GEOVISUAL ANALYTICS WEB-ENABLED TOOLS FOR DISSEMINATION OF OECD REGIONAL STATISTICS

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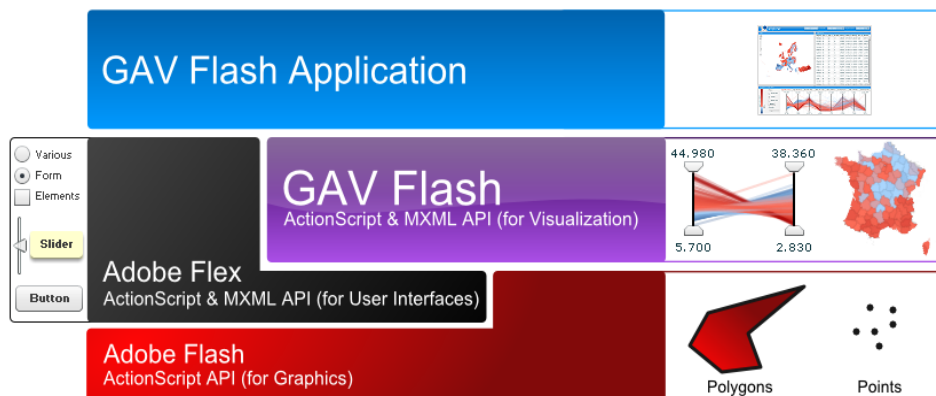
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Abstract

This paper reflects a challenging applied research task to stimulate, at global level, exchange of statistical measures and knowledge through innovative Geovisual Analytics techniques. Establish progress initiatives at international and regional (sub-national) levels for measuring and collaborating, through statistical indicators, economic, social and environmental developments and to engage both statisticians and public. Higher integration driven by institutional processes and economic globalisation is eroding national borders and creating competition along regional lines in the world market. Sound information at sub-national level and benchmarking of regions across countries, therefore, has increased in importance in the policy agenda of many countries. In this context, National Center for Visual Analytics (NCVA) has in close collaboration with OECD developed "OECD eXplorer" - a customized Web-compliant tool for interactively analyzing and communicating gained insights and discoveries about spatial-temporal and multivariate OECD regional data.

INTRODUCTION

GeoAnalytics tools are designed to support highly-interactive explorative spatial data analysis [3], [10], [13] of large geospatial data. They enable analysts to look at geospatial data from multiple perspectives and explore interesting and important relationships that may exist over a wide array of spatial and multivariate scales. GeoAnalytics research focuses in particular on integrating cartographic approaches with visual representations and interactive methods from the information visualization community and on exploring data and enabling collaboration and sharing of gained insights over the Internet.

In this paper we illustrate the introduction of a novel web-enabled advanced toolkit, composed of GeoAnalytics Visualization (GAV) components, which supports a broad collection of dynamic interaction methods using the Adobe's Flash and Flex 3 platform. GAV Flash is based on the principles behind the Visual Analytics research program (Thomas 2005), focusing on both explorative and communicative visual data analysis and analytics reasoning aspects (Figure 1).

Fig 1: GAV Flash toolkit is integrated and embedded with Adobe Flash and Flex. GAV Flash components are devel-

oped in Flash's scripting language called ActionScript (similar to JavaScript), an object-oriented language allowing the design of class-based web applications.

An emerging domain in web-enabled geographical application is the visualization of socio-economic information at detailed territorial level in a way to enable both the analysis of regional differences and performance within a country and comparison of different areas across countries. The GAV toolkit has been promoted for the exploration and analysis of the OECD regional database which contains socio-economic indicators for some 1,000 regions across OECD countries. Its development has been content-driven receiving suggestions from domain experts on how to combine geographical maps and information visualization presentations.

The key feature of the resulting GeoAnalytics demonstrator, called **OECD eXplorer**, is its deployment to internet users for dynamic web. A first version of OECD eXplorer has been released at the end of October 2008 on the OECD website (Figure 2). An extended forthcoming version (March 2009), will enhance the possibility to explore trends over time, provide novel functions for presenting stories about the statistics and combine metadata and maps status.

Fig2: A snapshot of OECD eXplorer. The web user interface with three coordinated and linked views (Map, Scatter Plot and Parallel Coordinate Plot (PCP)). The coloured indicator is "Elderly dependency rate", defined as the ratio of the population aged more than 65 years and the amount of people between ages 15-64. Two regions, Berlin and Paris, are highlighted in all views and their profiles (black line types) in PCP can be used for comparison including OECD EU mean values (green). Most of the red (high elderly dependency rate) appears in countries such as Spain, Portugal, France, West Germany and Italy and much of the blue (low rate) appears in Ireland, Holland and East European countries (OECD eXplorer, 2008).

The paper is organized as follows: Section 2 describes the needs for such a tool as seen from the OECD. Section 3 describes the main components of the GAV Flash Geoanalytics. Section 4 discusses how regional information is presented in OECD explorer, drawing examples from the OECD Regional database. Section 5 recalls the main issues emerged during the evaluation phase of OECD eXplorer and how they have been addressed. The last section concludes and sets out future developments.

THE USER PERSPECTIVE: THE OECD WISH-LIST

OECD countries have experienced a growing interest in regional development in recent years [12]. The performance of regional economies and the effectiveness of regional policy help determine a nation's growth and shape the measure of well-being across countries. For the past years the OECD has been studying regional disparities and development patterns in its member countries in order to evaluate innovative strategies and diffuse successful policies.

This work has generated new demand for sound statistical information at the sub-national level on the source of regional competitiveness. The *OECD Regional database* is a unique source of statistical information at sub-national level for all the OECD Countries. It contains yearly time-series for around 40 indicators on demography, economy and labour market opportunities, environment, social issues and innovation related activities for more than 1,700 regions of the OECD countries. Regions within each OECD country are classified on the basis of two territorial levels: the higher level (TL2) consists of 335 large regions while the lower level (TL3) is composed of 1,679 small regions. This classification,

adopted in many countries in the design of regional policy, facilitates greater comparability of regions at the same territorial level. The OECD regional database is available on the Statistical Portal at the OECD website, allowing users to search and combine information on different sectors.

Since 2005 the analysis of regional economies has been summarized in the biannual publication *OECD Regions at a Glance.* This publication illustrates, through graphs and maps, the use of regional indicators for the design and assessment of regional development policies. The focus is on the concentration of resources in a few regions within countries and the persistence of disparities among regions in the access to resources and in their performance.

While these activities have generated knowledge among experts, the OECD has since long felt the need to make regional data much more easily available on the web in an interactive and powerful way. In particular, to make a more extensive use of maps which, more effectively than a graph, can convey the four dimensions included in the regional database: statistical indicator, time variable, country value and regional value. Moreover, many users expressed wishes to be able to select subsets of the database and display the results in maps linked to analytical tools and export views of maps and charts for use in other contexts.

Target groups for such a knowledge-generating visualization tool are quite diverse. A primary target group would of course be the OECD experts themselves and the country experts involved in the policy evaluations. Other audiences include regional planners in countries, regional policy makers in a broader sense, journalists looking for interesting stories about regional differences, as well as the informed citizen. Because of the different expertise and needs of the target-groups, the tool should be flexible and adaptable, so that different versions could be presented to different audiences.

THE GEO-ANALYTICAL FRAMEWORK: THE NCVA TOOLBOX

The GeoAnalytics Visualization (GAV) component toolkit is based on the principles behind the Visual Analytics research program [16] including aspects of explorative and communicative data analysis. First developed for Microsoft's .Net and DirectX [7],[8], the GAV Flash components have now been adapted for the Internet using Adobes Flash basic graphics and Flex 3 for user interface design (figure 1) and developed in Adobe's object-oriented language Action-Script. GAV Flash offers a collection of high-performance interactive visualization web-enabled components based on common methods from the information and geovisualization research domain (figure 3). Highly interactive features that support a spatial analytical reasoning process are exposed such as pan, zoom, tooltips, brushing, highlight, visual inquiry, conditioned filter mechanisms that can discover outliers and dynamically linked multiple views adhering to Shneiderman's mantra [14] "*Overview and zoom, filter and details-on-demand*". The key novel Flash implementations of the toolkit are described in more detail below.
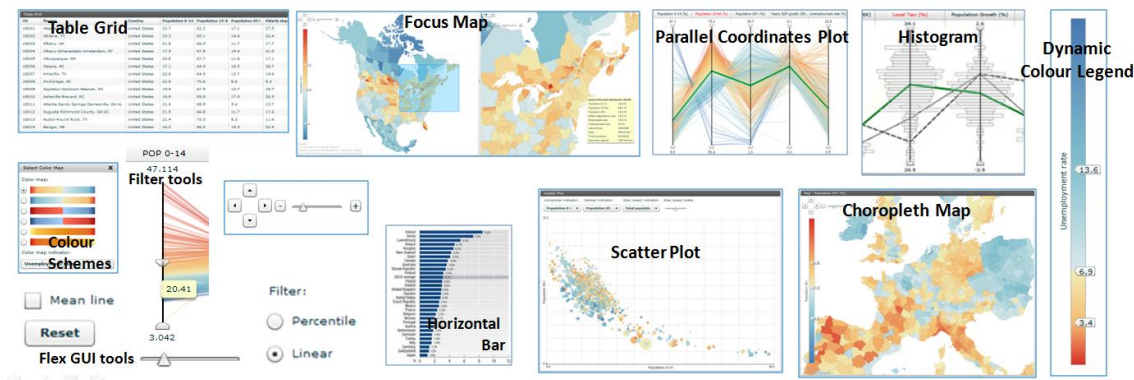

Fig3: Example of GAV Flash GeoAnalytics highly interactive components.

Layered components architecture

The GAV Flash framework enables rapid deployment of customized and user-centric applications by combining low-level atomic and functional components, each one performing a small specific task in the overall GeoAnalytics process (figure 3). The component way of thinking enables a shorter development time, scalability, extensibility, reusability and robustness of applications. An application is developed from two levels of components identified according to their nature in the context of object-oriented programming:

Atomic level components are those low-level, high-performance and typically underlying data structure dependent components that constitute the core of a dynamic GeoAnalytics application. Lower-level atomic components are used for developing functional and highly interactive components. Atomic components from Adobe Flex 3 or other vendors can

be used in assembling functional components. A rich set of component resources with fine grain control allows precise matching to user tasks.

Functional level components are the middle tier components that are constituted by the combination of one or more atomic components. These components typically implement the general functionality of high-profile software, for example, an extended parallel coordinates plot (PCP) component.

The *Application* is the level that is constituted by the combination of one or more functional components. This level is end-user accessible and typically implements one or more of the functionalities in a multiple-linked view environment.

This architecture enables developers to combine the components from GAV Flash with external Flash/Flex components according to the specific needs.

Multiple-linked and coordinated views

Spatial and multivariate data are effectively analysed through the use of multiple-linked and coordinated views. In order to detect complex patterns it is convenient to view it through a number of different visual representation methods simultaneously, each of which is best suited to highlight different patterns and features. These alternative and different views on the data can help stimulate the visual thinking process that is so characteristic for GeoAnalytics. GAV Flash uses Flash and Flex layout management to design various needed web user interfaces. The views are separated by interactive splitters allowing the user to scale the individual views and allocate more space to visual representation that is most important. The views are coordinated using a data linking method where the visualization components use the same cube data model and colouring scheme, and where any dynamic filtering or picking made in one of the linked visualization components propagates to all the others via Selection Manager.

Visual highlighting is another important feature in a multiple-linked GeoAnalytics application. Our implementation focuses on visual representations that use pre-attentive highlighting styles like colour, shape and transparency. Figure 1 shows highlighting implementation in the map, PCP and Scatter Plot views. A combination of transparency and thick coloured lines is applied in the PCP and hollow marked dots in the Scatter Plot.
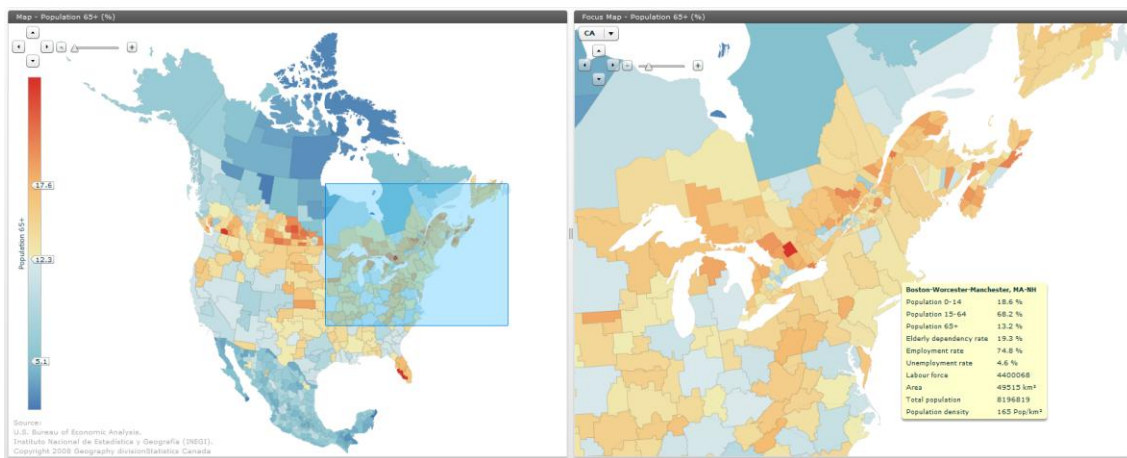

Fig4: OECD eXplorer with two choropleth maps (Focus&Context) for TL3 North America regions.

Dynamic classified Focus & Context maps

The choropleth map "Context Map" (figure 4) provides the overall context such as rich data-dense summary of a selected indicator for thousands of regions. Moving the mouse over the map, tooltips display actual indicator values for comparison. The "Focus Map" (right view) facilitates a zoom view for focusing on individual countries with regional areas of particular interest. The user selects countries from a pull-down menu. A zoom rectangle in the "Context Map" shows the position of the "Focus Map" view.

Parallel coordinates plot (PCP)

The parallel coordinates plot PCP [6] technique has a long history within the InfoVis research community and today is also accepted in various fields in industry and has demonstrated to be useful in several application domains. The strength of the PCP has already been demonstrated in many scientific environments [1],[2],[5] . The PCP is a suitable and proven information visualization technique that enables visual representation of spatial multivariate attribute data and hence a key explorative mechanism in a GeoAnalytics application. The relationships (or patterns) formed in the PCP have, over the years, been extensively evaluated and are today well-known by users in the GeoAnalytics research com-

munity – whereas the have, through this joint project, proven a new and welcome revelation to the statistics community in and around OECD. The technique supports a large number of tasks for both analyses of relationships between data items as well as between indicators. The GAV Flash enhanced PCP component is the first known Flash implementation and integrated with choropleth maps could help to increase its exploitation among the statisticians and public users. The PCP provides features:

- Revealing correlation between indicators;
- Estimation of degree of similarity between regions;
- Finding clusters and outliers;
- Analyze the characteristics of many regions;
- Picking and highlighting of interesting data items for profile and comparison;
- Comparison of individual characteristics of a region to the characteristics of all regions;
- Comparison of indicators associated with a selected region;
- Comparison of variations of values of different indicators;
- Dynamic range sliders and statistical methods for defining events such as exceeding of a given threshold and identification of outliers;
- Intuitive and dynamic visual inquiries, thresholds and conditioned filter operations using range sliders and familiar statistical methods;
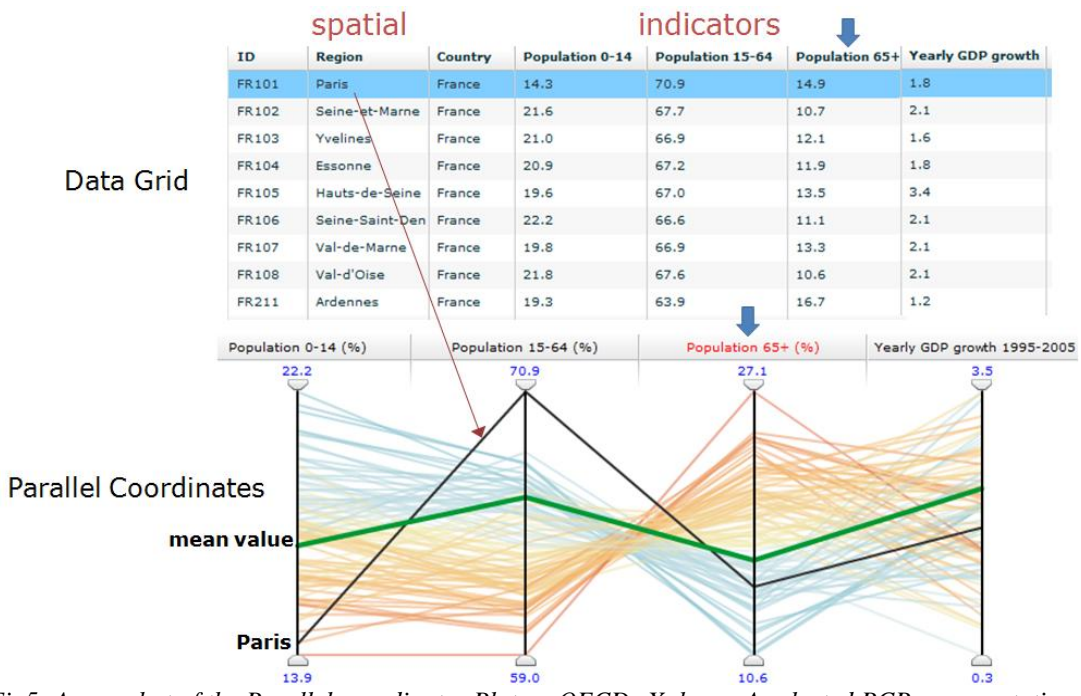

Fig5: A snapshot of the Parallel coordinates Plot on OECD eXplorer. A selected PCP representation with four indicators for small regions in France (provinces). An axis represents a single indicator and regions are represented by coloured strings passing through the axes. This representation enables analysis of relationships between several indicators. Negative relationship, for example, is shown between attribute "age % 15-64" and "age % 65+". Similar profiles of selected regions can be seen by highlighting – here Paris is highlighted in a black thick line. Inquiries and filtering (removing) regions can be performed using range sliders positioned at the top and bottom of the axes (see figure 5). The green thick line represents the mean value in the total regions considered (in this case European countries). Each column in the table corresponds to an indicator in the PCP and a string (regional area) to a row.

Each region is represented by a string (polyline) that intersects the axes at the values of the attributes for that region. Each axis represents a single indicator (e.g. population age groups 0-14, 15-64 and 65+ etc.) in the statistical data set. Each indicator axis corresponds to a column in the spreadsheet. The scaling of the individual axes typically ranges from the indicators minimum values at the bottom to their maximum values at the top. The string forms a visual representation of the characteristics of one regional area - see the highlighted thick black line representing Paris in the figure below. Differences between selected regions can be found by visually comparing the strings representing them and plotted with different line styles (figure 2). This new PCP Flash version has been further extended with dynamic visual inquiries, thresholds and filter operations using range sliders and percentile statistics. These methods facilitate a novel implementation of conditioned focus & context choropleth linked maps steered by a PCP described further below.

Visual Inquiries and Filter operations

Range sliders are attached to each PCP axis and the user can interactively select or combine filter methods thus altering constraints on indicator values. The range of an indicator can be specified by moving the handles on the top and bottom of the corresponding range slider (figure 6). Regions with values for selected indicator that fall outside of the specified range are filtered out. A combination of range slider movements can be used to dynamically formulate complex visual inquiries. These conditions and constraints will immediately reflect the contents in all visual views.
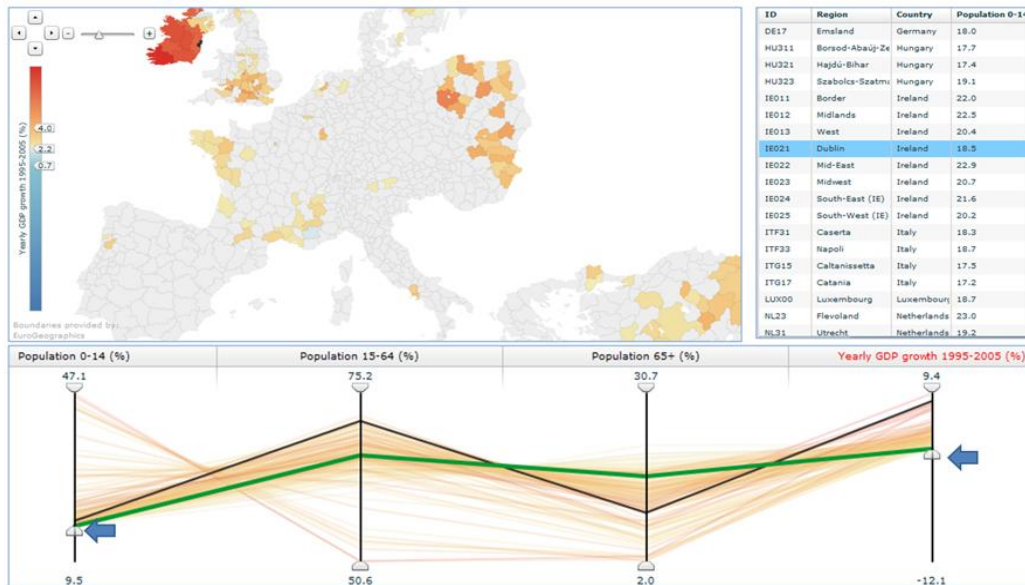

Fig 6: Filtering is here performed using range sliders positioned at the top and bottom of the indicator axes. The first filter condition represents "high percentage for age group 0-14 (above mean value)", followed by a second condition "high values for Yearly GDP growth 1995-2005 (above mean value)". The resulting map shows regions with potential future high economic growth based on a combination of both many younger people and a GDP growth pattern. The Data Grid provides a list of all regions that fulfil the condition.

Axis Percentiles

Using range sliders offers control of the data value of the filtering threshold. However, it does not return any information on the number of data items removed, and is limited to removal of data outside of the range slider. To facilitate the overview and understanding of data distribution the percentile method can be used [9]. By representing the position of specific percentiles and corresponding data values along the PCP axes the user can obtain a statistical correct understanding of the distribution of regions for current indicators. Visual inquiries using statistical measures - a novel dynamic filtering method based on percentiles has been implemented in the PCP, e.g.: "Find regions with an indicator *age 65+* below the 10% and above the 90% percentiles constrained by low values for indicator *unemployment* below the 50% percentile". Given the data lies outside of
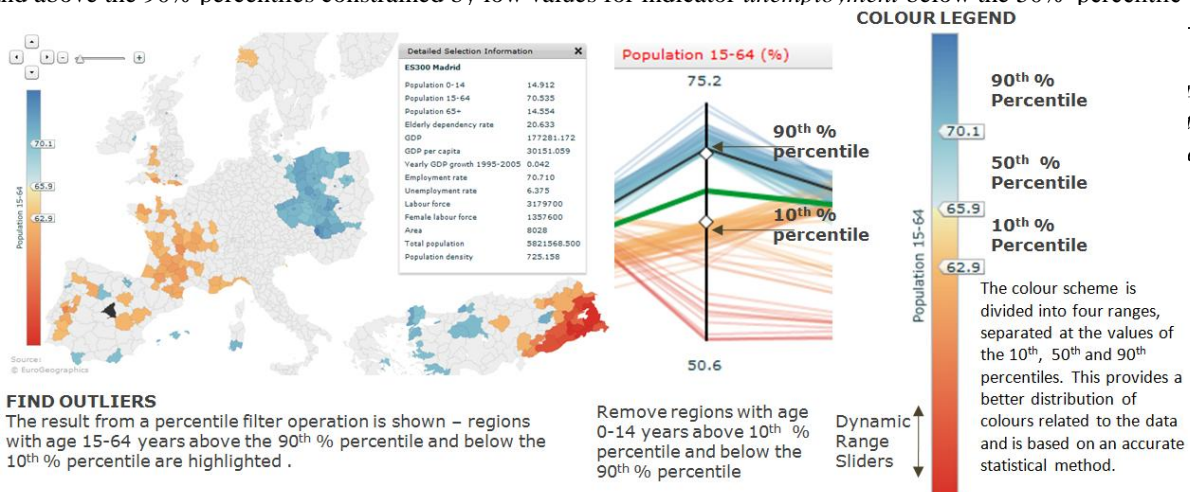
Fig 7: regions are distributed are regions 10%

Dynamic colour legend

Colour coding is a fundamental technique for mapping data to visual representations. We use perception-based colour schemes, which have been evaluated by domain experts and proven to be appropriate for the public end users and facilitate better insight into the data. By considering data characteristics we combine our colour scale legends with embedded fundamental statistics methods. Usually, colour mapping functions perform a linear interpolation based on the minimum and maximum of values of a chosen indicator, a method that leads to problems if the values are not uniformly distributed e.g. if outliers are plotted. In this case a wide range of the colour scale represents a small number of values and the majority of values have to cope with only a narrow range on the colour scale. Our (default) colour scheme is divided into four ranges, separated at the values of the 10%, 50% and the 90% percentiles (figure 7). This provides a better automatic distribution of colours related to the data based on an accurate statistical method and the visualization is improved in a way that differences between values can be more easily detected. Colour scales can also be adjusted interactively and dynamically (e.g. all linked views are updated immediately). The percentile value and corresponding data value is shown to guide the user when moving one of the three range sliders attached to the colour scale legend.

OECD EXPLORER - THE HISTORY AND THE RESULT

When the OECD and Statistics Sweden organised a seminar on innovative methods of generating knowledge from statistical information in Stockholm in May 2008, OECD and NCVA became partners, and it became apparent that the tools developed by NCVA had a lot of potential to meet the wishes of OECD. This started a cooperation that resulted, a few months later, in the launch of OECD eXplorer on the OECD's web site.
NCVA demonstrated ability and will to adapt the tool to the needs expressed by the OECD, and later to the proposals expressed by pilot key users during a two months trial, thus adjusting eXplorer in an ideal way to user needs. The current version of OECD eXplorer (http://www.oecd.org/GOV/regionaldevelopment) has two identical tools to analyze, respectively, statistics on large regions (TL2) and small regions (TL3). This choice was made to avoid complexity and long downloading time of large geometry files. OECD regions are analysed through four separate application scenarios grouping countries in continents and according to the territorial level chosen (figure 2 "Europe" and figure 4 "North America").

The choropleth maps are dynamically linked with a Scatter Plot, PCP and a Data Grid. All views are synchronized to the same point and indicator. We use Flash and Flex layout management, with dynamic embedded resizable views in a single coherent web user interface window that maximize the use of the screen area.

National economic performance is often compared across countries, and such comparisons are frequently used to highlight countries whose national policies appear to promote growth and development more successfully. However, national averages can hide wide regional differences in economic conditions and performances. The use of the filtering function in OECD eXplorer, through the percentile distribution, helps visualizing which regions within national borders are the main responsible of a certain characteristics and to what extend regions across countries are comparable. The use of lines and mean values in the PCP can help identify those regions that outperform their country as a whole or the OECD area and those that lag behind. Finally the scatter plot can highlight correlation among variables and patterns of association among different types of regions.

EVALUATION

The OECD eXplorer development followed a user-centric design approach [17]. A combination of domain experts from OECD, statistical managers and target audience have been involved in the various stages of the prototype design and implementation, providing user feedback about usability and utility evaluation. Our user-centric design process methodology involves public access to various evolution of the web-based demonstrator allowing distributed focus group discussions. The overall involvement and reactions have been very positive and many useful suggestions for improving have been incorporated in successive implementation iterations. A certain number of characteristics of the current version of OECD eXplorer derived from comments received during the evaluation phase. First, it was pointed out the need of having help functions and tutorial features for dynamic web-enabled GeoAnalytics tools targeted to audience whose expertise is not in geo- or information visualization technologies. Second, users asked to keep the entire structure simple enough, while maintaining some functions to analyze data and not only visualize them. In this context, for example, the PCP was considered not self-evident and therefore it was decided to keep it hidden in the start-up phase; at the same time filtering of data distribution was allowed through the dynamic colour legend. Finally the dynamic linked views were appraised to be very valuable for context and focus maps, scatter plot and table grid.
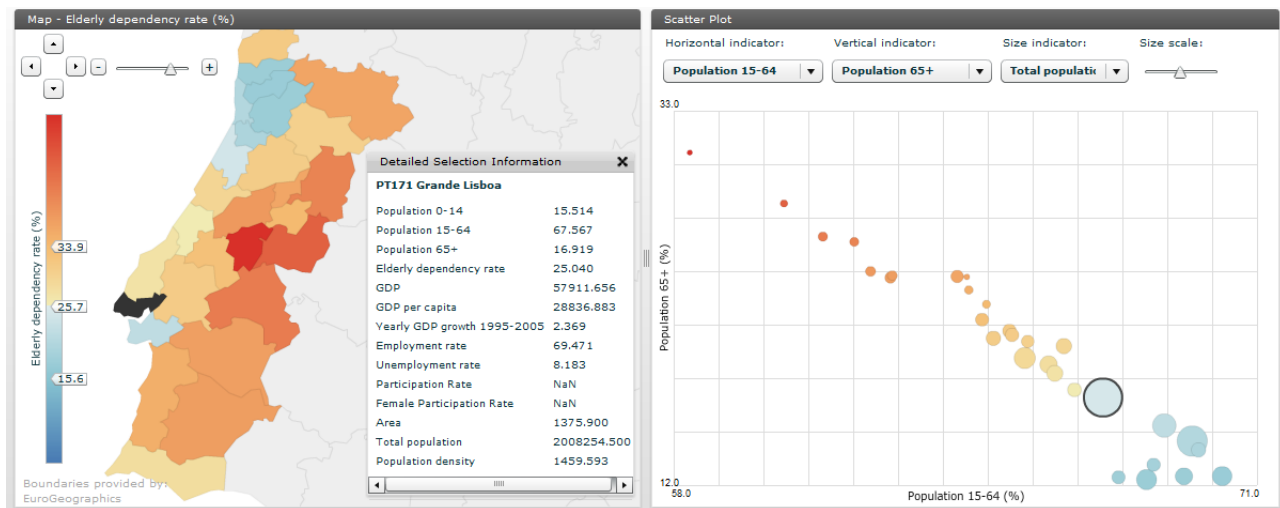
Fig8: OECD eXplorer can also be used to explore social-demographics data for selected countries. Portugal is here explored through two dynamic linked views choropleth map and scatter plot, displaying "elderly dependency rate %" (colour) and "age group 15-64" vs. "age group 65+" in the scatter plot where the radius indicates "total population". Lisbon is highlighted in both views and a "Detailed Selection Information" box shows all indicator values for this regions.

CONCLUSIONS AND FUTURE DEVELOPMENT

We envision that our web-enabled Flash demonstrator OECD eXplorer [11] could encourage the use of advanced GeoAnalytics science technologies, first because of its easy accessibility on the Internet. Secondly, by enabling the analyst to take a more active role in the discovery process of exploring regional indicators, for example, to identify those regional areas that outperform their country or OECD mean values. Likewise, we expect the tool to increase the interest in and knowledge of regional structures and development patterns among specialist and non-specialist users. The patterns of development may differ widely in urban and rural areas and regions may lag behind even when the national economy is performing well. Domain experts and statisticians claim that a sense of analytical reasoning and speed-of-thought interaction is achieved in OECD eXplorer through its ability to dynamically link views and thus see data. Choropleth maps, Scatter Plot, PCP and Table Grid are linked so that all of the views are synchronized to the same point in time. Major achievements in the GeoAnalytics web-enabled eXplorer and associated GAV Flash toolkit are:

- Introduction of a novel GeoAnalytics framework developed in the object-oriented language ActionScript with almost 100% deployment to Internet users for dynamic web;
- A proof-of-concept demonstrator OECD eXplorer developed in collaboration with domain experts from OECD;
- A Flash implementation of an extended PCP with embedded fundamental statistics based on dynamic percentile inquiry and filtering with virtually instantaneous response time;
- Promote the use of a layered component architecture facilitating customizable and scalable applications to be assembled from low-level components and placed in dynamic linked views for Internet use;
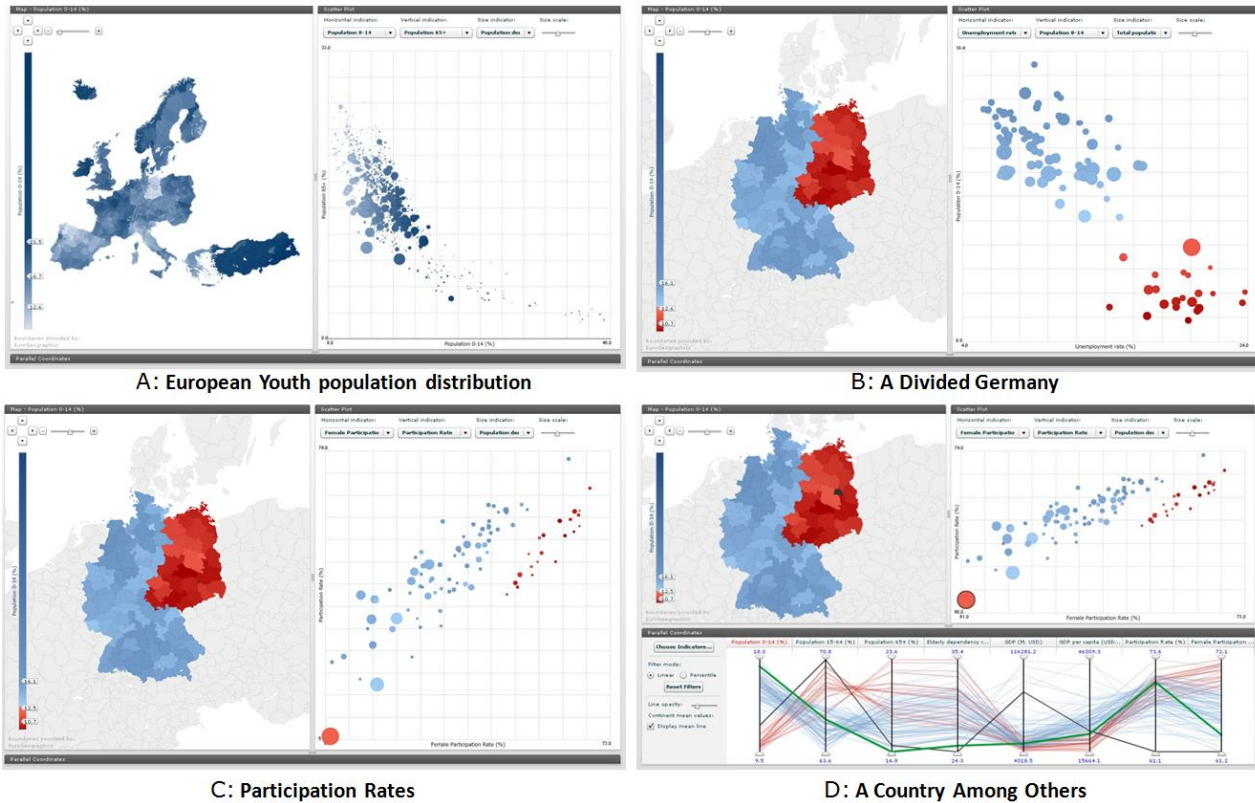
The planned next steps include a more comprehensive user task analysis. Can our customary GeoAnalytics applications be sufficiently powerful and flexible for exploration among domain specialists? Can simplicity and visual appeal tools help unskilled users, or should different versions (sub-sets) of the tool be offered to different audiences? The visual representation styles and interactions described in this paper are also part of ongoing efforts at the NCVA to design usable and intuitive visualization tools for general design guidelines of eXplorer demonstrators. Since the first version of OECD eXplorer was completed in the fall 2008, formative evaluations are taking place using domain experts, target public audience groups, web-based surveys, and verbal protocol analysis to refine the design and interaction of each visual representation method.

An extended version will be launched in March 2009 together with the report *OECD Regions at a Glance 2009*. Three key features will be included in this new version:

- Direct access, via an SDMX web service, to the entire OECD Regional database on the warehouse "OECD.Stat".
- Possibility to explore trends over time (yearly time series) for the indicators in the regional database
- Novel functions for presenting stories about the statistics embedded with interactive visualization.

The last point is for users to be able to save and then re-use or share with others what they have discovered. To achieve collaborative GeoAnalytics, a mechanism is developed that supports the capture and re-use of task-related explorative events in an analytical reasoning process through "memorized interactive visualization views" or snapshots. The overall goal of this new feature is to bring the entire explorative scenario through the snapshot mechanism into web-enabled report formats and share the results with others from this explorative analytical process. The normal contents of a static report, text and still images, are extended with interactive visualization, target data, snapshots or even a continuous story of snapshots and integrated into, for example, a HTML document structure. Figure 9 gives an example of a "story" ex-

A: European Youth population distribution

B: A Divided Germany

C: Participation Rates

D: A Country Among Others

plained through 4 snapshots.

Fig9: Example of a series of snapshots forming a story

A: On this map of Europe we see the regions coloured by the percentage of the population that is between 0 and 14 years in 2005. Darker regions have a greater proportion of young population. Iceland, Ireland and Turkey have the highest proportion of young people, with eastern Turkey taking the lead. After closer examination, we discover that young population rates are unusually low in the Eastern regions of Germany, north-western Spain, few regions in Portugal and north-western Italy.

B: Zooming in on Germany, we see that Eastern and western regions are in fact completely separated in terms of proportion of young people.. In the scatter plot we also see that the two groups remain separated in terms of unemployment rate with the Eastern regions on average displaying a higher unemployment rate.

C: Participation rate is the ratio between labour force (employed and unemployed people) and the total number of people aged 15 to 64. In this scatter plot we can see that the regions in former Western Germany (blue) have a lower participation rate among females than among males, while the opposite is true for the regions in former Eastern Germany (red). Berlin has the lowest participation rate of all the German regions.

D: The Parallel Coordinates plot gives us further options. Each line in the plot corresponds to one region in the map and one circle in the scatter plot. The thick green line represents the average values of all the regions in Europe. The Berlin region has been selected and therefore shows up as a black line. On the first axis (population 0-14), it is easy to see the separation of the two geographical blocks, with all the lines representing former Eastern Germany having lower values than the others. Throughout the rest of the plot we can follow these lines for different indicators, such as elderly dependency rate and GDP per capita. We can also get an indication of what the situation in Germany is like compared to that in Europe as a whole. For example, looking at the third axis (population 65+) we immediately see that all the German re-

gions have a higher percent of people above age 65 than the average. The GDP per capita, on the other hand, is distributed around the European mean.

ACKNOWLEDGEMENTS

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