V.I.P. – Supporting Digital Earth Ideas Through Visualization, Interaction and Presentation Screens

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【Abstract】

The concept of digital earth can be described as a large knowledge database for various application areas, such as geography, economic sciences, social sciences, environmental sciences, biology, and urban planning and development. Nevertheless, not only the gathering and compiling of data is important; extracting, mediating and representing the information to the human user is at the core of this entire process. How can this massive amount of complex information from the various application fields be made accessible to expert users working with the data, but also to citizens using the data as a public knowledge base?

For us, the three components *visualization, interaction techniques* and *choice of presentation display* are inextricably linked and therefore have to be considered when it comes to the question of information perception.

Visualization can be used to make complex data more accessible, especially for non-expert users. It helps both expert users and non-expert users acquire the desired data faster. All this can be achieved by tapping into the rules and particularities of how humans perceive and process information.

Furthermore, the display type can be crucial for the perception of information. Small, low-resolution screens are not suitable to display multi-dimensional data due to the limitation of both precision and screen real estate. These facts lead to flaws regarding workflow and information accessibility: the user has to perform permanent "zoom & pan" operations to perceive certain data.

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Also, single user workspaces limit collaborative work. It is known that multiple users forming a cluster in front of a small display to discuss data does not provide a fruitful outcome. Interdisciplinary communication is necessary and can be improved with a careful choice of the display type. Thus, high-resolution large displays and multi-touch cells enable face-to-face interaction, which significantly improves communication and workflow.

Last but not least, interaction allows the direct interpretation of human motion and gestures. Aspects of both simplicity and usability have to be considered when designing a system. Users have to be able to access information in a natural and intuitive way. This is crucial for public information systems, where one can consider the users as having different backgrounds and varying margins of expertise. Nonetheless, all users have to be able to operate the system without a long training period.

In this paper we will provide examples and concepts for all of the three components.

Keywords: Information Visualization, Display Technologies and Interaction Techniques, Public Participation and Public Awareness, Collaborative Work, Concept, Input and Output Devices

1. Introduction

In this paper we provide an insight to visualization, interaction and presentation techniques which can be utilized to suit the concept of digital earth as a large, ever growing, knowledge database.

In the past years diverse data has been collected, digitally rehashed and stored. The question is how we, the users, can benefit from this data?

The emerging of new display technologies and interaction devices open up new possibilities for interdisciplinary collaborations. Large displays can be used to visualize multi dimensional data, also enabling *face-to-face* discussions with multiple users. Technologies like multi-touch cells combine collaborative work and multi-user environment with intuitive interaction options.

A goal of the digital earth concept should be, to give a broader audience the possibility to access and understand geographic, economic, social, environmental, biological, and urban planning and urban development coherencies. Visualization, interaction and presentation can, in combination, give support in achieving this goal.

In the following we provide insights and examples to each V.I.P. (visualization, interaction, presentation screens) area.

2. Visualization

With the adequate visualization of complex data, users can access the information both more easily and quickly. Google Earth, a very popular virtual globe, can be utilized as a visualization tool, facilitating working with complex data sets, e.g. census data or climate mapping [9], [10].

Figure 1: Different approaches utilizing Google Earth as visualization tool for urban planning applications. Complex databases are visualized using Google Earth, making data mining and finding correlations more intuitive [9], [10].

Air Quality is monitored in nearly every city. Air Quality also has become a well-known catchphrase since public awareness was raised by particulate matter and carbon dioxide discussions. A high volume of measurement data is produced, based on the different pollutants and multiple measurements per day.

The challenge is to improve the accessibility of this complex data, both to the public and to the different actors working with the data. On the one hand, it is important to provide this data to the public as a basic, unfiltered information resource; on the other hand, the data is crucial to planners as a basis for planning decisions. In the later, it is important that actors with a different standard of knowledge can access the information.

This can be achieved by using suitable visualization techniques. FEVER, is a *visualization metaphor* for visualizing air pollutants. FEVER gives powerful user support, as the accessibility of important information is improved in a very natural, intuitive way, making it user-friendlier to explore the measurement set. By using FEVER, both workflow and user satisfaction is enhanced. Instead browsing through tables, the user can access each pollutant, visualized as a virtual mercury thermometer (see Figure 2).

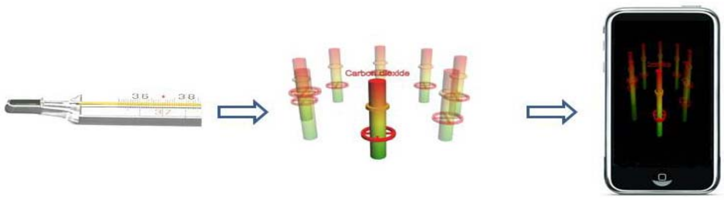

Figure 2: From real-life object to visualization metaphor: FEVER. Such a metaphor is also suitable for public information/awareness on mobile devices like smart phones. Citizen can receive actual information of *Air Quality*.

The visualization of different types of global data requires, especially in the current day and age of mobile devices, that visualization tools are built with portability and simplicity in mind, to allow the users to extract and analyze information in almost any location.

Sphere Library, an example for a lightweight visualization tool, is an Adobe Flash library that considers these aspects. Small and powerful, Sphere library (Figure 3) is oriented towards interactively visualizing a time-variant spherical environment containing scientific data, be it scalar or vector-based.

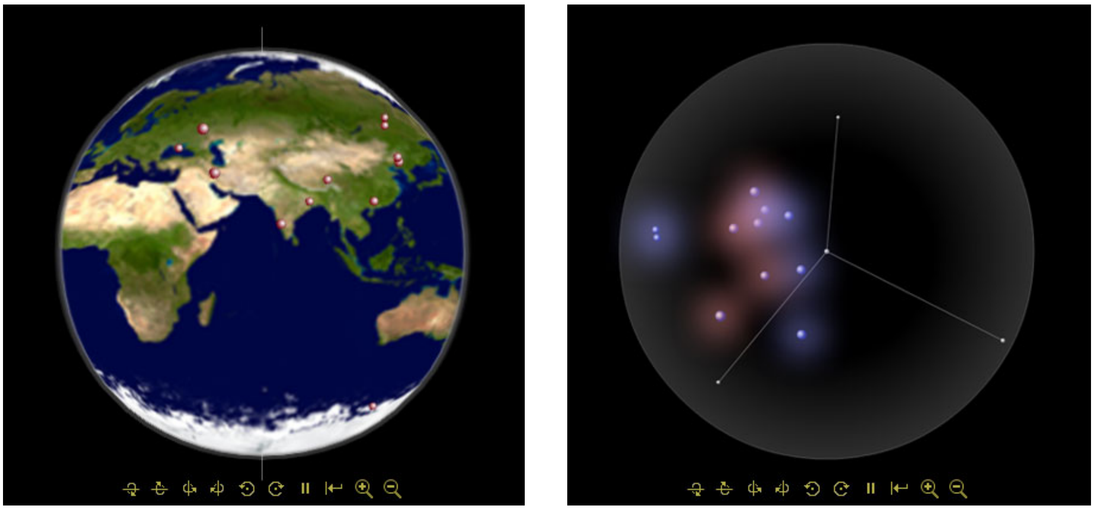

Figure 3: (a) Sphere library Web application highlighting the global position of a group of people. The markers are animated over time, suggesting the motion of the targets on the Earth's surface. (b) Sphere library-based software capable of representing positions inside, on and above the surface of the earth. The markers can be grouped via color clouds that have an additive property, and do not induce occlusion.

The library supports representation of information with a 3D radial distribution, where the entire 3D space is centered and can be rotated around its middle point. Additionally, the software supports standard operations, like translation, axis rotation, free rotation, zoom, etc. The user can interact with the application in multiple ways, similar with Google Earth, by direct mouse clicks, buttons on the screen or key shortcuts.

The input data can be formatted both in 3D Cartesian and spherical coordinate systems, making Sphere library predestined for devising specific globe-oriented representation applications. Additionally, while implementing an application, one can choose to generate a sphere of various radii, and either map a texture to it, or represent it in a translucent way. Thus, applications have been devised for representing data on the surface of a digitally rendered globe (Figure 3a), as well as programs for visualizing information inside a sphere - e.g. earthquake focal points (Figure 3b).

The main focus of the applications developed with Sphere library is the representation of different points of interest and their evolution over time. Clearly visible markers that can be positioned on, over or in a sphere generally achieve this.

As previously suggested, Sphere library also offers the possibility of animating the environment (e.g. rotation of the Earth) and the scientific information in it. Moreover, the changes in the data can be visually tracked and analyzed also by morphing, a procedure that represents various interactions between different markers over time. The markers can additionally be grouped into clusters that are represented in two ways: soft and cumulative clouds. These cloud representations (Figure 3b) try to highlight the spatial representativeness of selected features in a particular 3D location – similarly to 3D interpolation. The user can also influence the position of the markers interactively, as the library offers support for dragging them to different locations.

A special feature is the presence of an anaglyph support module that allows the development of stereoscopic 3D applications. These programs can then be viewed with two color glasses – red and blue, further enhancing the depth sensation of the user.

As the goals included an effective Web-loading process and execution inside a browser, but also the capacity to handle large datasets, a particular attention was given to the overall performance; currently, applications are developed with Sphere library that run well inside the Web browser with thousands of information markers rendered.

3. Interaction

Working in a 3D virtual environment generated by a computer is a task that benefits strongly from an interaction method oriented towards harvesting the 3D spatial intuition of humans. This type of 3D interaction, with its six main degrees of freedom (*DoF* in the following), is usually hard to achieve by means of a mouse, especially simultaneously.

Figure 4: Google Earth interaction with a 6 DoF mid-air device

To cope with this problem, multiple input devices have been developed in recent years that offer direct control of up to six degrees of freedom – three translation axes and three rotation axes. One representative device in this sense is the Space Navigator [15] that resembles a joystick, while allowing multiple separate actions. Besides offering complete control to the user over the directions of 3D space, the Space Navigator has the extra advantage of permitting the user to control multiple degrees of freedom simultaneously.

Nevertheless, such an approach still restricts the user's mobility to a surface (e.g. table) on which the device needs to rest, situation that is undesirable in multiple presentation and collaboration tasks. In this case, the so-called mid-air or free-space devices offer an alternative. One simple, but efficient implementation of such a mid-air wireless device is the Soap device [4]. Soap consists of a wireless optical mouse that is enveloped in a flexible hull. This combination enables the user to pick up the mouse and rotate it inside the hull, like a bar of soap. In the mean time, the mouse works in the same way – taking distance measurements, only that it does now measure motion as a reference to the inside of the hull instead of the surface of a table.

While Soap still remains a 2 DoF device, game controllers like the Nintendo Wii remote [8] can also be reprogrammed to function as a computer input device. By computing the angles that the Wii remote or Wiimote turns while held in the user's hand, one can already control the 3D virtual space. While the controller does not yet offer a complete and simultaneous 6 DoF interaction, it does compensate by a low cost of acquisition and software development, as well as other additional features like embedded infrared camera, mini joystick and buttons.

Similarly, the Apple iPhone [18] with its many included functionalities, is a device suited for being modified towards interacting with a three dimensional environment, like CAD applications or 3D navigation. As in the case of the Wii remote, the iPhone can be tilted and turned, movements that are detected and interpreted correspondingly by a target application. Furthermore, the presence of a small, local display can be an advantage in many scenarios.

Figure 5: Wireless mid-air devices for interaction with presentation technologies – (a) SOAP [4], (b) Wii remote [16] and (c) iPhone [18]. These devices have the advantage of being inexpensive, simple and intuitive to use, offering access to additional controls and user mobility.

The last two devices have the advantage of incorporating an accelerometer [7] that can control an application like Google Earth directly, by means of tilting the device in different directions. As a more complete alternative, the accelerometers inside these devices – together with other functionalities – can be used for gesture recognition [5]. Using a Wii remote or an iPhone, users can mimic throwing actions, moving, pointing, dragging and other complex operations. These actions are even better supported on an iPhone, which also incorporates a digital 3D gyroscope, thus allowing the determination of the user's hand orientation.

A particular approach for using the Wii remotes as a way of detecting gestures and interacting with a computer is presented in the next chapter.

Tag-Based Interaction with Large High-Resolution Displays

Because of their screen area, large high-resolution displays have been used for the visualization of large data sets, as well as for collaborative research. When dealing with large displays it becomes apparent that there is a lack of appropriate input devices for simultaneous interaction of multiple users. Collaboration is usually limited by the type and number of input devices used in most installations. Multiple users generally share a single device, and often, one person takes the lead and controls the visualization for the entire group. True collaboration, however, means every user has their own input device that they can use to interact with the data being displayed on the screen, and both the interaction device and the display wall potentially respond to each user's input.

Besides, there is a more general problem when working with large displays: *user group management* and *access control*. Often it is necessary to structure data sets and restrict access to certain parts of information through user privileges. Many approaches ignore user group hierarchies and present the whole data set to the entire user group. Thus, it is hard to deal with confidential data (e.g., answers to a quiz) and present information depending on the user status (e.g., student or teacher).

Tag-based interaction [11],[12] provides a simple solution to these problems for a variety of applications. The idea is to use today's most common electronic device, the cell phone, in combination with two-dimensional barcodes/tags (see Figure 7) as a way to interact with large displays. Tags are placed inside a scene are scanned by users with their camera-equipped cell phones which run a special tag-decoding software (see Figure 6). When a tag has been decoded, the cell phone connects to a server via Wi-Fi and launches a series of web-services that, in their simplest form, display computed data on the cell phone screen. However, more complex interaction metaphors are possible. Because each cell phone can be uniquely identified based on the IP address, it is possible to present information based on the current user status and access privileges.

A variety of two-dimensional barcodes exists (e.g., EZcode, QRCode, Maxicode and ShotCode) that mainly differs in the way information is encoded and the number of bytes that can be represented. Figure 7 shows an example of a *High Capacity Color Barcode (HCCB)* that has been invented by Microsoft and is able to encode URLs, free text passages, vCards, and dialers.

Figure 6: Scanning barcodes.

Figure 7: High Capacity Color Barcode.

Tag-Based Interaction with Google Earth

The tag-based interaction approach is used in a *Google Earth*-based application [11] that runs on a fifty-tile display cluster, whose LC panels have been arranged in a 10x5 grid (see Figure 8). Each screen has a native resolution of 2,560x1,600 pixels, resulting in a total resolution of 25,600x8,000. This corresponds to a display capacity of more than 200 megapixels. The application visualizes *census data* of Maricopa County, Arizona. Census data sets contain information about the age distribution, ethnical background and housing situation of a population in a certain area. They are structured into *census tracts*, each associated with a high-dimensional feature vector. The data set consists of 663 tracts and stores 60 values per entry. With that size, it is too large to be displayed on a single monitor system for proper investigation, and the number of dimensions is likely to cause information clutter.

Tag-based interaction enables multiple users to explore and investigate the data set simultaneously. Tracts are visualized as brown colored polygons with tract IDs and barcodes in their centers. When scanning a barcode, users decide whether they want a *description balloon* to pop up (see Figure 6) or whether they want to display tract information on their cell phone. Description balloons consist of tables that contain general information about census tracts (i.e., name, total population, total number of households and average household size). The data displayed on the cell phone is more comprehensive. Indicating an information class number can set a detail level for the number of values. The higher the number, the more details are displayed. Figure 8 illustrates a typical website that appears on a cell phone screen after scanning an HCCB. Twelve of the sixty feature values are displayed in a table and a diagram is shown to give a better overview of the census tract's housing situation. With the "publish" button at the bottom of the site (marked red) its content can be transferred to the public screen, which is located at the rightmost column of the display wall (see Figure 3). *A public screen* is a designated monitor of the tiled wall, which displays information that would normally only be visible on the cell phone screen. The idea is to facilitate group discussions by making the object of focus visible to the entire.

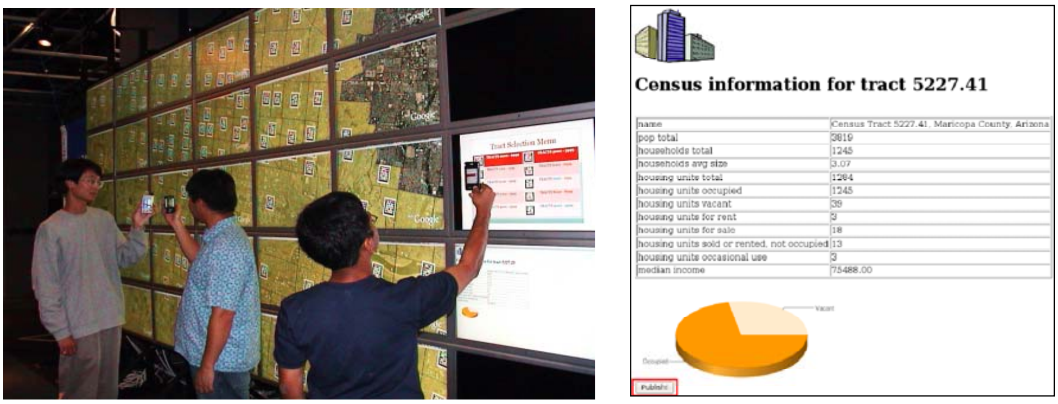

Figure 8: Tag-based interaction with Google Earth. On the right hand the Census tract information displayed on the mobile phone screen.

4. Presentation Technologies

Nowadays, the presentation technologies that can be employed for displaying digital information of various global aspects are rather diverse, ranging from standard computer terminals with monitors to large screens [6], [10], interactive surfaces [14] and projector walls [8] with various interaction modalities.

When speaking of large displays, tiled display walls are popular solutions. They are cost efficient (LCD-based), scalable and combine a very high resolution with a large screen size, making them ideal for visualizing large datasets.

Beside improved workflow, they also offer enhanced perception and cognition [1], [2], [3]. Users also can exploit the size of the tiled display, enabling the use of spatial memory and human-zoom (focus and context approach) [6] and collaborative work [10].

Figure 9: Tiled displays offer the advantage of large screen real estate combined with high resolution, making them ideal for displaying multidimensional data and collaborative work [10].

Sadly, the expenses for one of the later devices are usually high, making their accessibility limited. Additionally, combining large display technologies with useful visualizations and intuitive interaction methods can be a very complex undertaking.

To overcome these issues, the Wii-rtual Room interactive environment has been designed, as a simple and cost effective alternative to available commercial products. As the name already suggests, Wii-rtual Room has at the heart of its design a Wii remote based finger tracking [13], where the infrared camera of a Nintendo Wii remote [16] detects and tracks separate infrared light sources, offering a cheap solution for a mid-air interaction in the virtual environment.

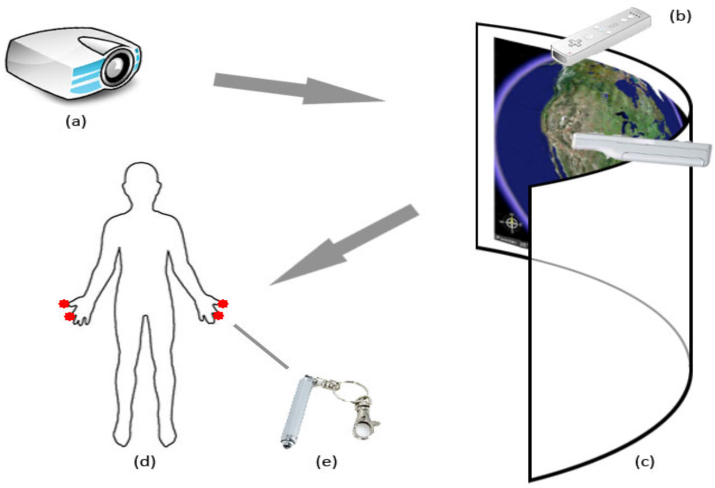

Figure 10: Representation of the Wii-rtual Room concept: (a) standard projector, (b) two Nintendo Wii remotes mounted on the projector screen, (c) an arc projector surface of 120 degrees, (d) user holding up to 4 IR sources, (e) simple infrared LED light.

The method, as described in Figure 10, requires the presence of a projector and a projection surface to represent the digital information, as well as two Wii remotes – connected to a computer via Bluetooth and used in combination to achieve stereovision – that track the presence and motion of up to four infrared sources.

In our configuration, the display image is projected in the virtual environment on a 120° arc-display. The rendered computer interface is controlled by hand and arm gestures, allowing for complex interactions: translate, rotate, select, pan, zoom etc. This is accomplished by using multiple small infrared LED emitters (Figure 10e) attached to the user's hands and fingers, two Wii remotes mounted on the display and pointing towards the user, as well as a .NET-based application using the WiimoteLib [17] library. This application collects the information from the two infrared cameras present in the Wii remotes that register the motion of the IR sources, and interprets these as commands. The complexity of the task is increased by the presence of multiple IR sources (4 or more).

The Wii-rtual Room can also be implemented by means of high-resolution webcams instead of Wii remotes, in order to detect particular shapes (called glyphs) drawn on small patches attached to special gloves on the user's hands. The glyphs are representations of simple shapes printed out on small pieces of cardboard. If required, more complex shapes, like the barcodes presented in *Chapter 3*, can be also used as detectable glyphs, as the upper limit of glyph complexity is only defined by the resolution of the webcams.

Compared to the IR-based approach, the webcam-glyph combination has the distinct advantage that it can function in an environment with multiple light sources, while visible light in the case of IR-cameras might create false positives. Thus, the two variations of the Wii-rtual Room complement each other, as glyph tracking requires a decent amount of visible light, and IR tracking functions best in darker settings.

5. Conclusion

In recent years the concept of a digital reflection of planet Earth has become more and more popular. The first models of planet Earth, basically virtual globes, rapidly became more comprehensive. Google Earth is one very popular example for this progress: users are able to contribute own content (ranging from pictures and 3D models); it also can be used as a platform for more complex *information visualization* and *information exchange* (e.g. database visualization).

Popular catchphrases, for example, are *civic participation*, *public information* and *public awareness*, *planning* and *decision support*, and *collaborative work*. With more enhanced display technologies and interaction techniques this systems will gain even more attention. On the one hand new display technologies open up the systems for collaborative work, on the other hand interaction techniques make a contribution to usability. Furthermore the progressive development in the field of smart phones/mobile phones also offer a variety of both interaction and visualization possibilities.

In certain application areas, especially urban planning, the availability of information is crucial. Without proper information sources, developing sustainable planning is impossible. But here first problems can arise: is the provided information valid? Are there issues with privacy, having sensible data in mind? Who else can access certain information, especially more sensitive data? These questions arise, especially when dealing with multi-user environments. The *tag-based interaction* approach addresses this problem. *Tag-based interaction* offers *access control* and *user group management*.

In general one can recognize a development process towards more user-oriented environments. With adequate visualization metaphors users can be relieved, browsing through information can be improved with thought through visualizations.

Intuitive interaction techniques offer the advantage of lower training periods, which is a plus for both expert and non-expert users. This fact means for expert users in work life: a reduced cost factor (less training), for non-expert intuitive interaction techniques are a reduced frustration factor.

The combination of V.I.P. (visualization, interaction, presentation) can offer a fruitful enhancement of the digital earth concept, making it more versatile.

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