TANGIBLE USER INTERFACES IN ORDER TO IMPROVE COLLABORATIVE INTERACTIONS AND DECISION MAKING

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ABSTRACT

Often people need to cooperate and interact in teams or discussion groups to achieve a common purpose, such as taking a decision, analyzing a problem or developing an idea.
Providing and sharing geo-information for a group of participants can be achieved with different traditional methods: with a map laid on the table, projecting data on a wall or with simply using computer monitors. A new approach to improve collaborative interactions focuses on two main aspects: an advanced visualisation of the information and a new approach in the human-computer interaction.
The traditional way of displaying geographical datasets is replaced by tangible interfaces where data is displayed on a table surface and used as central point for the discussion. The data presented on the table can also be accompanied by other devices as LCD or plasma's screen where it can be displayed in different environments, 2D, augmented reality or 3D virtual environment, providing a different visual approach to the same dataset.
Users interact with the system directly on the table surface, just with their hands or with drawing pens or with special coloured patterns. The system reacts on the movements on the table and responds displaying the requested information on the table surface. We expect that the new interaction is intuitive, attracts people to the table and invites them to interact with the table itself. However, further research is necessary to proof our assumptions.
The paper explains the concept of GI systems integrated with tangible user interfaces, describes and compares three solutions recently developed.

AN INNOVATIVE WAY OF COLLABORATIVE INTERACTIONS

Human communication can be stimulated, facilitated, improved and assisted because of the constant progress of information technology. Nowadays, thanks to hardware, software, data storages, networks for exchanging information, people can easily interact in order to exchange information, to discuss, to analyze and approach various kind of common problems. One way humans cooperate can be classified with the term of *collaborative interactions*. In collaboration and team works, people often need to constantly communicate with each other, to develop an idea, to create a design, to achieve a certain goal, to solve certain problems or to make decisions.

Participants gather together, cooperate, interact with computers via input devices such as mouse's and keyboards and evaluate information represented and displayed in output devices, such as monitors and wall papers.

Especially when collaborative interactions have to do with spatial problems, examples can be found in areas as public safety, national defence and emergency management where discussion groups are essential for quick decisions and rapid responses. Also in an urban context, for example, the choice of a suitable location for placing new constructions, such as buildings or offices is also a decision taken by a team group.

In general, real collaboration technologies deliver the functionality for many participants to augment a common deliverable. Fundamental aspects that need to be considered within collaboration technologies are:

- visualising geographical information;
- human-computer interaction;
- situational awareness;
- cognitive mapping;
- collaborative decision making

The first two of these aspects will be described in more detail.

Visualising geographical information

Nowadays the demand for a higher information density requires a good data infrastructure including databases and GI systems for analysis and display. These systems currently exist, but the display is usually limited to computer screens or wall projections. In general these traditional methods of visualising geographical information do not any longer satisfy the needs of the users, especially not in collaborative interactions.

Considering the urban context as example, strategic decisions were usually taken since ever by the decision makers gathered around a map placed on a table surface. A map laid on a table provides a good overview of the area of interest, makes possible to point to different locations and therefore it is a very useful mean to assist the communication. The described situation still exists today but it needs to be realised that paper maps are becoming a bit outdated.
The concept of standing around a map on a table surface to discuss and to make decisions on spatial questions has been replaced by a digital wall projection, but even this method is not optimal to discuss spatial issues.
A possible solution to allow again round table discussion can be realised projecting the output of the interactive GI system on a table surface. The discussion would have the table as focal point, people could converse referring to information displayed on the table, conducing to a clear and more efficient way of exchanging opinions. Additional information or different ways of displaying the data represented on the table could be presented in the system using output devices, such as plasma or LCD screens. If on the table the 2D representation of the area of interest is projected, this information could be for example augmented with attribute information or the 3D representation on the screens.
We will explore these possibilities, and we have to investigate the usefulness of this approach.

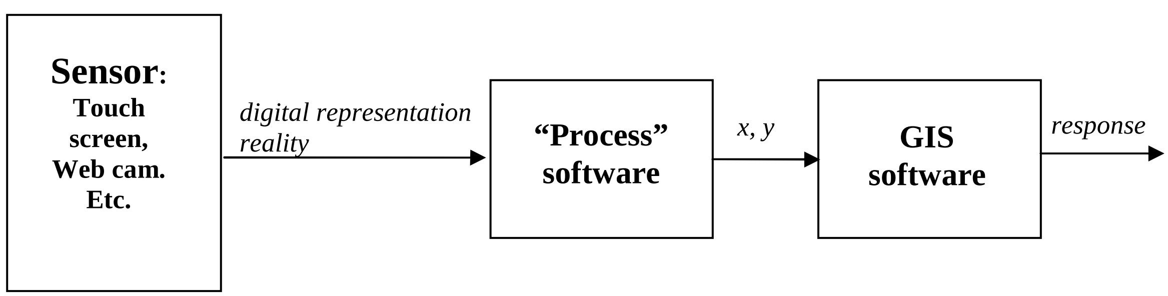
Human-computer interaction

When it concerns interaction between users and projected data on the table, a computer input device such as a mouse does not seem to be the right way to interact with the system since more than one person should be able to interact with the displayed data. In the traditional graphical user interfaces (GUIs) there is a clear distinction between "input devices", *controls* for the interaction with the computer, as mouse's or keyboards, and "output devices", for the *information representation*, as monitors or head mounted displays. The integration between controls and information representation would be the ideal solution for urban decision makers. The information displayed/projected on the table should become tangible for the users, allowing them to retrieve information, to make analysis and perform queries on data with a direct contact on the table. The concept of tangible user interface (TUI) seems the ideal solution for discussion groups. Users interact directly with the table surface and the system reacts to the user's request projecting a new representation of the information on the table.
The combination of a table projection, a GI system, a new method to gather the input information necessary for the action to be performed by the GI system on the desired location of the table form together a TUI system.

The components of a TUI system involved from the acquisition of the users input until the generation of the GIS response are:

- a sensor: a device that measures or detects a real-world condition, such as motion, temperature, heat, pressure and converts the condition into an analogue or digital representation;
- a "process" software: the software evaluates the information received by the sensor and translates it in location coordinates (X, Y);
- a GIS software: performs the requested GIS function at the location received from the "process" software and produces the demanded response.

The described components can be represented as follows:



These are the basic ingredients for creating a tangible user interface. In this paper three examples of TUI systems are considered in which either a webcam or a touch screen is used as sensor. In the case of the webcam, positions and GIS actions are given by positioning coloured objects/patterns on the table (refer to the paragraph "*The TangiTable*"). The user can move these objects or patters at will. Independently from the chosen sensor, the concept of the system does not vary: the output of the sensor is processed by software that evaluates the position where a certain action needs to be performed by the GIS software. The “process” software depends of course from the input of the sensor. In case of a touch screen sensor, the software just needs to translate the location touched by the user on the table to the right location used as input for the GIS software. When using instead the combination webcam-coloured objects/patterns, the “process” software needs to perform image processing to identify the coloured objects/patterns on the image got as input, calculate their position and recognize the colour that represents a specific GIS action to be performed. Retrieved position and GIS action, the information is sent to the GIS software.

The GIS software, once it knows the position and associated action, creates the requested output which will be projected on the table using for example a beamer with a high resolution. Participants can make adjustments to the system by simply using their hands and therefore intuitively use the system, get easily the requested action and collaborate together in a more efficient way.

ADVANTAGES AND DISADVANTAGES OF A TUI SYSTEM

Whether the use of a Tangible User Interface will become a success in a collaborative interactive process depends on a certain number of factors. There are common technical advantages and disadvantages described later in this paragraph, but there are also some theories predicting the acceptance or rejection of new tools. One of these theories is the Technology Acceptance Model (TAM) described by Davis in 1989 [10]. The model describes the factors determining the acceptance or rejection of a new technology. Davis explains that the actors using the new tool must have the idea that the tool is a useful one and that it is easy to use. These factors are summarised as perceived usefulness and perceived ease of use.

In the case of the TUI, people using the interface must have the idea that it is useful and that brings an added value. Secondly the TUI must be easy to use. The second factor is one of the key advantages of the TUI system. The TUI is meant to be intuitive. People can make changes on the interface by simply using their hands. Therefore the acceptance of the TUI is already half justified when regarding the TAM model.

Other factors determining the potential success or failure of a TUI system in a collaborative interactive process is of course the added value and cost of the system. The costs of the development and use of the TUI system are higher than the conventional methods in a collaborative interactive process, however if the added value becomes high enough, the cost does not make a difference anymore. How much people are prepared to invest in a new technology is described in the Willingness to pay model developed by Katz and Shapiro in 1985 [9].

One of the main added values of the TUI system is the immediate response of the system to input of the users on the table. A TUI system has been used within the Participatory spatial planning in Europe (PSPE) project, partly funded by the EU, to teach and inform people about the impact of changes in the area due to spatial planning activities. It has been observed that people show no hesitance in using the system partly because the ease of use, and the Hedonic value when using the system.

The key advantages and disadvantages of TUI systems are summarised below.

Advantages

- The new way of visualisation and interaction attracts participants to the table and invites them to interact with the table itself, facilitating and assisting the conversation around the table;

- Users usually do not hesitate to interact with the tangible interface, because they can easily operate the system using their hands. This seems to be a natural way to interact with the interface;

- Information is presented in different interfaces providing a different visual approach to the same dataset: for example on the table a selected area can be displayed in 2D, while on the screens attributes or the 3D representation of the selected area can be presented;

Disadvantages

- Transportability of the system is not always simple because of the amount, dimensions and fragility of the components: table interface, beamer, sensor, screens, and frame to hold components together need to be moved from a location to another.

- High costs: The costs are dependent on the cost of the single components used in the system. In general a webcam is less expensive than a touch screen, if we consider the sensor component. But think for example to the beamer, this one for a good use of the system needs to have a very good resolution and therefore an elevated price. Further costs rapidly increase when moving the system from one location to another. This implies costs to disconnect the system, transport costs and cost to assemble the system in the new location.

- Time and knowledge to build up the system: components need to be connected together, implying time and expertise in the hardware as well in the software.

SAMPLES OF GI SYSTEMS INTEGRATED WITH TANGIBLE USERS INTERFACES

The following paragraphs present a description of three known TUIs integrated with a GI system.

The TangiTable

Geodan developed a TUI system called TangiTable, a complete and dynamic virtual model. The development has been performed in collaboration with a company called RoVorm, which is specialised in building analogue city models and design and a Portuguese company called YDreams specialised in interaction software.

The central hardware components of the TUI system are:

- a beamer;
- a web-cam;
- a computer;
- a screen;
- a set of coloured patterns/objects;
- a table.

The beamer and the web-cam are connected to a computer. They both are suspended over the table. The objects/patterns are placed on the table surface by the users and can be used for navigation, querying and analysing data which is projected by the beamer on the table. Each of the coloured objects corresponds to a specific “GIS action” to be performed on the location where the object is placed: for example a green object represents a query tool, a red object a fly-over tool, a blue one a zoom tool, a black one a routing tool, etc. (see figure 1).

The software components are:

- a GIS application for the visualisation and analysis of the data in 2D as well in a 3D virtual reality environment;
- a database management system for the storage of the datasets;
- an application for the representation of data in a 3D augmented reality environment;
- a software to recognize colours and real shapes, such as the coloured objects which will be placed on the table.

The principle of the system works as follows. The beamer projects a 2D or 3D image of the data on top of the table surface. The projected image is just the output of the GIS application that is running on the computer to which the beamer is connected. Users can ask information of a specific location by placing one of the coloured objects on top of the table on a desired location. The web-cam registers the presence of the objects on the table and the software processes the information sent by the web-cam, identifies the shapes of the objects, its colour which defines a particular GIS functionality, its location and sends to the GI system all the processed information. The GI system responds to the requested GIS action to be performed on the specific location and the beamer projects the output of the response of the GI system on the table. In the case of a query tool, for example, when a user places the tool on a location on the table, information over data on that location will be directly displayed on table or on another display device, such for example a plasma screen.

Figure 1: Geodan Tangible user interface table

The entire dataset is initially displayed in a 2D environment where the user can select the area of interest. When the area has been identified, a 3D visualisation of the area is displayed on the table or on a plasma screen to let the user explore the region in more detail. The user can choose to take a guided tour through the area or to navigate manually and freely in the area by moving the corresponding object on the table. Buildings can also be selected to retrieve detailed information, such as age, available meters of office space, etc. A 2D map in the corner of the screen shows the location on the map as overview map for the user.

Data in 3D is visualised not only in a virtual reality (VR) environment as described above, but also in an augmented reality (AR) environment. An object placed on the table which represents an AR function for a specific building, will be recorded by the web-cam in the computer and an application places the corresponding 3D model of the building on the spot where the pattern is located. As result, the new image recorded by the web-cam will have incorporated the 3D model (see figure 2). The AR patterns can be placed on the table to represent structures that do not exist in reality yet. It can be used as planning tool to examine the consequences of a new object in the environment.

Another innovative aspect to be mentioned about the TangiTable is the use of profile recognition. Usually, in collaborative interactions, the number of datasets required during conversations is rather large, inexperienced users do not know what data is relevant and what is not and therefore it will take a long time to make a suitable data selection. To limit this effort profile recognition through radio frequency identification (RFID) is used in the system. Before the user approaches the system, his/her information is gathered, stored in the database and coupled to a RFID tag, which is part of the provided badge. When the user moves towards the model his/her profile is recognized and a selection of datasets will be automatically made based upon the profile information.

The main advantage of using a TUI system is the immediate display of the impact of the location of an object on the table. The movement of an object and the visual impact are instantly clear to the users gathered around the table. Another important advantage to be pointed out is the intuitiveness of the system. The objects on the table are easily and without hesitancy manipulated by users, therefore they can immediately and automatically interact with the entire system. Further, a discussion between several people around a table on which participants can point at, is easier and more natural than the situation where all participants are on one side of a vertical screen.

Figure 2: *AR example: the tangible interface and its objects are shown on the top half of the picture. A person is holding a pattern over the table surface. In the bottom half of the image the picture captured by a simple web-cam can be seen. In the filmed image, instead of the pattern, a 3D model of an office building is visualised.*

The MapTable

The second example of a tangible user interface is a table developed by the Dutch ministry for transport, public works and water management in cooperation with Alterra from the Wageningen University, Meander and Vortec.
The table was set up to improve water management activities and involve local expertise in the planning process. The MapTable is meant to support analysis and compare various initiatives in water planning activities. The table is mobile and can easily be moved to a planning agency or stakeholder meeting (see figure 3).

Hardware components:

- PC;
- Touch screen on wheels;
- Drawing pens;

Software components:

- Drawing tool running under ArcGIS 9.1;
- Hydrological model running under ArcGIS;

- Wooshpanel for navigation on the touch screen;

The table displays a map or image of the area in which a planning process is active. The application contains several map layers that can be switched on if necessary. Planners and other stakeholders can gather around the table to have a look at the planning area. Together they will draw their preferences on the screen and make a design of the new landscape. Once a plan has been designed and drawn on the table by the stakeholders, the model can start calculating the consequences of the implementation of the designed plan. Within 10 minutes the model will present the output on the screen. The model layer on top of ArcGIS will analyze the drawings and calculate the impact on the hydrological situation and the landscape.
Based on the outcome the designers can continue the planning activities and adjust the plan according to the feasibility of the made propositions. After a few rounds the optimal situation is reached and could be used as a final design for the planning area.

The current version of the MapTable is a pilot version. At the moment further developments are made to the system for improvement.

Figure 3: The MapTable in action. (borrowed from [1])

The TouchTable

The last example of interactive table described in this paper is one created by Applied Minds, Inc. in collaboration with Northrop Grumman. As all the three TUI interfaces described in this paper, also the TouchTable has been created, designed and developed considering concepts as advanced visualisation, collaboration technology, team work and key words as hands on, visualisation and collaboration. Images are projected from an overhead high resolution LCD projector and adjusted in real time according to the input given by the movement and pressure of the user's hands. This implies that a specific GIS action can be very intuitively performed: a pan function by moving the hand on top the display, a zoom in and out function by moving two fingers apart or together, a query function by holding the finger on a specific position. Users can even write notes in different colours on a kind of annotation layer or move the toolbar from one side of the table to another.

The table consists of a layer to display the projected image, a layer holding the sensor used as input device, in this case a touch screen, and a layer holding the frame of the table. The system is centred upon two INTEL based PC workstations and the information requested by the user is displayed on two plasma’s screens. The movements and the pressure of the hands of the user are detected by the touch screen and sent to the PCs. A specific “process” software (TouchShare software) processes the request, produces a new image and this one will be projected on the table. The GIS engine which runs on the background is ArcGlobe, the ESRI ArcGIS extension for displaying and analyzing data also in 3D.

Interesting to mention is also the TerrainTable, the 3D variant of the TouchTable, created and developed for the moment as prototype by the same group (see figure 4). Using an array of vertical pins beneath a silicone skin, the table can create virtually any curved surface within an area 52” x 40”, 6” high. When synchronized with a computer-controlled overhead projector, the TerrainTable makes a convincing topographical map. The table is equipped with an engine connected to the PC which adjusts the height of the pins according to the raster values to be visualised in 3D on the table. When performing a change of location on the table, such a zoom or pan, pins are send down, the user chooses the new location with movements of the hands and when the new extent of the raster to be displayed has been evaluated by the underlying GIS engine, the heights of the pins are recalculated according the new input and the silicon layer adapts again giving the new 3D representation on the table.

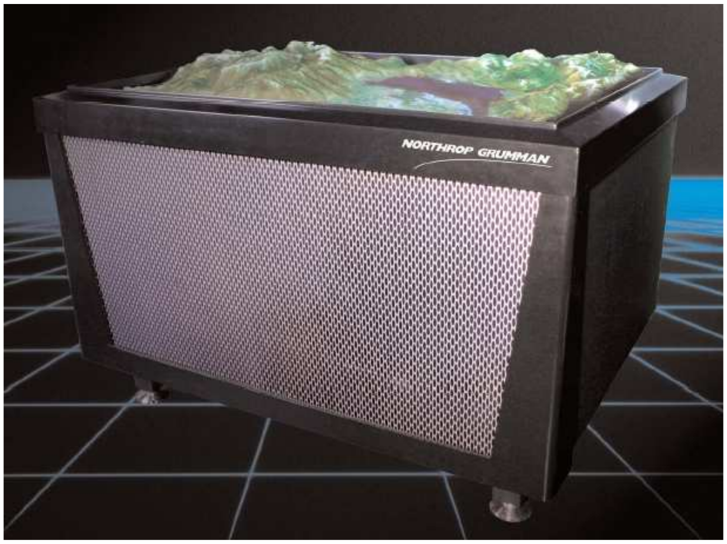


Figure 4: The MapTable in action (borrowed from [2])

Comparing the three systems

The table lists the main differences between the described systems.

Aspect	**TangiTable**	**MapTable**	**TouchTable**
Sensor	Webcam	touch screen	touch screen
Hardware	Beamer; web-cam; computer; screen; set of coloured patterns/objects; table; LCD-plasma screens;	PC, touch screen on wheels, drawing pens	beamer; touch screen; computer; screen; LCD-plasma screens;
“Process” software	needs to perform image processing in order to identify the positions of the patterns and their colour	needs to translate the location touched by the user on the table to the right location used as input for the GIS software	needs to translate the location touched by the user on the table to the right location used as input for the GIS software
Underlying GIS software	ArcGIS	ArcGIS	ArcGlobe
User interaction	movements of the patterns on the table	movements of the drawing pens	movements of the hands
System response time	Immediate	10 minutes	Immediate
Visualisation of the information	2D, 3D, AR	2D	2D, 3D
Toolbar	Projected on the table, but fixed on one location	Not integrated with the image on the table. Separate hardware that can be moved wherever on the table.	Projected on the table and can be moved from one corner to the table to another.
Status of the development	Prototype	Pilot version	Commercial product
Application area’s	Intended for urban context, but can easily applied to other fields	Water planning activities	Public safety, national defence, emergency management. Also this table can be easily used in other fields.
Innovative aspects	Use of a TUI , profile recognition via RFID, the implementation of augmented reality	Use of a TUI	Use of a TUI

POSSIBLE SCENARIOS

The systems described in the previous paragraph all deal with spatial issues, but they differ in both technological aspects as well as in their final function. The Geodan TUI is meant to provide information for foreign investors not familiar with the area. Therefore its weight lies in the appealing way the data is presented and in the relevance of the data for foreign investors. The MapTable is meant as a planning tool for water related planning activities. In this case the emphasis lies on the impact calculation of the designed plans. The TouchTable is mainly a GIS tool that integrates different location based information for disaster management. The most important aspect of this table is the availability of data and the rapid response analysis that can be performed.
However there are other scenarios thinkable in which a TUI will prove to be a useful tool for *collaborative interactions*. Examples are:

Education
People will learn faster when situations and problems to be analyzed are handled with a TUI system, rather than reading on paper about the same subject. When a TUI is running a model that responds real time to input on the table, people will be able to witness the real time effects by interacting with the table. An example can be given when the table displays a map of a road plan and an object placed on the table represents a building. The model, calculating the traffic density, can respond to the placement of the building on the table. In this way students can learn about the impact of new structures on the weight of traffic on the infrastructure.
The Geodan TangiTable described in the previous section will be used in secondary schools during the Geography classes. Students are becoming aware of spatial data within the Edugis project. This project makes it possible for teachers and students to work with a Geographical information system and geographical information at no cost. This project involves visiting the schools and assessing the use of the Edugis tools. It will be possible to visit the schools with the TUI to test the interaction of the students with the table. The research methodologies developed for testing the GIS environment will also apply when assessing the effectiveness of the TUI in Education.

Spatial planning
The table surface can also be used for spatial planning. The table surface can display a planning area. Users around the table can place objects and buildings on the table to find out what the future situation is going to look like. The “building blocks” can be moved across the table to choose the best location and whether the buildings with different functions are spread in a logical way in the area. The TUI in a planning process will be especially interesting as stakeholders can stand around the table and discuss and visualise the plans in real time. This interaction will most probably speed up the planning process.

Disaster Management
Recent floods, fires, terrorist attacks have tragically demonstrated the whole disaster management sector is under pressure for better, more elaborated and appropriate means for facing man-made and natural risks. This effort has a high priority in the political agenda in many governments in Europe and all over the world.

Amongst all, key issues in disaster management are the need to ensure interoperability of emergency services, provision of appropriate information and to ensure that citizens receive high-quality care. Extended cooperation is needed across different sectors, involved in risk management such as the Health Sector, Police and Fire Brigade and civil protection, beyond their specific services that are already coordinated with other organisations.
To fulfil these sophisticated tasks, new systems have to be developed that allow different service units to operate together (to understand each other) in any critical situation. In this respect, appropriate Spatial Data Infrastructure (SDI) and collaborative interactions is increasingly considered a critical aspect of decision making in disaster and risk management.

Conclusions

Based on our experiences and reactions of the users involved we recommend defining further research to the development and use of TUI as a strategic way to improve *collaborative interactions.* This research involves testing the effectiveness of the collaborative interaction system in spatial planning and educational situations. Schools and public spatial planning meetings will be visited with the system to actually measure the effects of the system and therefore being able to quantify the added value of using a TUI system over the conventional ways of interaction.
In our opinion the advanced visualisation and the innovative approach to interact with GI systems will really improve the communication in discussion groups. Information is easily shared between participants that are fully involved in the conversation thanks to the intuitive way to deal with the system. Dialog between users results natural and hesitation to interact with the tangible table does not seem to occur. These systems can be powerful tools in different fields from urban planning decisions, to educational purposes, to emergency management where decisions need to taken in very short time, to public safety, national defence.
In the next period we will focus on further development of the TUI and the theoretical framework of collaborative interactions.

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Toevoegen, enkele meer theoretische papers over TAM en *collaborative interactions*

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