying patterns in complex data;
3. Simple, easy-to-understand visualizations;
4. Predictions (albeit based on retrospective data) likely to provide some benefit in new and emerging infections, especially once a library of patterns is established (see below);
5. Identification of anomalies;
6. Tests of inter-relationships;
7. Assistance in understanding missing data.

Functional mapping can be described as a technique which helps interpret robust to incomplete, variable, or partially flawed data ("noisy" or "messy" input). These data are important in the study of migration as it allows policy makers to examine trends in population flow independent of geographic location. This technique was chosen as it provides:

1. Succinct visual summaries of the underlying trends in available data;
2. Interactive predictions, tailored to meaningful subsets of those affected;
3. Education appropriate to experts, policy makers, and lay-persons at various educational levels;
4. An alarm for unexpected or novel events.

The technique should scale easily for different sizes of the input data-base.

Methodology

In studying migration patterns, the authors selected the statistical technique of multidimensional scaling (MDS) to further model immigration and emigration patterns. The MDS approach provides such a method to extract and to visualize underlying trends in the migration data. As discussed above, MDS is a data-reduction technique, well-established in other disciplines, but not yet readily available in the migration literature as a tool for modeling immigration. The technique has been successful in modeling the spread of cancers throughout the body and the spread of disease across states and counties in the United States. This approach adapts MDS to model the movement of people from nation to nation.

For this study, data were retrieved from the United Nations Common Database. As the name implies, this is a database of statistical information on virtually all topics the UN finds relevant. International Net Migration data is available for 192 countries with coverage beginning in 1955 and projected through 2050. More specifically, an Excel file was downloaded from that site, displaying net migration from all countries, every 5 years from 1955 to 2005 (United Nations, 2007). The future projections available on that site were not included. Multidimensional Scaling analysis of net migration data (49 selected countries with the most migration either in or out, every 5 years from 1955 to 2005, from the UN public web site) yielded a statically significant 3-dimensional functional map, explaining 72 percent of the variance (exceeding what is considered to be a “large” effect size, $p<.01$). Figure 1 displays this functional map:

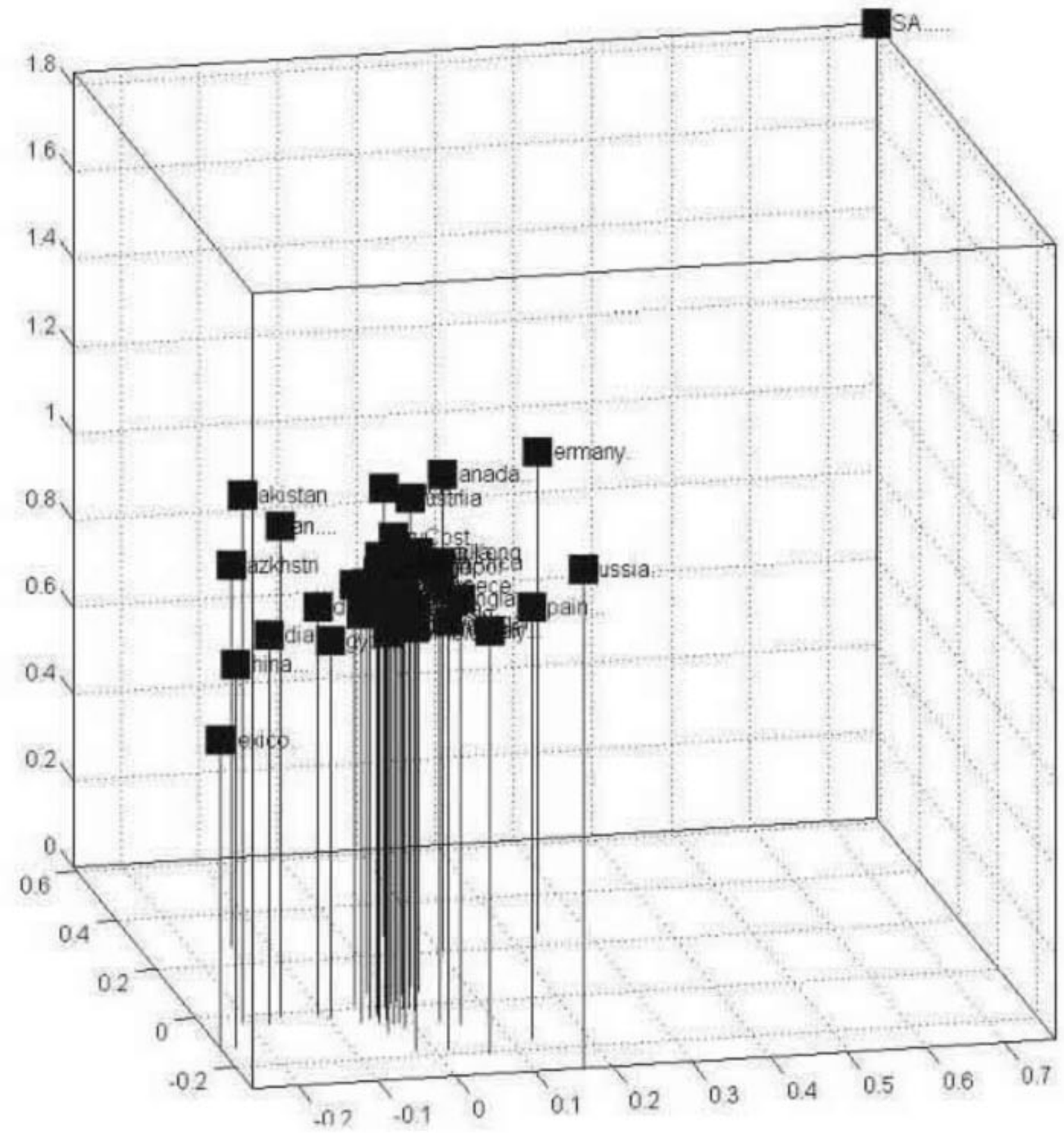


Figure 1

"Distances" in this map are proportional to the absolute value of differences in net migration. Thus, USA in the far upper corner is very distant from Mexico (in the lower left corner) because the USA has a large positive net migration and Mexico has a large negative net migration. Study of this functional map indicates countries scattered along this Net-Inflow to Net-Outflow diagonal axis in the functional map. China, India, and Egypt are close to Mexico. Germany, Canada, and Australia are more closely aligned to the United States (comparatively).

Visualization

Once a significant functional map is found, it is relatively simple to create an on-line visualization of the underlying trend extracted from the data. Figures 2-5 show several screen prints from an interactive program that can be seen from the James Madison University

Department of Communication Sciences and Disorders web site (James Madison, 2007). http://www.csd.jmu.edu/csdsquared/Migration/Mgrtn1.htm

Select a flow (immigration or emigration) of population from the menu on the left. Then move the slider to "spread" the population. The computer is modeling the expanding "shock waves" from the "starting locations" in the functional map. Colors on the geographical map change as the wave passes the countries in the functional map. The almost totally green state in the country depicts the clinical threshold, that time when the population flow is just starting to be evident. Switching from immigration to emigration, done by clicking on a different item in the pull-down menu, shows a different pattern of population change.

Figure 2

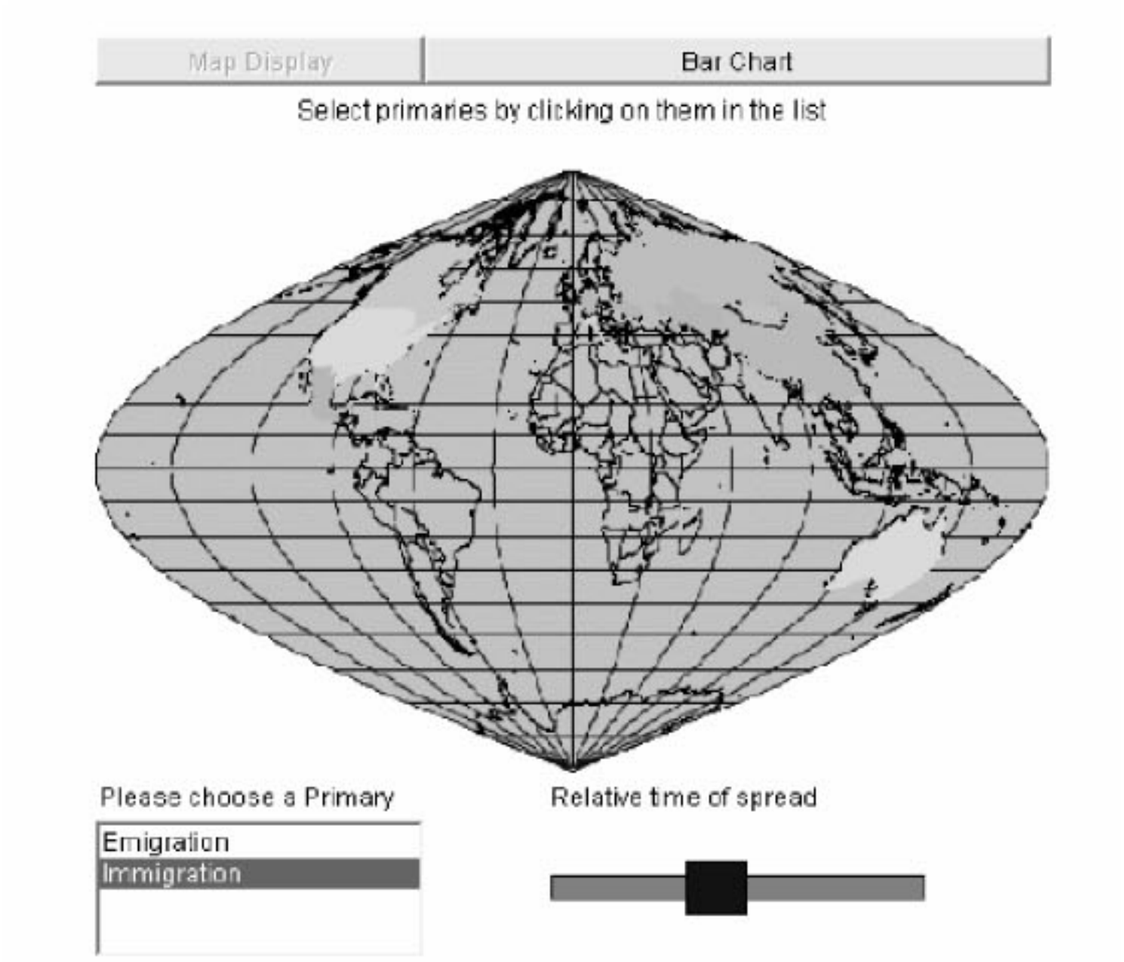


Figure 3

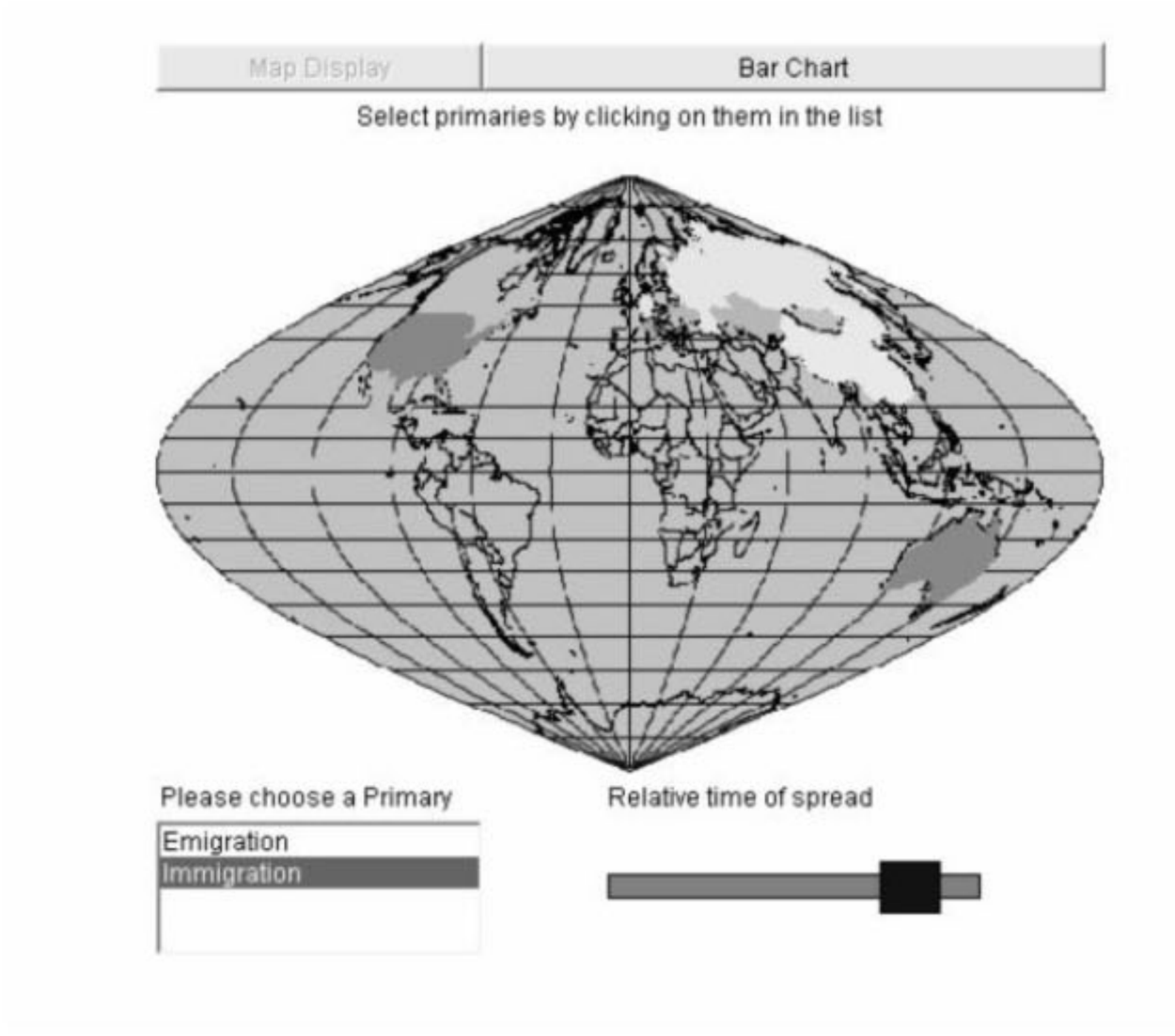


Figure 4

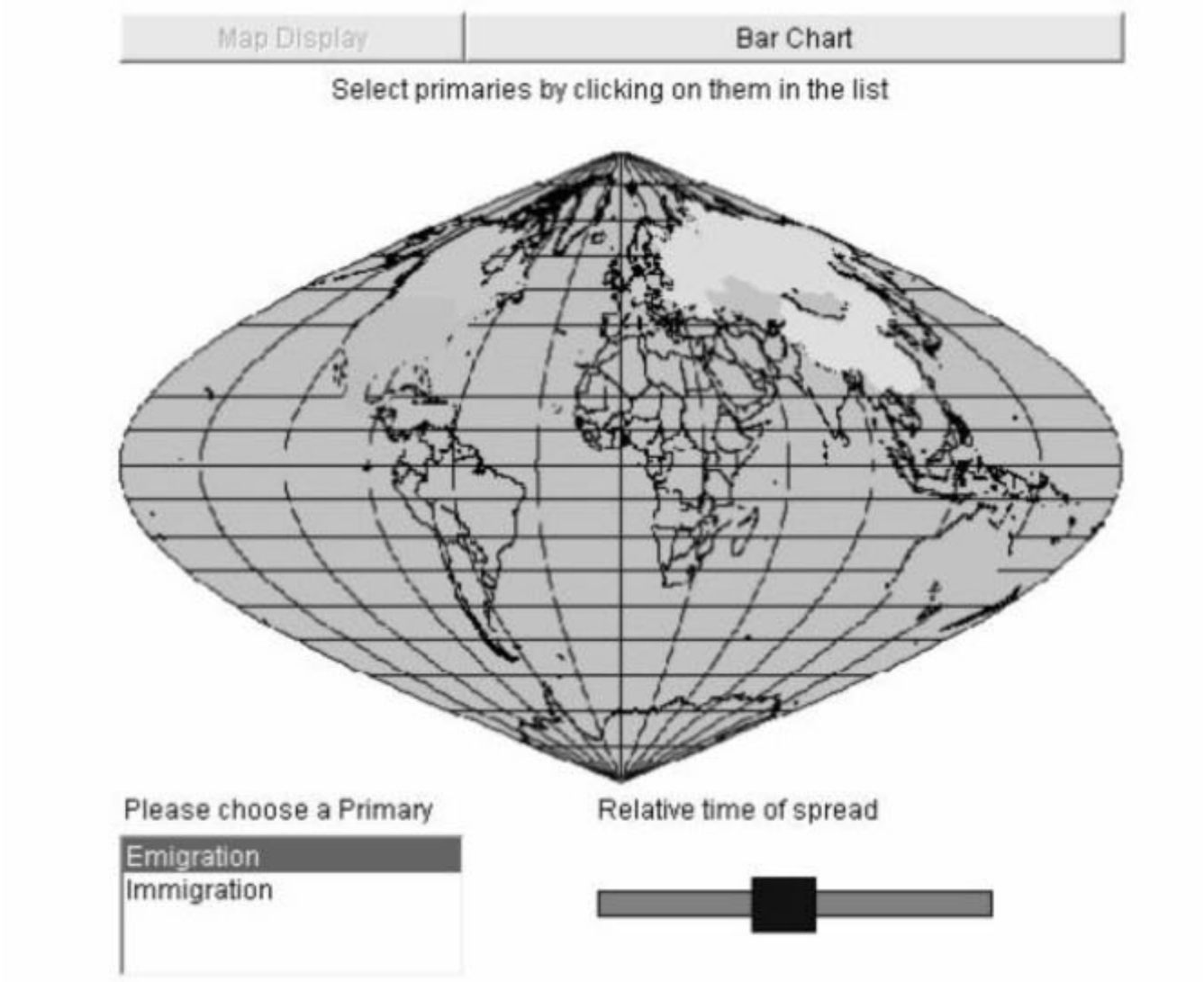
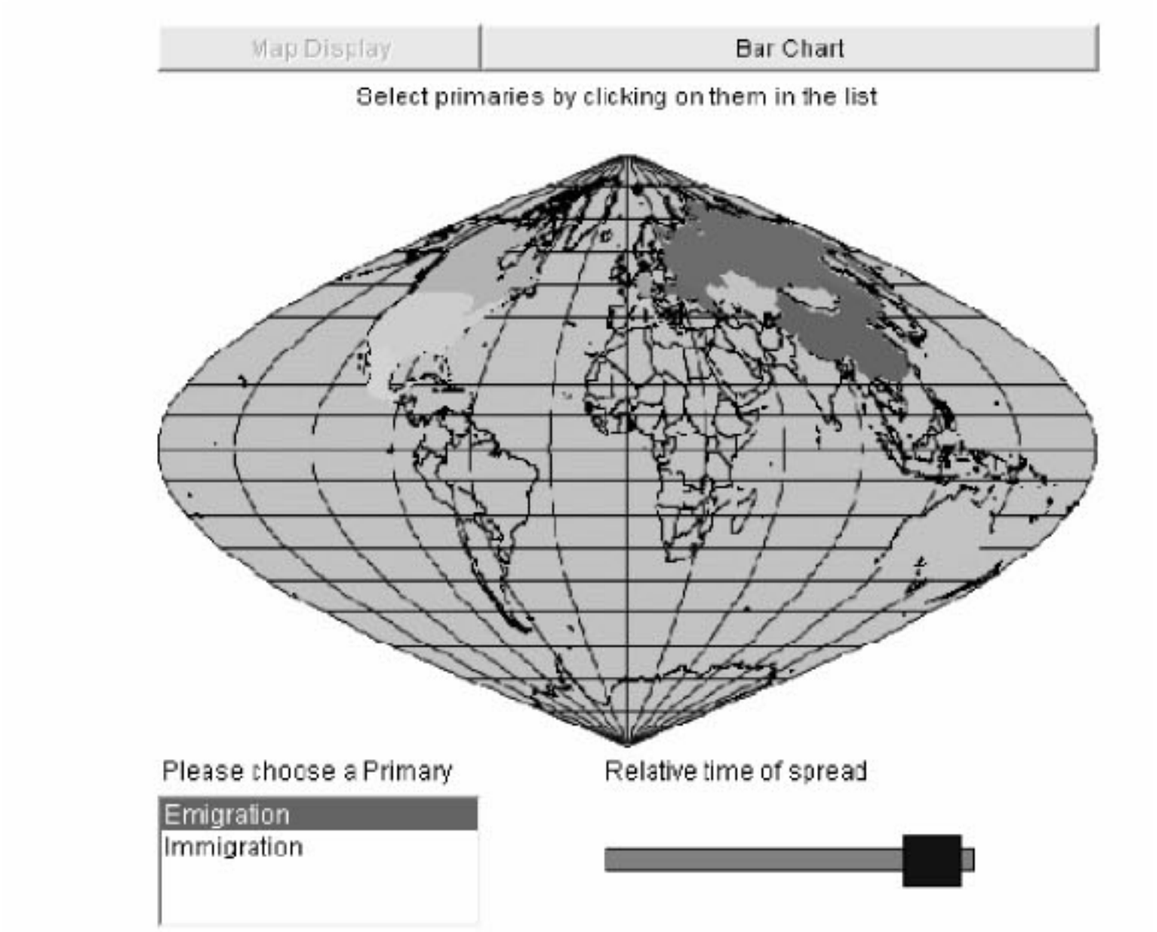


Figure 5



The visualization also provides a depiction of the data in a more traditional form, as seen in the bar graph in the lower-right quadrant of Figures 6-9. It is often said that "a picture is worth a thousand words." The functional map "picture" is likely more meaningful for decision makers, researchers, and lay persons who want to learn about the essence of the epidemic.

Figure 6

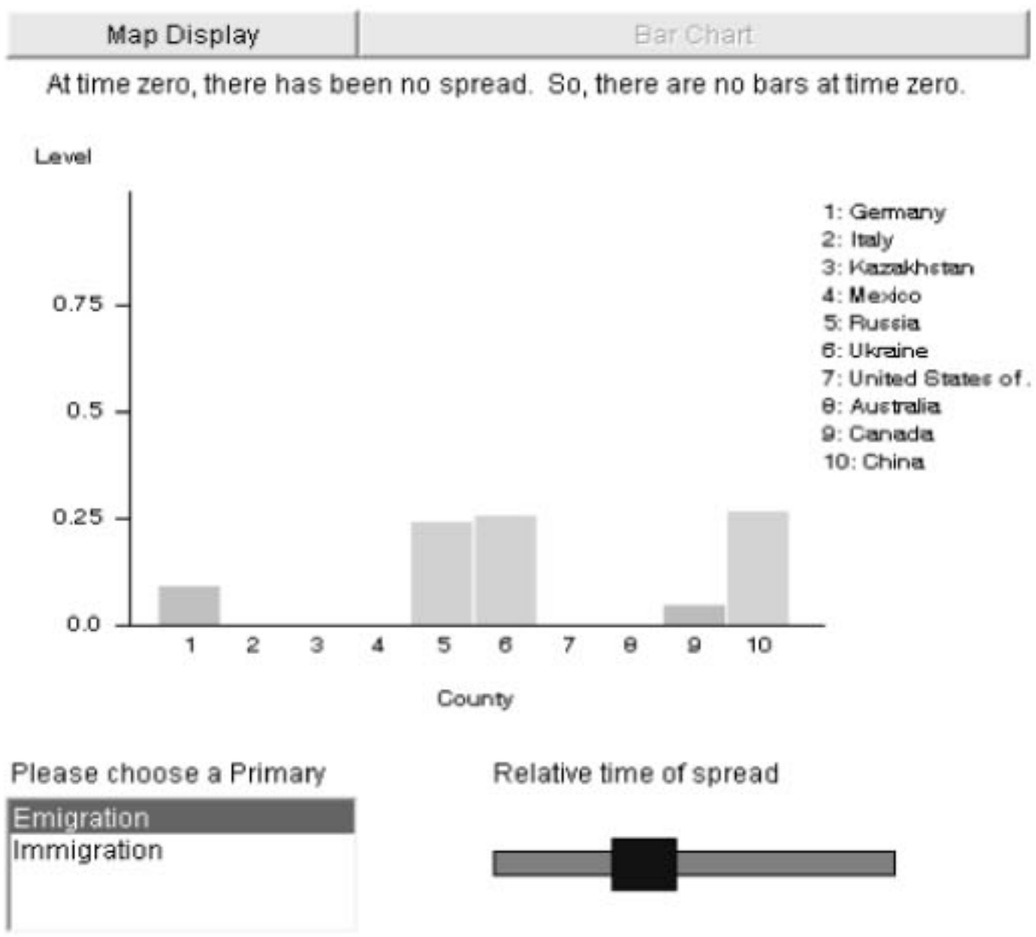


Figure 7

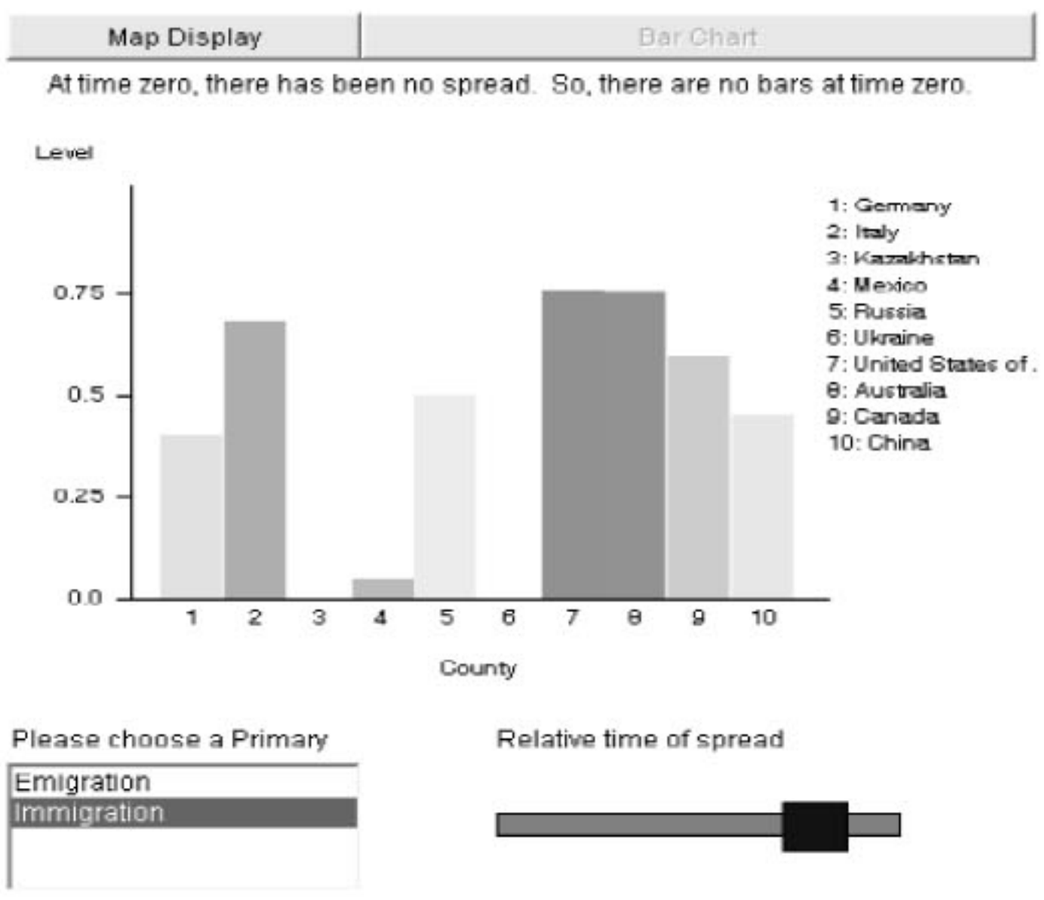


Figure 8

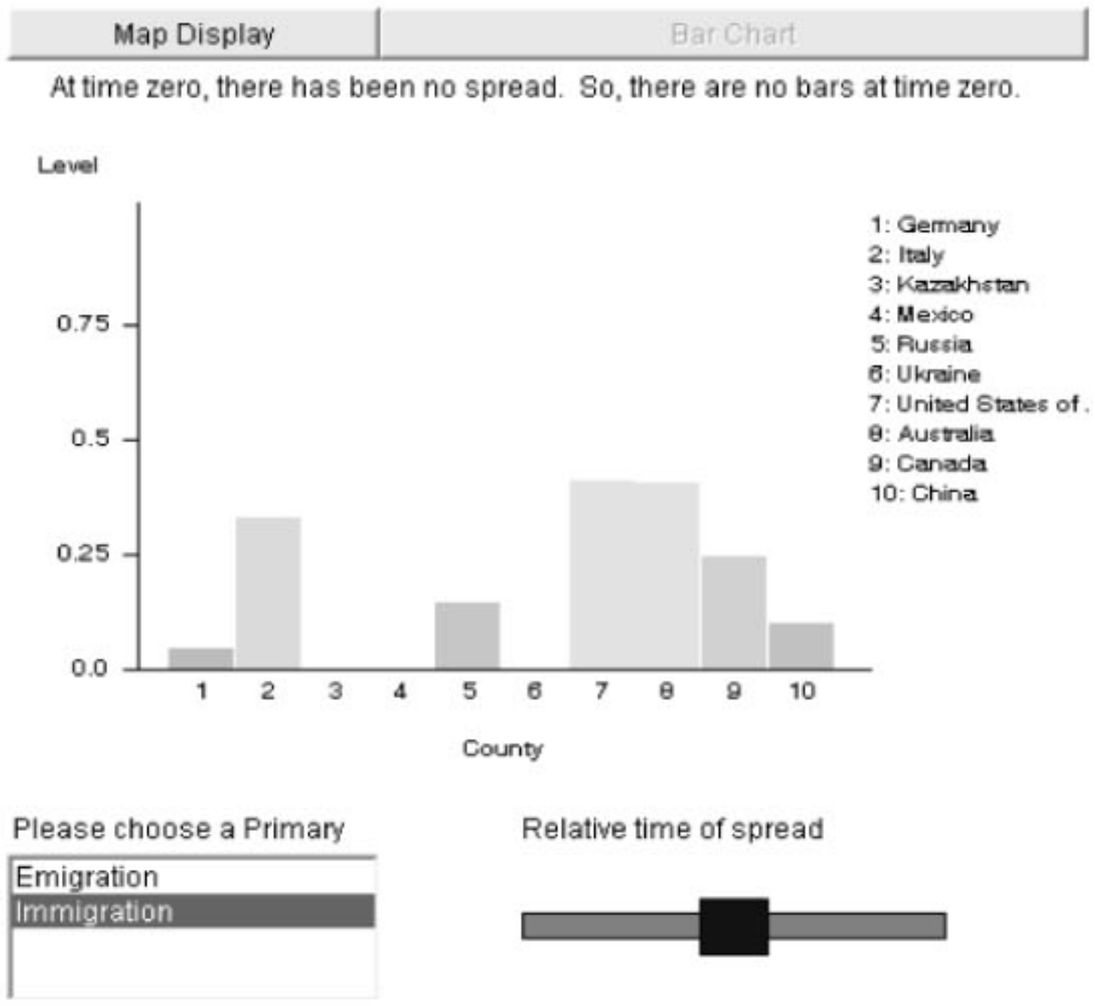
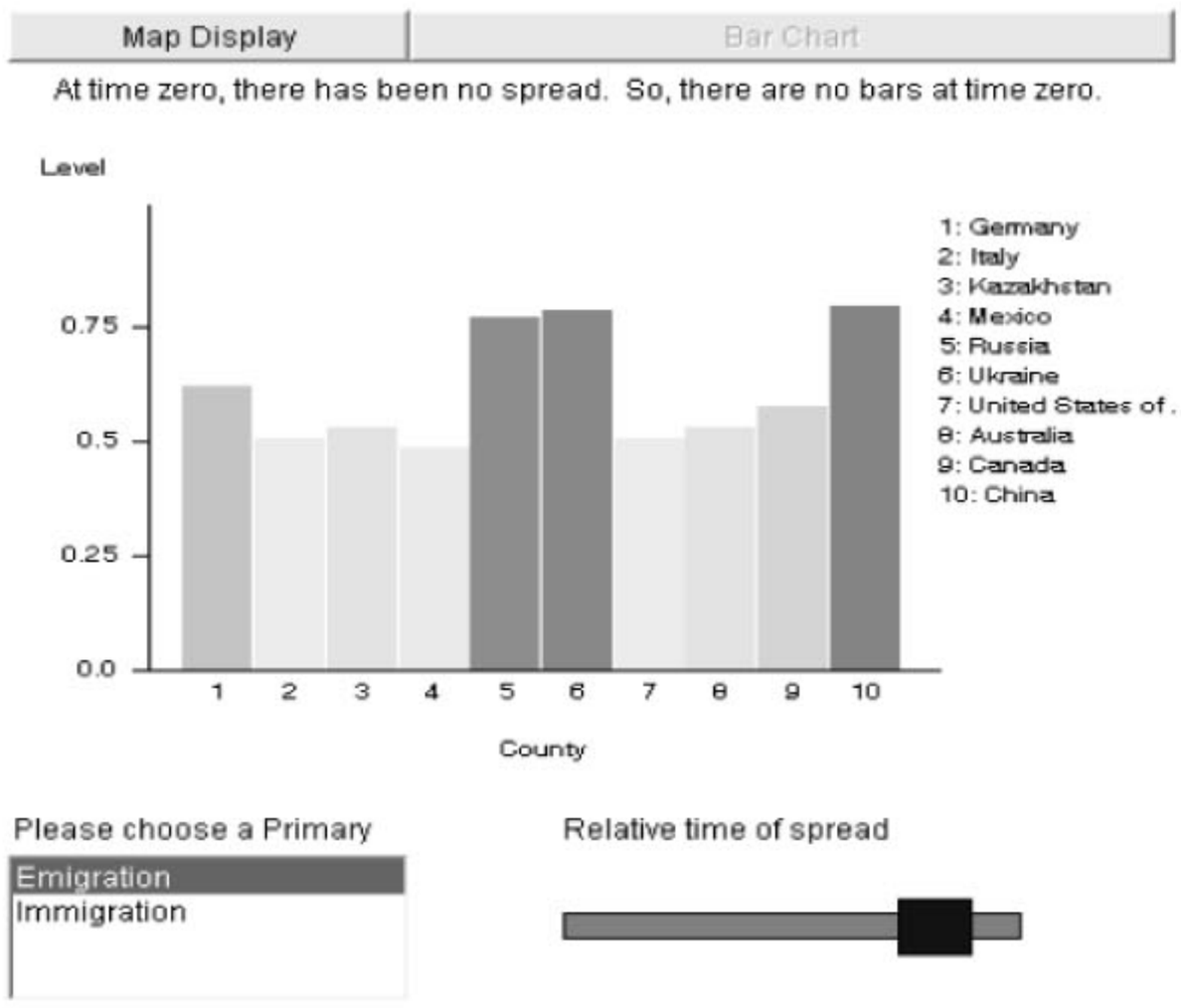


Figure 9



Future Research

This preliminary research can be furthered to address issues in the social sciences, government policy, and national security arenas. Through manipulation of the project parameters, new visualizations can be developed, providing the user with rich, data displaying what countries share similar functional migration locations on a map, as a result of a variety of factors, such as the environment, the geo-political landscape, conflict, religion, economics, and a host of other conditions that motivate migration. These visualizations would be particularly valuable to the decision-maker in setting economic policy, preparing for pandemic influenza, or securing borders against malicious intent.

Conclusions

The result of this study is statistically significant, $p < .001$, explaining 72 percent of the input data, n=49. Figure 1 shows the resulting "functional map." Distances in this map represent differences (absolute values) in migration flows.

It is encouraging that this initial attempt to "map" migration patterns is statistically significant. This is expected and simply indicates that the computer is able to extract some non-random pattern from the input data. It is also expected that several insights from this visual summary emerge, and that many are consistent with known trends in these archival migration data. This demonstrates the capabilities of this algorithm to better understand global migration strategies, successes and failures.

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