XGOBI AND XPLORE MEET VIRGIS

Jürgen Symanzik, George Mason University,
Renato Pajarola, Georgia Institute of Technology,
Peter Widmayer, ETH Zürich.

Jürgen Symanzik, Center for Computational Statistics 4A7,
George Mason University, Fairfax, VA 22030, e–mail: `symanzik@galaxy.gmu.edu`

Key Words: Virtual Reality, Geographic Information System, Dynamic Statistical Graphics, Statistical Computing Environment, Linking, Linked Brushing.

Abstract

In this paper we report on a linked environment of the three programs XGobi, XploRe, and ViRGIS. While XGobi and XploRe are statistical packages that focus on dynamic statistical graphics and provide analytical statistical features, respectively, ViRGIS is a 3D Virtual Reality Geographic Information System (GIS) that allows real–time access to, and visualization of, geographic data. The XGobi/XploRe/ViRGIS environment is based on the Remote Procedure Call (RPC) technology previously developed for the ArcView/XGobi/XploRe environment. It allows linked brushing and the exchange of data and commands — completely transparent to the user.

1. Introduction

In our previous work, we developed an open software system consisting of the Geographic Information System (GIS) ArcView, the dynamic statistical graphics program XGobi, and the statistical computing environment XploRe (Symanzik, Kötter, Schmelzer, Klinke, Cook & Swayne 1998, Symanzik, Cook, Klinke & Lewin 1998). In this current project we move on one step and replace the commercial GIS ArcView with the experimental Virtual Reality GIS ViRGIS. The combination of ViRGIS with XGobi/XploRe allows to implement and explore new functionality that is conceptually not possible in the ArcView/XGobi/XploRe environment.

In Section 2 of this paper, we describe the three software packages we have linked, i. e., XGobi, XploRe, and ViRGIS. In Section 3, we look at the main features and implementation issues of the XGobi/XploRe/ViRGIS environment. As an example of its use, we look at Swiss city data in Section 4. We conclude this paper with a discussion of our

achievements so far and our planned next steps in Section 5.

2. Software

We will only provide a short overview on XGobi and XploRe and mostly focus on ViRGIS in this section. Additional information on all three packages can be found in the cited literature.

2.1. XGobi

XGobi is an interactive dynamic statistical graphics program that has been specifically designed for data visualization in the X Window System™. Main features are dotplots of single variables, scatterplots of two variables, and several variants of grand tours and projection pursuit guided tours for multivariate data. XGobi supports missing values and linked brushing among multiple XGobi windows. The most recent reference on XGobi (Swayne, Cook & Buja 1998) describes XGobi as in 1997. Examples of its use such as the visualization of experimental measurements of laser performance and high–dimensional geometric objects can be found in Buja, Cook & Swayne (1996). XGobi can be downloaded for free from `http://www.research.att.com/~andreas/xgobi/index.html`.

2.2. XploRe

XploRe (Härdle, Klinke & Turlach 1995) is a statistical computing environment with a set of built–in statistical methods, a high–level programming language that allows the user to develop additional functions and external libraries, and a modern user interface. Information on the most recent version, XploRe 4, can be found in Klinke & Kötter (1996). XploRe can be downloaded for free from `http://www.xplore-stat.de/`.

2.3. ViRGIS

The growing interest in GISs has lead to more and more complex applications that require the mainte-
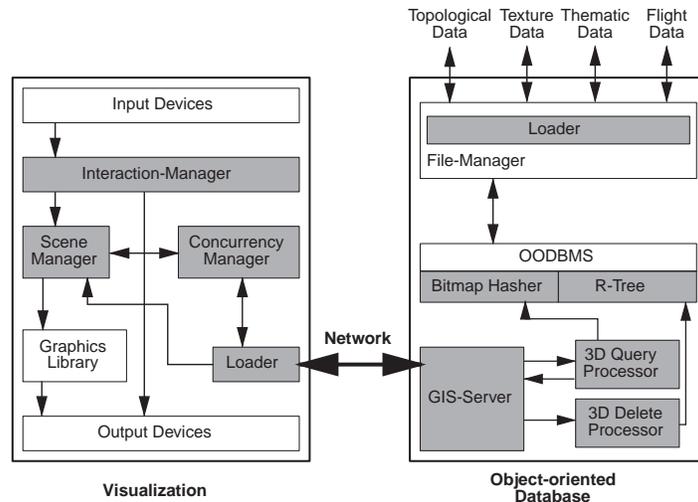

X Window System is a trademark of MIT.

Figure 1: System Architecture of ViRGIS where a visualization unit and a database unit are loosely coupled.

nance of an increasing variety and amount of data. To be useful even for a non–expert user, a GIS should allow the user to explore a virtual world of her choice — indeed quite a powerful metaphor of user interaction (Coyne 1995). The user might, for instance, look around in the virtual alps to find a suitable place for her skiing vacations (Szabo, Stucki, Aschwanden, Ohler, Pajarola & Widmayer 1995). Proper visualization of the scene and all relevant data at the same time is crucial for the ease of use of the system as a whole (Hearnshaw & Unwin 1994). Such a GIS interface could in fact be one of the prime examples of a post–WIMP[1] user interface (van Dam 1997).

The system we developed, ViRGIS (Pajarola, Ohler, Stucki, Szabo & Widmayer 1998, Pajarola & Widmayer 1998), maintains 3D terrain data in vector form (such as surface triangulations), raster data (such as satellite images), and non–geometric data (such as population counts of cities). It allows a user to move through the scene in real–time by means of a standard input device such as a mouse, and to interact with the data in the GIS. Thus far, our interface is a *desktop VR* or video user interface in the classification of Agnew & Kellerman (1996).

Real–time walk–through in 3D scenes is not new: a number of software tools are available that support it. Usually, they limit their walk–through capabilities to a scene that is loaded once and stored in main memory. Our visualization component allows to dynamically maintain a large virtual world, or only a part of it, at different resolutions, and update it accordingly to user interactions. To reduce

the graphics load, ViRGIS displays exact data only where needed, that is, in the close neighborhood of the observer. The farther away we look, the fewer details we can see in reality and need to see in a virtual world. We therefore maintain data in various *levels of detail (LOD)* and access only those levels that are needed.

The efficiency problem that current VR systems have whenever the memory requirements exceed available main memory is one of the reasons for combining two loosely coupled components in ViRGIS — one for visualization and one for data handling. Figure 1 shows the overall system architecture of ViRGIS in which these two components communicate over a (local area or wide area) network.

In the visualization component, the *scene–manager* takes care of updating the visible scene dynamically according to the user's movements and also maintains the different LODs. Furthermore, it keeps track of what is already loaded and what needs to be requested from the database. The database component maintains the data in spatial access structures that support arbitrary rectangular range queries. A server application provides easy network access to the databases.

For the XGobi/XploRe/ViRGIS environment presented in this paper we used an Inventor–based visualization component of ViRGIS. This version uses different grid resolutions of the terrain for different LODs and provides interactive manipulation (rotation, translation, zooming) of the rendered scene. Another ViRGIS visualization component is based on the Performer Toolkit and provides high–performance real–time fly–throughs. In that version, different LODs of the terrain are adaptively created

[1] WIMP stands for windows, icons, menus, and a pointing device.

on–line using the restricted quadtree triangulation model (Pajarola 1998*b*, Pajarola 1998*a*).

Additional information on ViRGIS can be found at `http://www.inf.ethz.ch/department/TI/pw/staff/pajarola/virgis.html`.

3. The XGobi/XploRe/ViRGIS Environment

The XGobi/XploRe/ViRGIS environment is planned as an experimental environment that allows to implement and explore new functionality that is conceptually not possible in the ArcView/XGobi/XploRe environment. Since we have access to the source code of all three programs, we can easily add new functionality to either of the programs. The main idea of this environment is to have a GIS (ViRGIS), a dynamic statistical graphics programs (XGobi), and a statistical computing environment (XploRe) working as closely coupled programs in a homogeneous environment. Obviously, at first glance there exist other software links and environments with similar features. However, the innovation comes through ViRGIS that provides features that are not commonly available in standard GISs, as seen in Section 2.3. We will discuss the main features and implementation issues of this environment and provide a comparison with the ArcView/XGobi/XploRe environment in the remainder of this section. At the current point of time, the XGobi/XploRe/ViRGIS environment is available for SGI^{TM} workstations only.

3.1. Features

Based on data accessible through ViRGIS, we are capable to activate XGobi and XploRe (via XGobi) from within ViRGIS and pass the statistical data into these two packages. This allows to conduct a graphical exploration of the data in XGobi and a more detailed statistical analysis in XploRe.

At this stage, the main feature of the XGobi/XploRe/ViRGIS environment is the linked brushing option that combines quite heterogeneous windows and displays. Obviously, linked brushing is available between XGobi and XploRe. In addition, we can also select points from a textual representation in ViRGIS. This textual representation and any linked XGobi window and XploRe display are also linked to the ViRGIS Inventor view of the 3D terrain. Thus, brushing in one window results in all linked windows being updated. Unfortunately, brushing in the ViRGIS main Inventor view is not

SGI is a trademark of Silicon Graphics, Inc.

possible at this point of time but it is planned as one of our next extensions.

3.2. Implementation

The interprocess communication used in this environment is based on Remote Procedure Calls (RPCs). For the implementation of the RPC mechanism on the ViRGIS side, we closely followed Symanzik, Majure, Cook & Megretskaia (1997). This report provides the required information how to set up an RPC client and server according to the ArcView/XGobi/XploRe standard and specifies which commands are needed to start up XGobi and exchange data and brushing information with it.

Only one minor modification was required on the XGobi side. In addition to the link options "arcview" and "xplore", a new link option "virgis" had to be added. This link option, passed as a command line parameter from the invoking program, i. e., Arc-View, XploRe, or ViRGIS, tells XGobi about the command structure it has to support, in particular how to encode brushing information. Although the command structures how XploRe and ViRGIS communicate to XGobi are identical, the link to ViRGIS does not allow to pass data from XGobi into ViRGIS and to use smoothers in ViRGIS (these are features available in the link with XploRe). Theoretically, additional programs could also use the link option "virgis" to connect to XGobi with all XploRe features being disabled. Due to the sequential invocation of the three programs — first ViRGIS, then XGobi, and finally XploRe — no modifications at all were required on the XploRe side. It does not matter for XploRe whether the data originates from ArcView, ViRGIS, or XGobi — as long as XploRe directly communicates to XGobi and XGobi is responsible to forward any brushing information to additional programs in the environment.

One question that arises when linking 2D and 3D displays is how to translate brushing symbols. Naturally, a circle in 2D relates to a sphere in 3D. But which 3D–object relates to a "+" and "×"? Unfortunately, no optimal solution has been found so far. Another problem relates to brushing with the "default" color in the differently colored backgrounds of the graphics windows (defaults are black in ViRGIS, dark blue in XGobi, white in XploRe). This has been solved by mapping the "default" brushing color with respect to each individual window. Thus, points that are brushed in black in XploRe show up in white in XGobi and ViRGIS and vice versa. All other colors are preserved in all three packages.

3.3. Comparison with the ArcView/XGobi/ XploRe Environment

The main differences between the Arc-View/XGobi/XploRe and XGobi/XploRe/ViRGIS environments are due to the different natures of the incorporated GISs. ArcView only displays a top view on the 2D terrain while ViRGIS provides a 3D visualization. Also, ArcView loads data upon its initialization while ViRGIS (particularly the Performer version) loads only that part of the data that is needed at a particular point of time.

The main difference, however, is that ArcView is a full commercial product where an external software developer has no access to the source code and has to use the interpreted Avenue programming language to superimpose new functionality to ArcView. This is obviously not the most efficient solution. Alternatively, ViRGIS is an experimental GIS with very limited functionality. No efforts are being made to compete with a commercial GIS. However, since a software developer has access to the ViRGIS source code, experimental new ideas can be implemented quickly and efficiently.

4. An Example: Swiss City Data

As an example, we look at data from 3019 Swiss cities. The data set contains demographics such as "Sprache" (language) spoken in that city, ZIP, and "Einwohner" (population). It should be noted that Switzerland is a country where mainly three languages are spoken, i. e., German (1), French (2), and Italian (3). Figure 2 shows XGobi and ViRGIS with the Italian–language region and some of the biggest cities being brushed. Figure 3 shows how the full XGobi/XploRe/ViRGIS environment can be used to explore different characteristics of the language regions.

5. Discussion

Prior to becoming a component of the XGobi/XploRe/ViRGIS environment, ViRGIS did not conform to the RPC mechanism that previously allowed ArcView, XGobi, and XploRe to communicate with each other. The idea of brushing and linked brushing was also unknown to ViRGIS. Therefore, the main achievements so far have been the incorporation of the required RPC functionality into ViRGIS and its upgrade to support linked brushing.

In future directions we plan to make use of these newly won features and implement new interactive brushing ideas. Currently, brushing in most GIS applications is at most marking a region and highlight-ing the points in this region. With interactive controls such as in ViRGIS, we can implement for example a "Flight–Over–Brushing" where points are brushed that are at a certain distance from the observer who is supposed to fly over the landscape. Also, when linked to a statistical display, a "Field–Of–View–Brushing" where points are brushed that are in the current viewing direction of the observer might be quite useful for an exploratory analysis of the underlying data in a spatial context.

And, as indicated earlier, we do not use the Performer version of ViRGIS in our linked environment so far. However, this version and its capability to load new data in real–time from a database might be very useful for an exploratory data analysis. As an example, when we graphically explored satellite images (Symanzik, Cook, Klinke & Lewin 1998), it often would have been convenient to zoom into an interesting region and look at this region at a higher resolution. An interactive zoom into different regions based on the statistical displays and immediate update of those displays after a zoom occurred might be very useful in a variety of fields such as public health, the environments, and agriculture, i. e., whenever data is available at different resolutions and for different regions.

References

Agnew, P. W. & Kellerman, A. S. (1996), *Distributed Multimedia — Technologies, Applications, and Opportunities in the Digital Information Industry: A Guide for Uers and Providers*, ACM Press and Addison–Wesley, Reading, MA.

Buja, A., Cook, D. & Swayne, D. F. (1996), 'Interactive High–Dimensional Data Visualization', *Journal of Computational and Graphical Statistics* **5**(1), 78–99.

Coyne, R. (1995), *Designing Information Technology in the Postmodern Age*, The MIT Press, Cambridge, MA.

Härdle, W., Klinke, S. & Turlach, B. A. (1995), *XploRe: An Interactive Statistical Computing Environment*, Springer, New York, NY.

Hearnshaw, H. M. & Unwin, D. J., eds (1994), *Visualization in Geographical Information Systems*, John Wiley & Sons, Chichester, UK.

Klinke, S. & Kötter, T. (1996), XploRe 4 — A Statistical Computing Environment, *in* F. Faulbaum & W. Bandilla, eds, 'SoftStat '95 Advances in Statistical Software 5', Lucius & Lucius, Stuttgart, pp. 113–122.

Pajarola, R. (1998a), Access to large scale Terrain and Image Databases in Geoinformation Systems, PhD thesis, Department of Computer Science, ETH Zürich.

Pajarola, R. (1998b), Large scale Terrain Visualization using the Restricted Quadtree Triangulation, *in* 'Proceedings Visualization 98', IEEE, Computer Society Press, Los Alamitos, CA. Forthcoming.

Pajarola, R., Ohler, T., Stucki, P., Szabo, K. & Widmayer, P. (1998), The Alps at your Fingertips: Virtual Reality and Geoinformation Systems, *in* 'Proceedings 14th International Conference on Data Engineering, ICDE '98', IEEE, pp. 550–557.
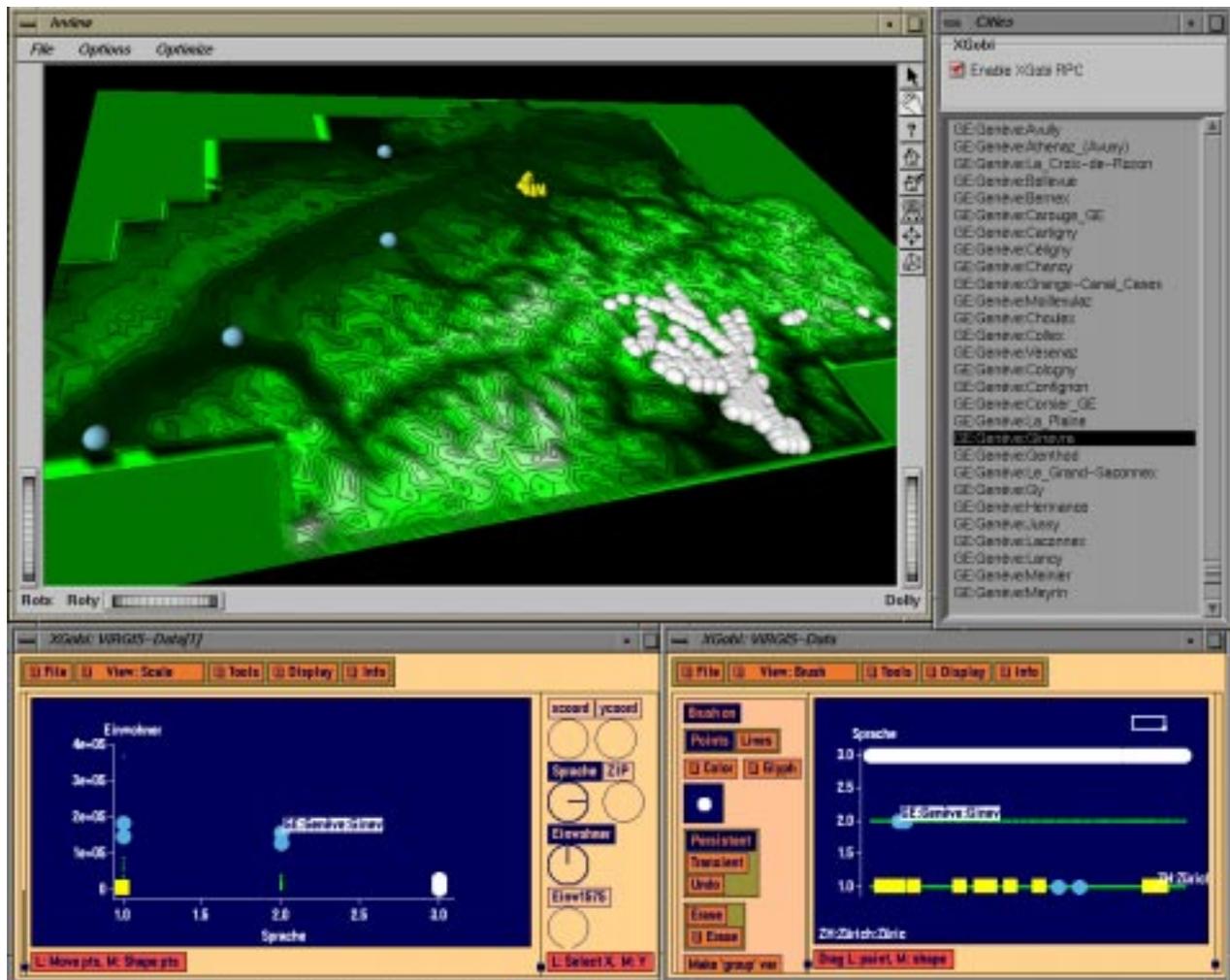
Figure 2: In this figure, ViRGIS and two XGobi windows have been linked. The upper left window shows the ViRGIS Inventor view of the 3D Swiss landscape. The upper right textual representation shows the Swiss cities for which point data is available in ViRGIS. The lower right XGobi has been invoked through ViRGIS and displays a dotplot of "Sprache" (language). The lower left (cloned) XGobi displays a scatterplot of "Einwohner" (population) versus "Sprache" (language). In the lower right XGobi, Sprache = 3 (which represents Italian) has been brushed. This relates to south eastern Switzerland as can be seen in the ViRGIS Inventor view. In the lower left XGobi, the second and third biggest German–language cities and the two biggest French–language cities have been brushed. As it can be seen in the ViRGIS Inventor view, these cities (Bern and Basel & Genève and Lausanne) are all located in the western part of Switzerland. Prior to brushing in XGobi, several smaller cities in the region of Zürich have been brushed in the textual ViRGIS window (but have been scrolled outside the visible range now) and are represented as small cones in the central part of the ViRGIS Inventor view. As the related filled boxes in the two XGobi windows reveal, these are German–language cities that have at most 10,000 inhabitants. Genève has been labeled in three of the windows. Digital elevation model RIMINI © 1996 Swiss Federal Office of Topography.

Pajarola, R. & Widmayer, P. (1998), 'Virtual Geoexploration: Concepts and Design Choices', *International Journal of Computational Geometry and Applications*. Forthcoming.

Swayne, D. F., Cook, D. & Buja, A. (1998), 'XGobi: Interactive Dynamic Graphics in the X Window System', *Journal of Computational and Graphical Statistics* **7**(1), 113–130.

Symanzik, J., Cook, D., Klinke, S. & Lewin, N. (1998), 'Exploration of Satellite Images in the Dynamically Linked ArcView/XGobi/XploRe Environment', *Army Research Laboratory Special Report*. Forthcoming.

Symanzik, J., Kötter, T., Schmelzer, S., Klinke, S., Cook, D. & Swayne, D. (1998), 'Spatial Data Analysis in the Dynamically Linked ArcView/XGobi/XploRe Environment', *Computing Science and Statistics* **29**(1), 561–569.

Symanzik, J., Majure, J. J., Cook, D. & Megretskaia, I. (1997), Linking ArcView 3.0 and XGobi: Insight Behind the Front End, Technical Report 97–10, Department of Statistics, Iowa State University, Ames, Iowa.

Szabo, K., Stucki, P., Aschwanden, P., Ohler, T., Pajarola, R. & Widmayer, P. (1995), A Virtual Reality based System Environment for Intuitive Walk–Throughs and Exploration of Large–Scale Tourist Information, *in* 'Proceedings Enter95: Information and Communication Technologies in Tourism', Springer, Vienna, pp. 10–15.

van Dam, A. (1997), 'Post–WIMP User Interfaces', *Communications of the ACM* **40**(2), 63–67.
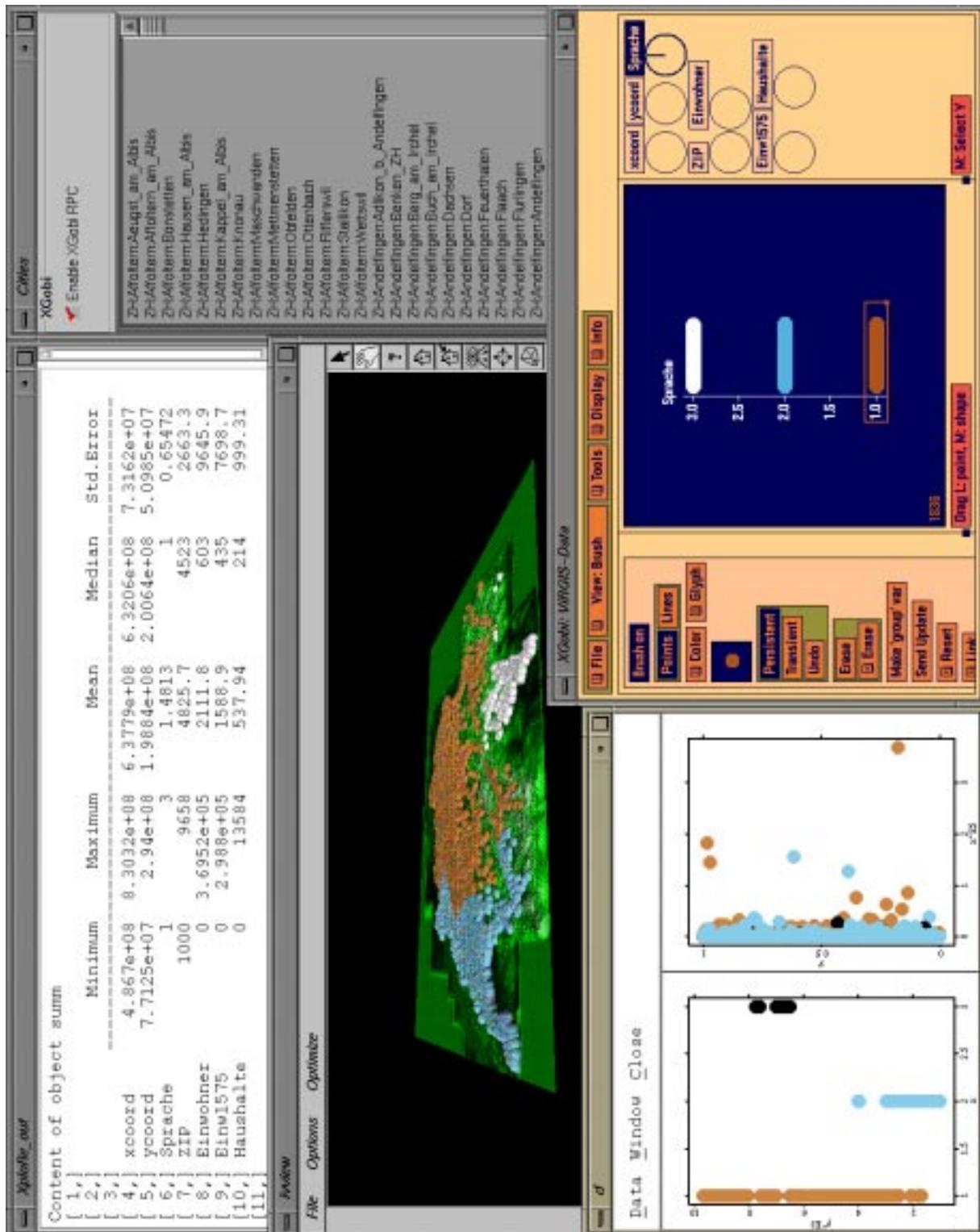
Figure 3: Similar to Figure 2, ViRGIS has been linked with one XGobi window which displays a dotplot of "Sprache" (language). In addition, two XploRe windows are shown. The upper left XploRe output window shows some summary statistics for the 7 variables of the Swiss city data. The lower left XploRe graphics display contains two plots: a scatterplot of "ZIP" versus "Sprache" (left) and a dotplot of "Einwohner" (right). Through linked brushing, the three different language regions of Switzerland have been highlighted in the ViRGIS Inventor view. Different characteristics of these regions can be seen in the XGobi window and XploRe display. Digital elevation model RIMINI © 1996 Swiss Federal Office of Topography.