PerspectiveView: Seeing the World from Different Perspectives

Billy Shiu Fai Lam

Abstract—This paper describes the design and implementation of PerspectiveView, a web-based application for visualizing temporal geospatial datasets and their correlations. Building on top of the existing geovisualization tool, AmMap, perspectiveView integrates bimodal control mechanisms that allow the user to alter the choropleth mapping of multiple sets of data on the world map dynamically using novel interaction combinations. The application determines the set of geospatial data to display based on the user's head position detected through a web camera; by shifting the head from left to right, the user selects between viewing two different datasets or their correlation values on the map. The application also implements a dynamic cross map and timeline control, allowing the user to identify any spatial trends that exist in the datasets at the same time. Combining data selection using head-coupled interaction and theasholds and time adjustment using the mouse simultaneously offer a interesting two-way control that engage the user into using the application and understanding the geospatial data.

Index Terms—Head-coupled interaction, choropleth mapping, interactive map, temporal geospatial visualation, bimodal control

INTRODUCTION

Imagine yourself meeting a seventeen-year-old teenage boy who never knew how a hamburger or fried chicken tastes like. In fact, the fast food restaurant that you can afford to go to everyday and spend 15 minutes of your time on is like a family fine-dining occasion to them. How would you think or act differently on all the everyday things you so easily take for granted in your life?

Poverty, hunger and amongst many other issues are severe and increasingly prominent in many places around the world, and certainly more and more emphasis are being put on these global issues that at times seem so distant to us? How can we better bring these issues into the proper perspectives into our own lives? Unfortunately, not many of us would have the opportunity to spend our lives travelling to these parts of the world to interact with the people living there and experience their lives; how can we better raise public awareness of all these issues around the world? Given the advanced technology and the amount of information available on the web today, is it possible to create an easily accessible web application that can help and interest the general public see the world in the proper perspectives? These questions form the motivation of the PerspectiveView project, a web-based application that utilizes novel and interesting interaction schemes to engage users into exploring different temporal geospatial datasets.

Tools for visualization multi-dimensional data are usually designed and geared towards domain experts, whom make use of such tools to aid their analysis related to their work, such as climate changes, spread of an epidemic or any other geospatial trends and shifts over time. These tools are not usually widely accessible, not to mention their complex controls and analysis tools that more than likely require deep learning curves, preventing the average users from utilizing these tools in meaningful ways. Furthermore, visualization tools are usually limited to a unimodal, one-dimensional interaction, relying on the mouse as the only input to control properties related to viewing the datasets, i.e. using the mouse to select/rotate, using the keyboard to switch between categories/states, or using a combination of keyboard and mouse to zoom/pan. Are there ways that we, as designers can help users browse through the datasets more efficiently and perhaps with better understand-ability? Would adding extra dimensions of interaction be beneficial to visualizing data, given that the added interaction does not burden the cognitive load of the user? For example, if the user is looking at a set of geospatial data on the world map over time, are there any ways that they can control the time and other properties, such as changing the color encoding schemes simultaneously? One possible solution is to automatically playback the data over time, but that requires the user to switch back and over between multiple controls if they need to have full control of the timeline to compare the data at different times. Head-coupled interaction is one possibility, as it is a natural motion we use in our daily lives to see things from different perspectives.

In attempt to explore these multi-modal visualization techniques, a geospatial visualization prototype, called PerspectiveView, has been developed. The prototype utilizes existing face detection techniques to track the user's head position to perform coarse selection between different datasets to be displayed on a world map, simulating "seeing the world from different perspectives", while freeing up the mouse to perform other necessary, and more precise interactions simultaneously. Thus, it provides a bimodal control scheme that helps the user to explore and understand datasets in an engaging and novel manner. While such bimodal interactions can potentially be applied to different datasets and visualization tools, the PerspectiveView prototype described in this paper focuses on visualizing correlations between two sets of temporal geospatial data of different countries. In particular, the system is intended to expose information related to income, fertility, population density and other similar data that are closely related to the humankind. For example, how are poverty and population density related in different regions of the world over the past decade?

This paper is divided into five sections. In Section 1, previous work related to temporal geospatial visualization, head-coupled and bimodal interactions are presented. In Section 2, the solutions that PerspectiveView implemented are described and justified. In Section 3, I provide the implementation details of the PerspectiveView prototype, followed by screenshots of the application and scenarios of use. A discussion of the strengths and weaknesses of the application is detailed in Section 4, and directions for future work in different areas are provided in Section 5.

1 RELATED WORK

Much work has been done on geospatial visualization related to both temporal and correlation analysis. Some of the work involves using three-dimensional (3D) displays [9] to visualize both spatial and temporal dimensions. 3D displays are useful when the temporal dimension are associated with duration data, in which the duration can be represented as length along one axis in the 3D space; it becomes difficult to visualize geospatial data that changes temporally, as in the case with most world geospatial data, in which a data value is associated with both a time and a location (i.e. year and country) There are other systems that are more similar to PerspectiveView in which they are used to visualize correlation

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between temporal geospatial datasets. Monmonier [13] first introduced the idea of encoding correlation data with a spectrally encoded bi-variate map, also known as the “crossmap”, in which a data point’s color encoding is mapped according to which quadrant region it belongs to. MacEachren [10] implemented the dynamic crossmap technique in their HealthVis tool that explores health statistics in the United States containing both spatial and temporal information. Users were able to adjust values for the crossmap in order to filter and focus on a specific range of data and to identify any spatial trends or shifts over time. The system was extended [5] by integrating Parallel Coordinate Plot (PCP) techniques in attempt to better visualize multi-variate data, though at the time no significant advantage was found of its use over the crossmap technique, and visualizing beyond bi-variate data is outside the scope of this project.

On the other hand, few have explored the area of coupling gestural inputs in visualization systems. Related to head-coupled interaction, Ware and Franck [16] evaluated the effectiveness of stereo and head-coupled perspective rendering for tree structure visualization and concluded that a combination of both techniques led to a significant increase in performance than 2D rendering. However, the study was done with primitive tasks that involved abstract 3D tree structures; transferring its findings to abstract datasets that have no particular spatial relationship is questionable. In more recent work, Ball and North [2,3] explored the effects of physical navigation in large-scale, high-resolution display. It is interesting to note that their results showed physical navigation provides a better performance improvement than peripheral vision in map exploration, but performing physical navigation on a small-scale display, as is the case for PerspectiveView, is a much different interaction. Besides, the interaction necessary in PerspectiveView is an abstract mapping instead of a spatial one. Furthermore, Guiard [7,11] extensively studied on the asymmetric bimanual interaction related to two-handed inputs, indicating humans are accustomed to perform coarse interaction with the non-dominant hand and precise control using the dominant; it would be interesting to see in PerspectiveView if bimanual control using a combination of head motion and the dominant hand could be a preferred and effective interaction scheme in visualization.

2 SOLUTION

There are two main design requirements that the PerspectiveView visualization system needs to satisfy: accessibility by general users and reliable face detection, as described below:

- Accessible by General Users
  As PerspectiveView is intended not only for geospatial domain experts but the general public users, it is important to keep the application easily accessible and usable. Given the popularity and reliance of the Internet over the past decade, the most apparent solution is to implement the visualization tool as a web-based application. The interface of PerspectiveView needs to be intuitive and easy to work with, without complex controls and analysis tools that require a deep learning curve and take away from the positive user experience. More importantly, the application needs to provide color-blind free visual encodings to ensure the visualization reaches out to the percentage of population with color blindness. Rainbow or other colourful schemes are definitely not options for PerspectiveView.
- Reliable Face Detection
  Head-coupled interaction, in a lot of ways, is a fairly novel technique to the public, even though they have increasingly been integrated into gestural-based video games and digital cameras. Nonetheless, performing head-coupled interaction in a web-based application is something that few had done. In order to use head-coupled movement as a control mechanism, the face detection has to occur in real-time and be smooth and robust enough to render itself usable as a control.

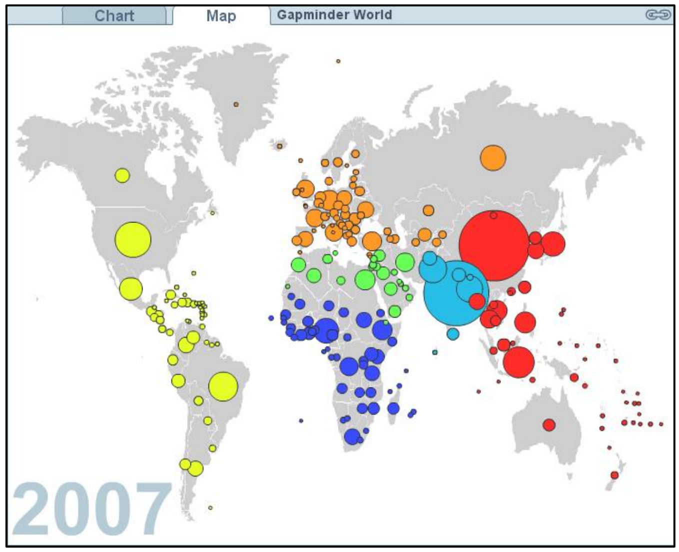

Figure 1. Clustering and whitespaces in GapMinder [http://www.gapminder.org]

2.1 Visual Encoding

There are few possible alternatives to display geospatial data on a map, such as glyphs. Using glyphs could allow multi-dimensional data to be shown on the map, but glyphs usually involve more complex visual encodings, and they might not be easy to understand for many users who have less experience with information visualization techniques. Therefore, it is important to utilize simple encoding techniques that general users are familiar with, such as a country boundary-based choropleth mapping, or the pin-point color markers used in the Google Earth API. While using pin-point color markers is simple to implement, as only a single point latitude and longitude information is needed for each data point, but at the outermost zoom level, these markers can form clusters and cause occlusions at smaller country regions, such as in some Africa and Middle-East countries, making the markers hard to comprehend. Zooming can mitigate the cluttering problem, but pin-pointing still leaves the map with a lot of whitespace on large country regions, making the visualization less appealing. Figure 1 illustrates these cluttering and whitespace problem on a map used in GapMinder [6]. Thus, PerspectiveView resorts to using the traditional choropleth mapping that colors the entire country region based on its data value. Zooming and dragging can be incorporated into the map to allow users to focus on smaller country regions that might be harder to see on the outermost zoom levels.

The PerspectiveView application needs to be able to visualize correlation between two datasets over a period of time. PerspectiveView implements the “crossmap” technique as described by Monmonier [13] to show the correlation between the two datasets using a bi-variate color map. In particular, the system utilizes a similar technique as MacEachren [10], in which the threshold values of each dataset can be dynamically adjusted to allow focussing on a subset of data within specific correlation ranges. For example, the user can adjust the threshold values to group countries that have an income per capita of $15000 and an employment rate above 70% into one color encoding. As such, the user can easily filter out specific regions and identify any spatial trends or shifts of the data that may occur over time. Furthermore, in order to enable the user to easily distinguish between the datasets currently in view (i.e. the user can switch between two datasets and an additional set that shows

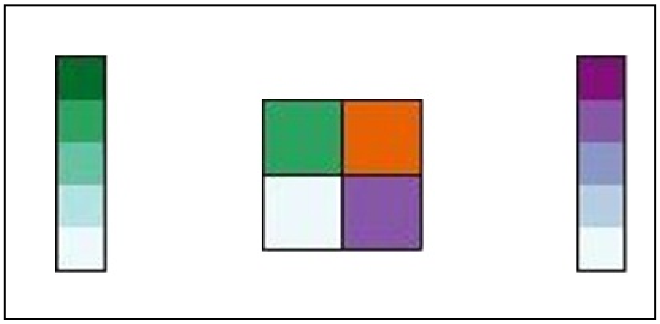

Figure 2. PerspectiveView color schemes: (left to right) dataset 1, correlation, dataset 2

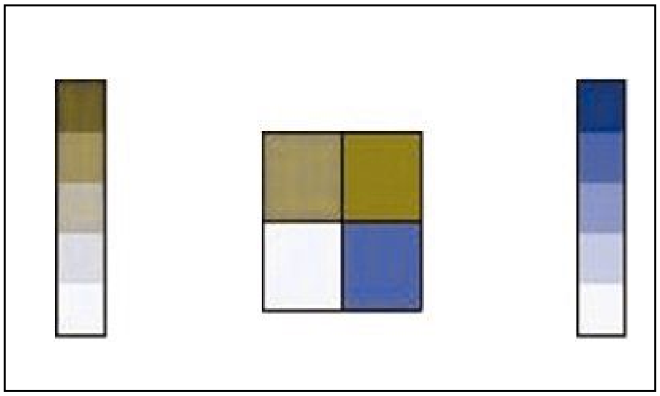

Figure 3. Color schemes ran through VisCheck

their correlation values by head-couple selection), the application utilizes differing color schemes for each of the datasets. For datasets one and two, two five-scaled, single-hue 5-level segmented color schemes that vary in saturation values are chosen. For the dynamic crossmap that shows the correlation relationship, the system uses diverging colors to show each of the four regions. To allow the user easier correlate between the datasets, the crossmap region that only contains a high value in dataset 1 would show the same hue used in dataset 1, and vice versa for dataset 2. Figure 2 illustrates the visual encodings of these three datasets. As aforementioned in the design requirements, the system needs to be color-blind safe. Vischeck [15] was run on these colors and revealed that the colors are clearly distinguishable from each other each through color-blind visions as shown in Figure 3.

2.2 Bimodal Control

While head-coupled interaction can be achieved through accessing the user's web camera to perform face detection, the detection is relatively coarse-grained and unstable. Compared to using the mouse, head motion is unsuitable for precision control such as selecting specific values or moving to specific regions on the map, not to mention that it could be a tiring exercise for the user. However, simple head motion, such as shift slightly from left to right or from front to back, can possibly be suitable for offloading some interaction to the gestural movement of the user instead of leaving everything to be controlled by the mouse. For example, performing fixed-level zooming through tracking the distance of the face from the display to determine which zoom region it falls into, or selecting different operation modes of the application through looking from different angles to the display. Both of these, amongst others, are possible techniques worthy of further exploration, though detecting depth could be tricky by using a single web camera alone (i.e. estimating depth through the size of the detected face region window could be largely error-prone). Other techniques such as using a stereo camera setup or positioning the camera at the side to track the user's profile face are more complex setup that most users would not have access to; these techniques violate the accessibility design requirement. Therefore, the later concept of shifting the head sideways is chosen for the PerspectiveView application.

There are several mappings that are possible with visualizing geospatial data and the shifting head motion. First, the system can map the head position to a timeline control, changing the data over time. Second, the head position can be map to some fixated threshold regions to quickly switch between different subsets of the correlation data. Third, the user can shift from left to right to look at different categories of datasets. The first two alternatives require dividing the camera image stream into small vertical regions, depending on how long the timeline is or how many threshold regions there are. Thus, the solution might not be scalable to a longer timeline or more threshold regions between the datasets. PerspectiveView explores the third option: a interaction combination technique in which the user selects between three sets of data to be displayed on the map based on the head position (dataset 1, dataset 2, and a correlation set between the 2 datasets), while the user can control the timeline and also the threshold values to change the visual encoding shown on the map by using the mouse. Figure 4 illustrates the general concept and interaction used in PerspectiveView:

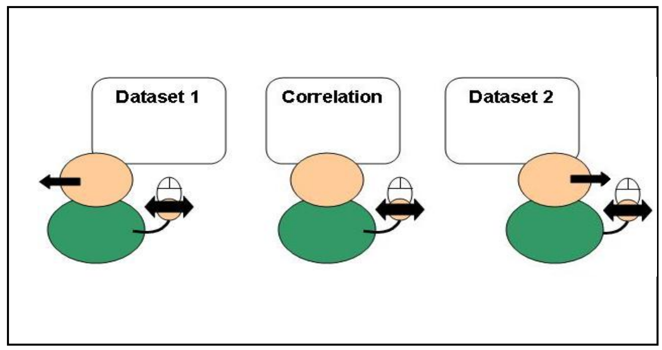

Figure 4. PerspectiveView interaction

3 System Implementation

PerspectiveView is implemented in Adobe Flex, integrating existing tools including the ActionScript 3.0 library MariLena [12] for performing face detection and amMap [1] for displaying geospatial data on an interactive Flash map. The following subsections describe each of these components in greater details, along with the modifications that were made to incorporate them into the PerspectiveView application. Figure 5 shows a screenshot of the PerspectiveView interface and descriptions of the controls and components.

3.1 MariLena Face Detection

MariLena is an open source code project that ports existing OpenCV face detection algorithm to ActionScript 3.0, and it opens up a completely new gateway of head-couple and gestural interaction possible with applications on the web. The usage of MariLena is similar to the original OpenCV version in a lot of ways, including the same frontal face Harr feature cascade [14] file. Much of the MariLena source code was left unchanged in its integration into PerspectiveView besides some camera parameter adjustments. Since the image quality is not of priority concern for the system as long as the face detection can occur accurately without noticeable lag, the web camera was configured at initialization stage to run at 320 by 240 pixels at 20 frames per second. Another change made to the source code was the horizontal flipping of the images before the detection stage, so that when displayed, the user's head in the image is inverted and corresponds to the side which the user is physically located.

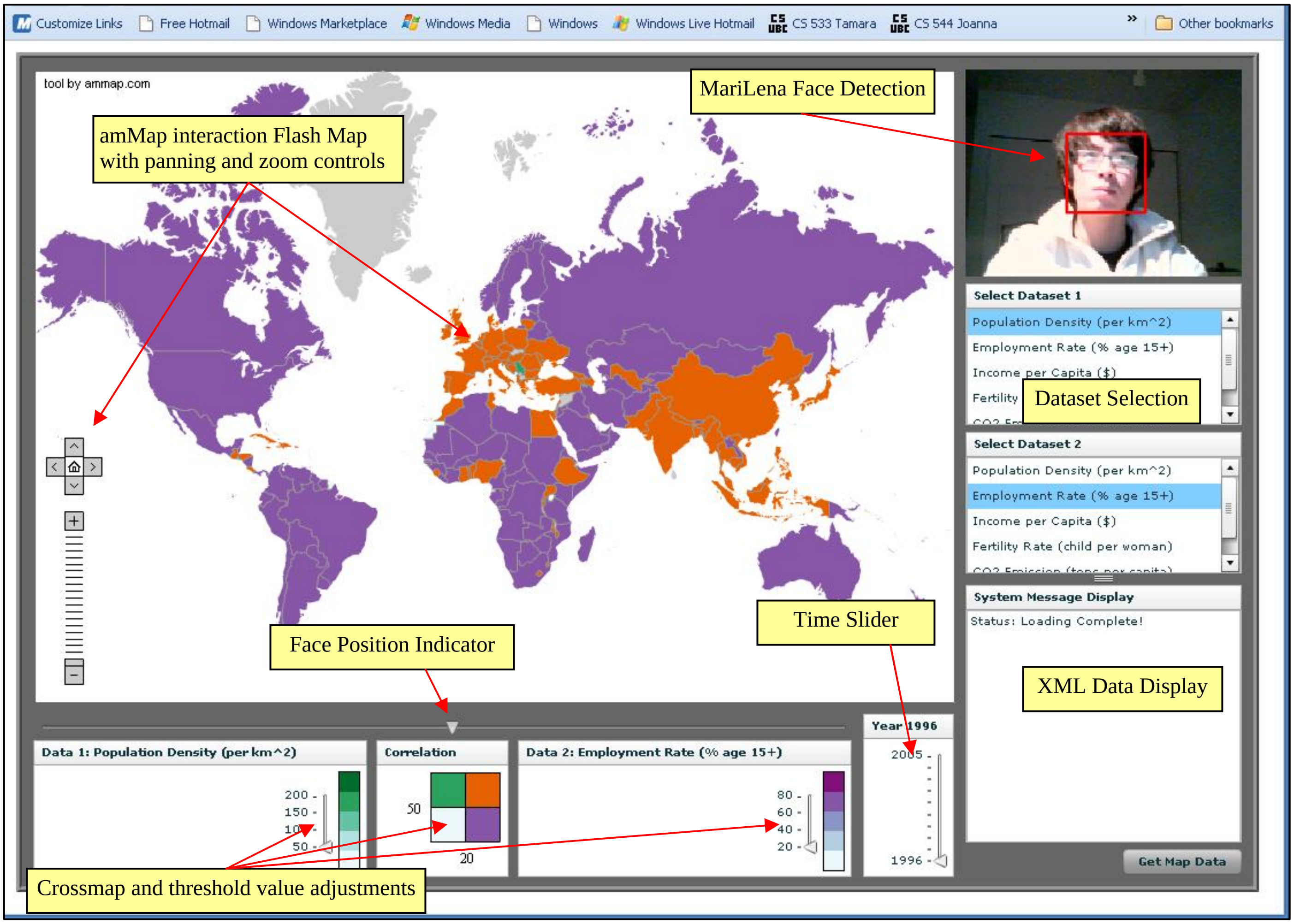

Figure 5. Screenshot of PerspectiveView prototype

3.2 amMap

amMap [1] is an interactive map tool developed in Adobe Flash that provides an effective platform for displaying geospatial data using choropleth mapping technique. The tool provides interactive controls that allow the user to zoom, pan, drag and hover over different regions of a map to look into more details if available. amMap takes country or regional associated data stored in XML formats as input, allowing the user to specify data values, descriptions, hyperlinks and even images with each country regions. While being a standalone visualization tool, amMap's limited external interfaces prevents it to effectively establish a two-way communication with external components. It is also limited to accepting one XML data file as input at a time and displaying only a set of one-dimensional values. It supports minimally a timeline features which allows the user to import a XML file that contain data entries for multiple years, but it does not provide an interface that can manipulate the time slider through external controls. Given these limitations, a Flex control interface has been implemented to provide a lot of workarounds to communicate data with the map, though the solution posed a number of limitations which would be discussed in the Future Work section.

3.3 Flex Control Interface

The Flex control interface of the PerspectiveView links face detection, amMap and the datasets into one single application. The Flex component provides controls for selecting which two datasets are to be visualize, adjusting the year of the data on the map and also the threshold values for the correlation crossmap. The MariLena face detection algorithm is integrated into the flex component as an ActionScript class, and the image feed of the detection result is displayed to monitor the robustness and reliability of the face detection (as shown in the top right corner of Figure 5). The bottom left of the application shows three panels corresponding to the three datasets that the user can currently view by changing the head position. Above the three panels is a face position indicator that is mapped to the horizontal position of the detected face. Whichever panel the slider thumb is pointing to indicates the dataset that is currently being displayed on the map; this provides a visual feedback for the user, enabling them to more accurately perform dataset selection using head motion. Effort has been made to stabilize the face detection and to improve its robustness, as false detections can occur and cause the dataset selection to jump abruptly. A simple moving window filter is used to determine the current dataset selection by averaging the last 10 (window width = 10) face detection results. The filter introduces a .5 second delay (20 fps); informal usage of the application shows that the thumb slider remains fairly stable even there were occasional false detections and sudden jumps in the face tracking results.

3.4 Datasets and XML-data Generation

While the MariLena face detection algorithm could be nicely integrated, JavaScript functions are needed to interface between the Flex control interface and amMap. Communication is minimal, however, as the settings for amMap can only be initialized once during runtime, and new XML data are generated and transferred to amMap dynamically when needed. PerspectiveView currently contains 5 different datasets for 152 countries over a span of 10 years (from 1996 to 2005). These dataset samples are retrieved from GapMinder [6]; they include population density (people per kilometre square), employment rate (percentage of population above 15 years old), income per capita ($), fertility rate (children per woman) and Carbon Dioxide emission rate (tons per capita). Missing information in the datasets are replaced with -1's and are always displayed on the map with the lowest saturation color of the 5-level segmented color scheme used for the dataset. The datasets are stored in a single database file in comma delimited format, and the file is loaded into the flex application in its entirety by the application at the initialization stage. However, only the necessary XML-format data are generated at any given point in time to avoid overloading the application with unnecessary resource consumption.

For each dataset, four values are pre-computed that are used to partition the dataset into five subsets, corresponding to the color schemes used in the application. These four values are of constant intervals and are determined rather arbitrarily without properly analyzing the distribution of the data, but they are informally tested to spread the data as evenly as possible into the five partitions. Then, color encoding for each country in the XML data entry is generated on-the-fly by mapping the partition of the data value to the 5-level segmented color schemes and the crossmap color scheme. For each selected dataset, a XML-format data string compatible with amMap is needed for each data year; this results in 20 XML-format data strings, 10 per dataset. In addition, for each crossmap threshold pair between the two datasets, a XML-format data string needs to be generated. As there are 4 pre-determined threshold values per dataset, a total of 16 data strings are generated per correlation crossmap per year, total to 160 data strings over the period of 10 years at any given point in time. These 180 XML-format data strings are computed dynamically whenever the user changes the selection of any of the two datasets that are currently being viewed. While the generation process introduces a slight delay, the user can browse through the selected datasets and their correlation smoothly. Adjustments to different threshold value pairs and year do not introduce additional delays, as the application only needs to pass the corresponding data string to amMap that has already been computed and stored. Figure 6 illustrates sample XML data outputs that the system generates.

3.5 System Screenshots and Scenarios of Use

An interaction walk-through of the system provides a better understanding of how the PerspectiveView application can be used. Consider a specific task scenario of a user, Sam, trying to understand the relationships of income and fertility since 1996 to 2005 using PerspectiveView:

- Figure 7: Sam opens up PerspectiveView through the browser; by accessing the web camera on Sam's computer, the system starts tracking Sam's face.
- Figure 8: Sam clicks on the "Run Map" button at the bottom right of the application to see the map initializes; he selects income per capita as the first dataset and fertility rate as the second dataset on the right side panels
- Figure 9: Sam shifts his head to the left to look at the income per capita dataset. He scrolls through the time slider to identify changes of income over the 10 years in various regions of the world. Although there does not appear to be any significant spatial shift over time, it is clear to him that the dominant high income ($20000+) regions are central around the First World countries, namely, North America, Western and Northern Europe, Australia, and Japan. While regions in Africa and in Middle-East are dominantly low-income.
- Figure 10: Sam shifts to the right to explore the fertility


```
<area title="PORTUGAL" mc_name="PT" year="9" index1="3"
        index2="0" value="0" color="#8856A7">
                <description>114.66 57.4</description>
</area>
<area title="PUERTO RICO" mc_name="PR" year="9" index1="3"
index2="0" value="0" color="E66101">
        <description>440.89 42.2</description>
</area>
```


Figure 6. Sample XML data of two countries

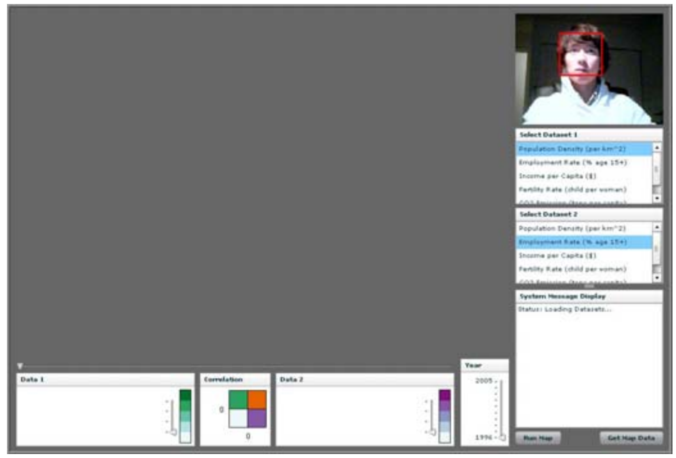

Figure 7. PerspectiveView initializes

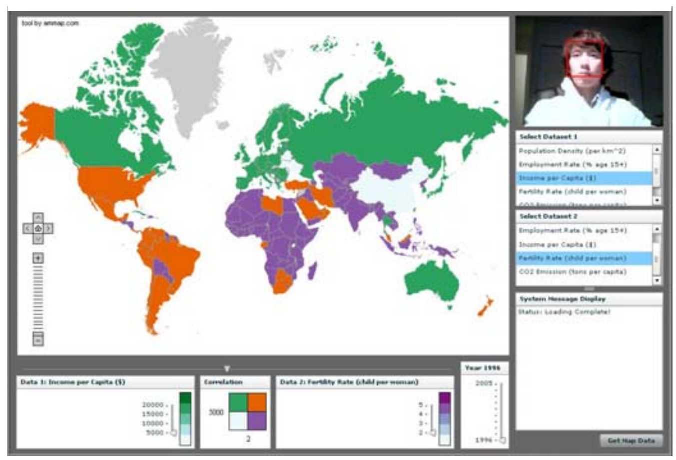

Figure 8. Run map and data selections

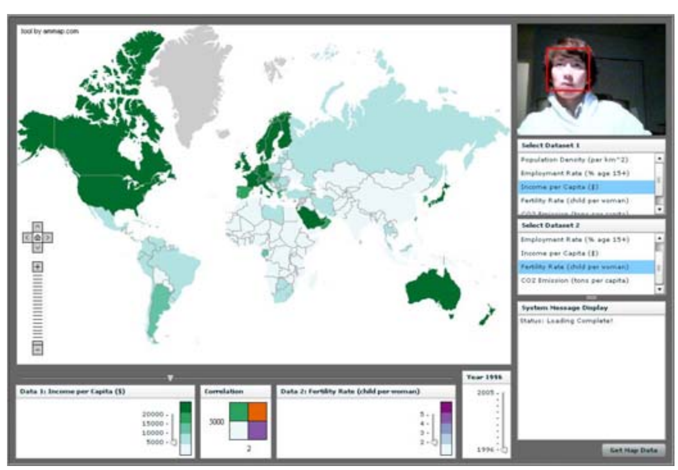

Figure 9. Shifting to the left to explore income data (note the shift of the face position slider)

data that he has previously selected. Again, he scrolls through the time slider in order to identify any interesting trends. While he could not detect any major spatial shifts, he notices a slight decline in fertility rate in many parts of the world since 1996. No countries appeared to have increased fertility over the particular period of time.

- Figure 11: To better understand the relationship between these two sets, Sam stays in the centre region to explore the correlation values. He begins with threshold values of {income per capita = $10000, fertility rate = 3 children per woman}, but little information could be conveyed through the map.
- Figure 12: He goes on to adjust the income per capita threshold to $15000 and is able to come up with more conclusive results. In general, high income and high fertility do not co-exist, as seen by the patches of greens and purples on the map. The two countries that are of particular interest to Sam are Saudi Arabia and Oman, which have high income and high fertility over the entire 10 years, as indicated by the orange patches. Sam looks up information further on the Internet and realizes these two countries' economy are primarily based on fuel and oil, which other countries in the world heavily depend upon; their prices have increased more than double since the 1990s.

Similar action-packed interaction can be used to explore other datasets. It would also be meaningful for the user to zoom in to a specific region (i.e. the Africa continent) to see a clearer view of the smaller countries and perform exploration and analysis within it. It promotes understanding to countries that are less visible in the whole world view.

4 Discussion

Though no formal evaluation has been done that compares the bimodal interactive control of PerspectiveView with other similar geospatial visualization tools that display datasets and correlations over time, initial usage experience shows that PerspectiveView is very engaging, giving the user a sense of immersion into the application. Few web applications provide support for gestural input; with the MariLena project, different head-coupled or gestural interactions are becoming possibilities on the Internet. PerspectiveView takes a step at tackling the areas of web-based gestural based interaction and multi-modal control for visualizations. It is arguable that using head motion as a control mechanism adds physical and cognitive load that the user might not be accustomed to, and the dataset selection task in PerspectiveView is a simple one that can be easily replaced by keyboard or joystick control with the non-dominant hand. Why is it necessary to use head-coupled interaction? If gestural input is determined to be a feasible approach, a tri-model interaction scheme involving both hands and the user's head can providing an even richer and engaging experience in different visualization tools and applications.

The web application runs smoothly on a 2.4GHz, 2.00G RAM, MS Windows XP machine without any noticeable lag; however, running PerspectiveView on a less powerful machine (1.6GHz, 1.00G RAM MS Windows 7 Notebook) slows down the interaction experience. This may attribute to the large resource consumption that is associated with all the Adobe Flash components (amMap, face detection and the Flex control interface) used in the application, as they consume more resources than regular HTML-based web pages, particularly with the interaction-rich computation and communication that are happening within PerspectiveView. Another

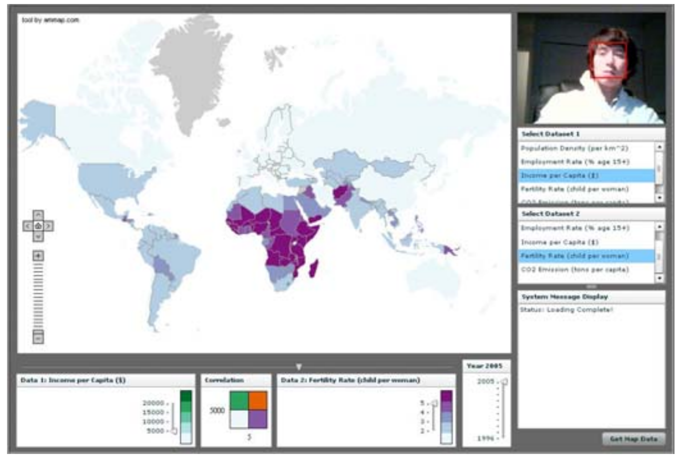

Figure 10. Shifting to the right to explore fertility data

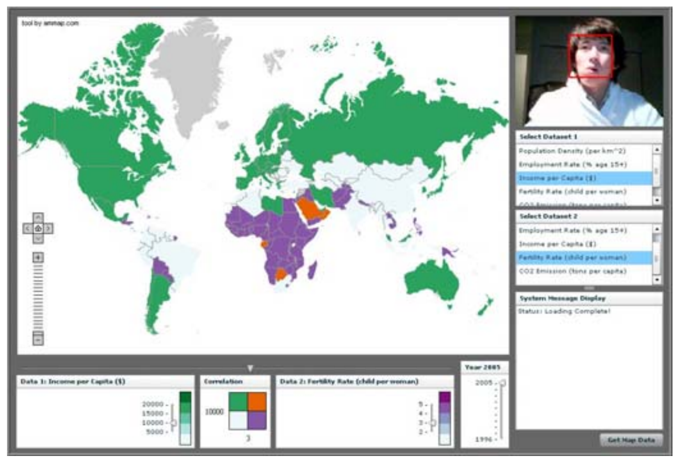

Figure 11. Seeing correlation at {$10000, 3 children per woman}

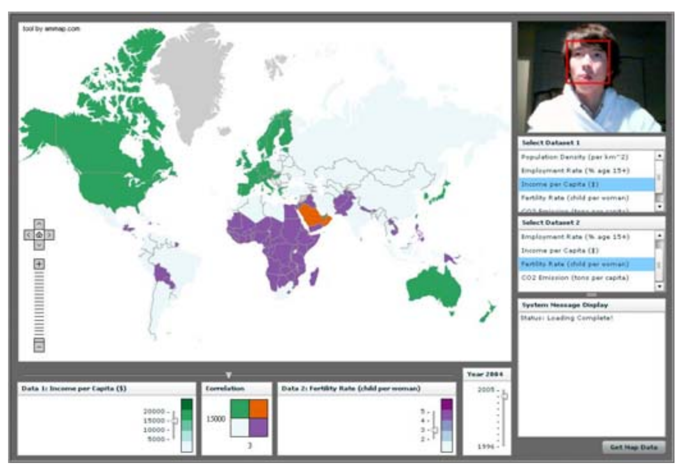

Figure 12. Seeing correlation at {$15000, 3 children per woman}

apparent problem is the application's inscalability with the web browser window; the current PerspectiveView prototype is configured to run at a fixed size (1070 x 720 pixels), deeming it unsuitable for machines with smaller screen real-estate. Related to the visualization itself, one major weakness with the application is its incapability to allow for user-defined threshold values for the correlation crossmap, limiting the users from identifying trends that might have existed within the pre-determined thresholds. It would be meaningful and more practical for the user to be able to alter threshold values for each dataset, so s/he can focus and filter on the subset of data s/he wants to be viewing. An even better approach would be to allow for upper and lower threshold boundaries, so the users can focus on middle range regions of the datasets. However, the current fixated-value implementation is designed to cope with the limitations of the amMap's external interface, as new XML-data strings need to be created with each new correlation threshold pair before passing into amMap.

5 Future Work

While there are a lot of areas that the PerspectiveView prototype can improve upon, it brings up various directions for future work that few have explored previously. These improvements and future work can be categorized into i) datasets and their ranges; ii) data handling and software interface; iii) head-coupled motion and evaluation.

5.1 Datasets and Their Ranges

The five datasets compiled for testing the PerspectiveView prototype are fairly static over the period of time that we analyzed, thus it was difficult to identify much interesting geospatial trends and shifts that are associated with them. Comparing correlations between the five datasets revealed very minimal change over the ten years. It might be worthwhile to compile other categories of data, such as poverty, disease spread and morality rate, or even extending the current sets of data to a longer period of time, though finding older, complete data for all 152 countries would not be an easy task.

On the other hand, deriving color encoding schemes suitable for displaying large data ranges of different distributions remains a difficult problem. For example, the highest data value for population density in the current dataset is {Singapore: 6247.38 people per kilometre square}, along with a few others that scatters on the high end of the spectrum, while more than two-thirds of the countries are below the 100 people per kilometre threshold. It is likely that many other world data sets behave the same way, showing the large range of differences in different parts of the world. Current strategy resorts to eyeballing the data to find the threshold values that give the best partition and spread for each dataset, but the solution clearly does not make the extrema in the dataset stand out, defeating the initial motivation of developing PerspectiveView. An alternative approach is to use a continuous color spectrum instead of the 5-level segmented color levels, but it still does not solve the problem if the dataset is not evenly distributed. A better, more complex solution would be to incorporate statistical analysis to provide proper partitioning of the datasets. [8]

5.2 Data Handling and Software Interface

The current data storage and generation strategies are mostly designed to cope with the limitations associated with the external interface with amMap. Dynamically creating and storing 180 XML-data strings for 152 countries is inarguably not the most elegant solution. Due to time constraint and for the purpose of rapid prototyping, an actual database was not created to store the datasets, but it would be an important future work if the datasets continue to expand and more dynamic interactions are required. Furthermore, because the Flex control interface of PerspectiveView and the amMap tool are different embedded objects in the web page, Cascade Style Sheet (CSS) styling is currently used to position amMap precisely over the flex control components using absolute coordinates; PerspectiveView runs properly both in Google Chrome and Mozilla Firefox but presents a problem in MS Internet Explorer, as objects become misaligned with each other. At the point of writing this report, the application has not been tested on other browsers; however, it is likely that custom CCS styling code has to be written for different browsers to ensure compatibility across the web community.

Related to features within the application, it would be a decent enhancement to allow users to import their own sets of data to visualize, given that they adhere to the XML-format required by amMap. In addition, augmenting the map with information such as descriptions, images, hyperlinks to each country region can further aid the users' understanding of the meaning and histories behind the datasets, such as when Sam was trying to find out why Saudi Arabia and Oman have high incomes and fertility rates. Such feature can make PerspectiveView a much richer and informative application.

5.3 Head-coupled Mapping and Evaluation

An interesting future work that extends from this prototype can be a full-scale evaluation of utilizing head-coupled interaction for visualizing data, in addition to the conventional mouse and keyboard control. Certainly head motion can be mapped to other interactions such as shifting the head sideways or front and back to view the datasets at different times, zooming in and out or even using eye gaze to control the exploration and dragging of the map. The interesting research problem is how much control can be offloaded to the head motion until the cognitive and physical workload becomes too straining. Does this type of multi-modal interaction better facilitate exploration of geospatial data? Furthermore, how does using the head for coarse selection or control compared with the non-dominant hand? The PerspectiveView prototype elicits all these questions that are worth further investigate into.

6 Conclusion

PerspectiveView is a web-based geospatial visualization application that combines head-coupled interaction techniques for coarse dataset selection and precision mouse control for timeline and correlation threshold adjustments. Its novel interaction paradigm for exploring datasets aims to stimulate users' interest in the task of exploring various temporal geospatial datasets to help them better understand global issues. While evaluation remains to be done regarding its usability and cognitive load added to its users, PerspectiveView's gestural-based, engaging interaction seems promising to be able to extend to other areas of visualization interactions and web-based applications.

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