Hands Free
A Wearable Surveying System for Building Surveying

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Abstract: Activities in the building industry in Europe concentrate increasingly on a combination of renovation and new-building. A prerequisite for comprehensive IT supported design and planning in the context of existing buildings is both the use of on-site computer-aided surveying techniques and the integration of all professional disciplines in an integrated information and communication system. The starting point is often the building survey on site. An examination of currently available IT tools and hardware shows insufficient support for planning within existing built contexts. Surveying equipment has been derived from other disciplines without being modified to cater for the specific needs of building surveying. This paper describes a concept for computer-aided digital building surveying equipment based upon a wearable computer and AR to close the gap between specialist equipment adapted for use in building surveying and the need for simple straightforward surveying equipment for architects and engineers.

1 BUILDING SURVEYING – THE CURRENT SITUATION

Most of the buildings that Germany will need over the next couple of centuries are already built. More than half of all current building costs are in the renovation sector and this proportion will continue to rise (BMVBW 2001). Planning tasks will therefore increasingly concentrate upon the intelligent use and conversion of existing buildings. In most cases, the building survey is the starting point for all further planning activities.

Current practice-oriented applications in the field of building surveying only provide insular support of specific aspects of the building survey. The majority of available systems deal only with the building survey and in most cases support only specific surveying techniques. Complete solutions aimed at supporting the entire surveying process are not available. As a result different surveying techniques must be combined according to particular constructive approaches.

In most cases the term “building survey” is understood to mean a geometric survey of the physical dimensions of a construction translated into architectural plans, sections and elevations, but this is only one aspect.

Building surveying involves measuring and documenting a building, usually on site, using a variety of different instruments and technologies ranging from the measuring rule or tape to a camera or tacheometer. On site conditions are usually less than ideal for standard computers, which are usually conceived for desktop use. Surveyors are often to be found climbing ladders or working in cramped attics or damp cellars. Electricity is often not available and direct sunlight can make even the best of displays difficult to read (Figure 1).

Figure 1 On site conditions

The building survey is often undertaken by architects and civil engineers. They require easy-to-use tools for data capture, often coupled with hands-free interaction with a computer. At present the current situation is far removed from this scenario.

2 HANDS FREE – MODULAR WEARABLE COMPUTER SYSTEMS FOR BUILDING SURVEYING

The name "Hands Free" is also the aim of the project – the design of a portable computer tailored to the requirements of building surveying and, with the help of Augmented Reality (AR), to the process of building surveying. The project aim is twofold – the development of a powerful wearable computer and the conceptual development of a modular software solution based upon an analysis of the building surveying process and the needs of the user.

Based upon an analysis of building surveying processes, a conceptual design and an experimental platform (server-client software architecture) for an integrated IT-supported building survey have already been realised. These form the background to this project (Petzold 2001, Weferling et al. 2003, Thurow 2004).

Wearable computers represent a paradigmatic change in the use of portable computers. A wearable computer is worn on the body and typically consists of a variety of components which can be incorporated into clothing and, in contrast to laptops or handhelds, assist the user in their interactions with both real and virtual environments. Wearable computers allow the user to have his or her hands free for other tools and can both accept and provide information whilst working, for instance using transparent displays. Wearable computers open up new interaction possibilities between the user and his or her work environment both in terms of information capture and storage as well as information provision using AR technologies. The following aspects are relevant for the use of wearable computers in on-site building surveying:

- Ergonomic design of wearable computing hardware
- Interaction techniques for the hands-free use of wearables
- Usability methods for wearables; design and user studies
- Augmented Reality: providing virtual information to the real world

2.1 The Wearable Computer Platform

Our current project takes these investigations one step further and examines the development of a concept for a practical, mobile, digital configuration and system environment – a wearable computer for surveying and planning on-site. Based on the client-server software architecture, we designed hardware systems for physically supporting the surveying process following the same modular concept in order to fit the software concept (Petzold 2001, Weferling et al. 2003, Thurow 2004).

2.1.1 Wearable Ergonomics

Currently available wearable computers, which might serve for the building surveying task, are box-shaped modules to be worn on the user's belt. To be comfortable they are reduced in size and weight. This kind of solution is not very suitable for our purpose because it's coupled with decreased computation power and operational time.

Figure 2 Ergonomic studies using plaster of paris to determine areas of the body least affected by movement and therefore most suited for wearing solid items

Based on the design approach of Gemperle et al. (Gemperle et al. 1998) we devised a concept for a modular system whose shape and arrangement fits the user's body.

To examine the ergonomic placement of rigid parts, we plastered a torso and then performed typical movements when surveying buildings (Figure 2). By examining how the plaster of paris creased and ruptured we could identify areas of high motion and dynamic change and areas of relative stability. This enabled use to place computer modules on parts of the body that impede the movement of the user as little as possible (Doppleb et al. 2004).

2.1.2 Hardware Concept

Different work tasks can be identified which depend on the target to be surveyed and site-specific constraints. One possible approach is to provide all possible tools for all kinds of surveys. This, however, means that much of the time redundant equipment is being carried. In order to increase comfort and functionality whilst working, it is more efficient to select the equipment to be worn according to the specific requirements of the next surveying task. As the different tasks require different tools, a concept was devised which follows the analogy of the carpenter and his tool belt. The operator is able to move about with his hands free but has the tools within easy reach whenever he needs them.

The wearable computer system is therefore as modular as the software platform. The ability to interchange computer devices is straightforward and follows the “hot plugging” plug-and-play functionality known from USB-ports. A further important consideration for successful modularity is the ergonomic positioning of interface connectors - in our case VGA, LVDS and USB (Figure 3).

Figure 3 Distribution studies for hardware components

We propose their placement just above the collarbone, in close proximity to the shoulder, from where cables for non-wireless devices (e.g. HMDs) can be routed along the arm or neck/head.

2.1.3 Design Evaluation

A wearable computer for building surveying is not worn everyday, and as such can be expected to accommodate more load than normal clothing and provide more power than a handheld device. A backpack-like arrangement with a comparatively large computational unit for more powerful demands was devised. This solution is also influenced by working comfort regulations. The straps do not only carry the weight but are also used to route cables to the interface connectors in the area of the collarbone.

Figure 4 Volumetric model of the backpack housing with HMD plugged in at the collarbone connectors

The 'backpack' contains parts which do not need to be accessed in everyday use: the CPU, the PSU and hard disk (Figure 4). Interactive devices such as the digital pen, laser distance meter, digital camera etc. are located in front of the straps or the tool belt. A chimney-like ventilation channel in the backpack ensures that even high-clocking CPUs do not suffer from thermal difficulties.

Figure 5 Commercially available components used

For additional flexibility, the nine core unit is a cluster of interchangeable units – a scaleable PSU (up to 88W), an interchangeable hard disk (1.8" 40 GB), an embedded PC (up to 1.8 GHz Kontron ETX) and wireless communication modules (WLAN and Bluetooth) (Figure 5 and Figure 6).

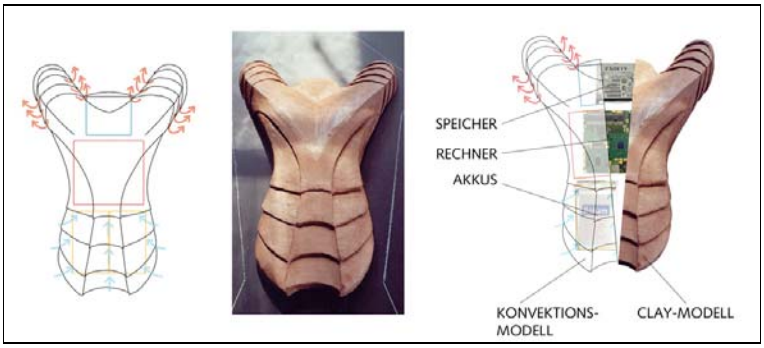

Figure 6 Model of internal hardware architecture, a cluster arrangement of data storage device, CPU and power supply

2.1.4 Prototype

Currently activities focus on the technical realisation of a prototype. The interaction of the individual components has already been tested (Figure 7) and a custom designed PCB complete with electronic components is currently being built (Figure 8). A further aspect is the choice of appropriate materials for the casing or skin. These must be light but also robust and must also dissipate heat effectively.

Figure 7 Test configuration

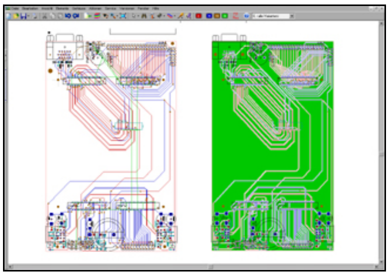

Figure 8 PCB layout

2.2 A Software Concept Based upon a Portable Computer and Augmented Reality

The second aspect of the project is the conceptual analysis and envisioning of application scenarios and the development of user interfaces for wearable computers that can be used for building and planning tasks on site. Wearable computers can enhance productivity in the surveying of existing buildings in a number of ways.

The usual process of surveying buildings consists of a series of manual steps. To develop an IT system for this process each stage had to be analysed and delineated. The first step typically employs a sketchbook in which outlines of ground plans and façades are made. The second step is the actual measurement of the building's dimensions (with inch rule, distance meter and tacheometer). Alternative surveying methods and further details can be added subsequently. These provide data for various scale models and provide the basis for further planning. For an optimal evaluation of the working steps for a computer application, the most essential working processes were simulated, analyzed and reconsidered from an ergonomic point of view to support the surveyor with the most viable user interface in the given situation (Bürgy 2004). The following assumptions were made with regard to the functional and qualitative basis for the processes. Augmented Reality, gestures and speech recognition should work sufficiently. Visual tracking is without markers, edges/form recognition work within acceptable tolerance ranges. This project uses a marker-less approach (Vacchetti 2004) allowing to work without obstruction on site. The approach allows the positioning of the user and the superimposition of a virtual model using an "approximate geometric model".

2.2.1 Application Scenarios for Building Surveying – The Sketch Survey

A number of different application scenarios were developed for the implementation of AR technologies. By way of example the following considers the initial sketch survey of a building. The concept enables the user to create 2D sketches using AR. The tool works simply by moving one finger in the air (Figure 9). It is possible to keep the field-of-view almost entirely free of tool buttons and menus by using gesture recognition and speech recognition to enable an intuitive interaction with the computer. An additional menu for alternative control is provided (Figure 10). This application is more than sufficient for the first estimation of a site by an architect and provides all necessary requirements for the further surveying of an object.

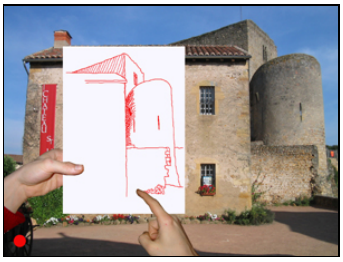

Figure 9 2D freehand sketching

Figure 10 Align with reality / possible menu structure

The 3D sketch was designed to take over the function of a sketch book with 3D abilities. Through the addition of measurements it can be made more precise than the 2D sketch. The process should be fast and does not require many different tools (for instance a distance meter). Further information can be added to the model in the form of text, texture and pictures. The working process is also based on an AR interface. The laser distance meter results are simultaneously processed into a 3D model. As a result it is necessary to track user and device – the user should be able to move either him or herself or the measuring device without affecting coherence between the real object and 3D model.

Figure 11 Tools which are generally used but refer to special objects like moving a point appear depending upon demand and context.

Additional interfaces such as speech and gesture recognition help keeping the screen free of menus, although these menus can be displayed if required (Figure 11). Tools which are generally used but refer to special objects like moving a point appear depending upon demand and context (i.e. when selected).

Further scenarios have likewise been envisioned and described in detail, for instance, the (head up) display of non-visible information, the display of far-away details (akin to camera zoom), the steering of motorised tacheometers as well as communication with other experts in the planning processes.

2.2.2 Sketching in the Air

The ability to "sketch in the air" is a pre-requisite for the scenario described above. As part of the concept tests this means of interaction was tested in more detail. The first test examined 2D sketching for describing room perimeters, elevations and details without haptic feedback.

Figure 12 Sketching in the air – test equipment and results

The tests were carried out in the office as well as on site. The test equipment included data glasses with camera, a data glove and test software module. The results obtained were of a quality satisfactory for sketching purposes (Figure 12).

Further test series examined typical CAD-like functionality such as selecting a point or drawing a line. Such functionality is necessary in order to determine the current position of the user when an "approximate geometric model" is not yet available.

2.2.3 Visualisation of the User Interface and User Interactions

Initial testing of the user interface and interaction methods was undertaken using an interactive programming environment for games (Quest3D). As the project progresses the user interface can be simulated and the acceptance of the design and menu system evaluated before being implemented as part of the entire system (Figure 13).

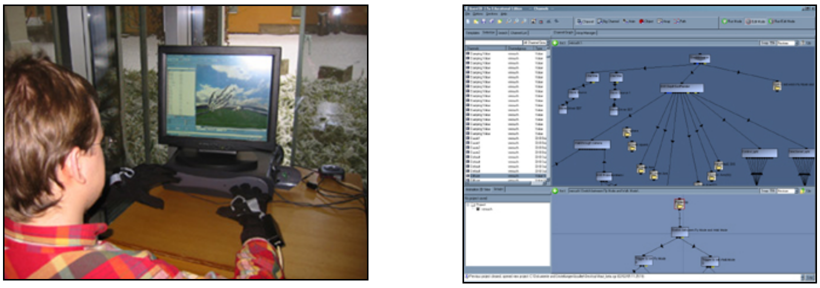

Figure 13 Test environment for evaluating the user interface

3 CONCLUSION

The IT support of building surveying and especially the improvement of the underlying processes is a complex task. In approaching this task with an interdisciplinary research team, we developed the concept of a wearable surveying system and AR-based applications.

This software architecture enables the system to be designed according to the analogy of a tool belt offering task-specific tools needed for specific tasks in the surveying process. For this system to be become viable in use, software and hardware design has to be undertaken in parallel. It was therefore most important for us to emphasize the concurrent design process of software developers, architects, IT experts and product designers. Our proof-of-concept implementation of the software architecture already demonstrates that wearable computing is both very practical and also feasible. While it already contains a significant amount of geometrical and structural logic, it is flexible enough to be expanded further. The hardware design is finished and will be implemented in an ongoing proof-of-concept system.

Future project stages will include on-site testing of the wearable computer in real conditions, the integration of AR-tracking and the implementation of the software tools as described. The combination of all of these activities is necessary to be able to assess the practicability of wearable computers for building surveying.

Once the entire system has been tested and optimised its scope could conceivably be widened to cover further associated tasks such as facility management or on-site design and planning.

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