# Wearable Computer for Building Surveying

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**_Abstract_**

*More than half of all building investments in Germany are in the renovation sector and this proportion will continue to rise.*
*The aim oft this research project is twofold: to design a practice-relevant software concept for the support of the entire building surveying process embedded in the planning process, and to develop a practice-oriented mobile, digitally supported equipment and system environment for the digital architectural surveying of buildings.*
*This paper will discuss the concept, the design and the first prototypes of a wearable computer system, supporting building surveying processes. We illustrate the functionality, the ergonomics and the hardware and software architectures.*
*Keywords: wearable computing, building surveying, mobile IT support, software and hardware architectures*

## 1. Introduction

Since the beginning of the 1990’s the focus of planning activities has shifted away from the construction of new buildings to renovation and construction within existing contexts. More than 60% of planning activity concerns existing buildings.[1]
Reliable and informative documentation is an essential pre-requisite for planning in general but especially for the planning task with existing buildings, where existing plans and building documentation are hardly available, very basic or often not up-to-date.

**Figure 1: usability problems with current technology**

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. The geometric survey is typically undertaken using geodetic or photogrammetric measuring techniques and equipment that have been adapted for use in building surveying as shown in Figure 1.
The consequence: current building surveying and planning working practice is characterized by:
- a high level of mechanization;
- the need for specialists in geodesy / photogrammetry;
- a lack of simple tools for architects & engineers;
- the reduction to solely geometric data;
- the inclusion of a lot of redundant information.

## 2. Approach

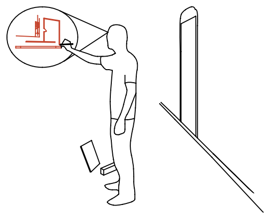

**Figure 2: sketching in the air -> vision with Seethrough-HMD**

We envision a fully computer-supported surveying process. This supporting IT system will help to avoid unnecessary data transmission between different analog and digital media, and thus avoid unnecessary media breaks (data transmissions ....). The envisioned system will fully support the surveying process in every single step.

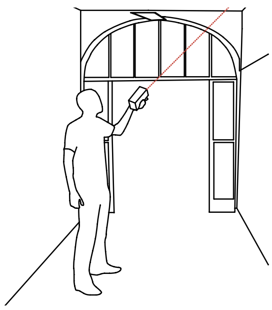

**Figure 3: pointing to measure -> vision with tracked distancemeter**

To minimize the time and money spent for surveying of a building-site, we split the whole working process into different steps. These steps are ordered in a way as to get more detailed information with every new step. At the same time, we ensured that the information of a given step is saved for reuse in later steps, according to the surveying targets in the appropriate surveying phases:

1.first site visit: information about inventory, identification of objects, visible damages;
2.sketch-based spatial information: sizes and volumes, sketches of building;
3.detailed ground plan: detailed analysis of building conditions;
4.exact 3D geometry;
5.evaluation / check, acceptance of work and facility management.

Building survey is not simply a geometric description of a building. In addition to the structured capture of the building geometry, other formal, informal and relational data is also captured and stored within the information container. The geometry structure is linked with formal-descriptive data.

The captured data should serve as a basis for further design and planning activities [2,3,4].

## 3. The Hardware Concept

There are different work tasks, which depend on the surveying-targets (see Section 2). One possible approach is to collect all available information in one step. It will be more efficient to do only the necessary steps at a time. These different tasks require different tools, which the surveying person will carry on-site. It is quite similar to carpenters who put their tools for different work tasks in their tool belt. They do so to have their hands free to move about and have the tools reachable every time they need them. We take this analogy as an example of what we want to achieve in developing our wearable surveying system. Based on the analysis of the five surveying targets (first site visit, sketch-based spatial information, detailed ground plan, exact ground plan and evaluation / check), we identified the following tools as necessary for certain steps in the surveying process:

- tape measure;
- voice recognition;
- digital camera;
- digital sketchbook;
- distance-meter;
- voice recorder / recognition;
- tacheometer;
- powerful computer unit;
- CAD software;
- previously collected data.

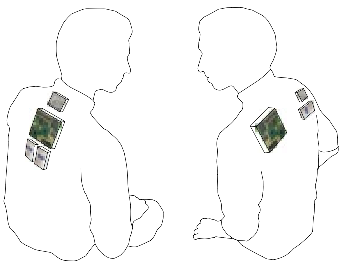

**Figure 4: embedded PC, batteries and harddisk placed on the human body**

Our approach is to get all building site information together in one CPU that serves for all necessary activities. Information should be linked immediately to its context. Thus, we use one basic module that provides the computation power for CAD and voice-recognition. We designed all attached periphery to be flexible, compatible and exchangeable, to reflect the carpenter's tool belt analogy.

### 3.1. Design Evaluation

In the beginning, we thought about splitting the whole computer into little modules, that we could distribute all over the surface of the body of the user. This way we wanted to achieve a wearable computer system to be worn very flat on the body, resulting in an unobtrusive device.

To achieve the anticipated system, we intended to use a board like the flexible Twinflex® circuit boards but those are not yet commercially available as motherboards. Thus, we decided to use available technology and developed a design that will come close to our design goals.

Our further investigation went on in ergonomic terms, to which our wearable computer should comply. According to the ergonomic studies of Gemperle et al.[5], we searched for areas where rigid parts may be worn close to the human body. So we plastered our body (Figure 5, 6) and moved afterwards simulating typical movements of building surveying tasks, to recognize how the surface is breaking into

**Figure 5 and 6: plaster experiments**

pieces. Thus, we could identify the largest possible size and the ideal location for the computer modules that would not disturb surveying tasks while being attached to the body of the surveyor.

We developed different possibilities of wearing those parts according to our results of ergonomic studies and the requirements resulting from the different surveying steps. The idea of wearing a simple textile shirt, which connects the used parts with conductible textile, showed that textile is too flexible to keep the rigid parts in its position. Weight pulls them downwards - a disturbing slinging movement at ones body.

**Figure 7 and 8: two wearable mockups**

Another idea to wear the solid parts at a more

rigid harness like piece made of semi flexible plastics, turned out to work well to some degree, but this solution lacks the possibility of changing it between persons with different physiognomies (Figure 8).
So we decided for a system based on straps known from backpacks. Those would be adaptable to different body ergonomics and provide more stability than shirt-like textiles (Figure 7).
All of these studies consist of four rigid parts, that we found to be comfortable to wear in our plaster experiment. These are two main cases worn on the users bladebones and two smaller units positioned above the collarbones that should contain the interface connectors.
It turned out, that the positioning of the connectors does work very well, as it provides a comfortable working range even for peripheries that wont work wireless. The cable just goes along with the arm or head orientation (Figure 9).
Even the cases for motherboard, batteries and harddisk, worn on the back, may be functional and comfortable, unless we get asymetrical distribution of heat and the weight of heat sink, necesary for high-clocked processors. Thus, we decided for another concept that, similar to modern backpacks, will keep the CPU away from the human body and secure permanent and sufficient ventilation.

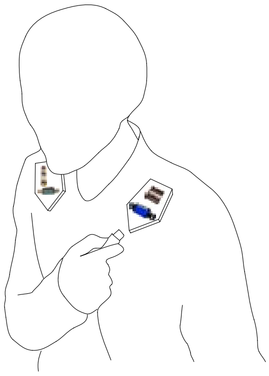

**Figure 9: collarbone-placed interfaces**

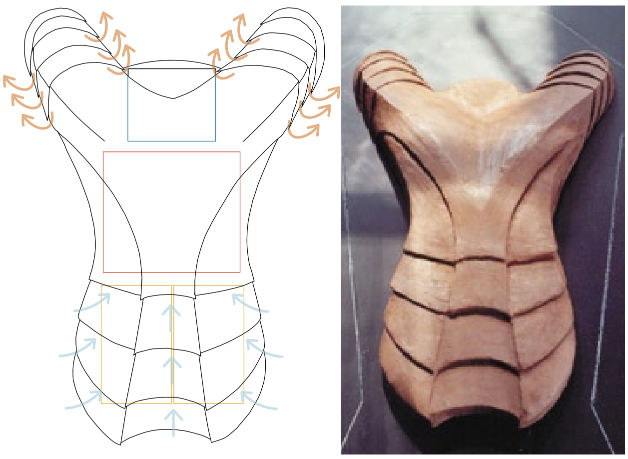

**Figure 10: wearable-chassis model made of sheds to provide high flexibility and ventilation**

We propose two different styling concepts, that focus either on minimalized size or maximized ventilation and flexibility. The shape of the chassis will go through more design iterations, while we are finalizing the technical architecture inside. Finally, we will evaluate the working unit with a specially designed client / server software by T. Thurow [6].

## 4. Conclusion and Outlook

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 that runs a modular software architecture. The cooparation of modular software- and hardwarearchitecture enables the system to be designed after a tool belt analogy offering the task-specific tools needed at a certain point in the surveying process.
We will continue this interdisciplinary reasearch investigating different aspects, such as work process analysis, usability as well as hardware and software concepts. Simultaneously, we will evaluate the current system in field-tests at actual surveying sites.

**Figure 11: cable route model from connector to HMD** [7]

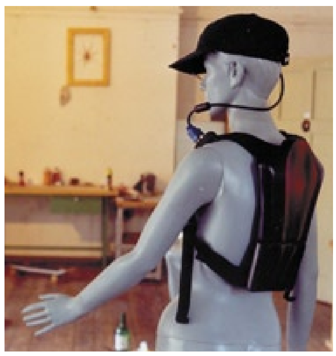

**Figure 12: model of backpack-like wearable computer** [7]

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