GET THE SURVEYING BUILDING DATA INTO THE CAAD SYSTEM: A Realistic Approach for the Practice

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Abstract. The digital support of the planning process is currently a central focus of our research and will be presented and discussed in this paper. Concepts and prototypes for the computer-aided support of the planning process are being developed as part of a special research project "Construction and materials for the renovation of buildings". The paper examines the flexible combination of different surveying techniques and geometric abstractions achieved with the help of geodesic computational adjustment methods. Selected aspects have been implemented and investigated as prototypes and the prototypes are described and discussed.

1. Context and deficit analysis

1.1. PLANNING-ORIENTED BUILDING SURVEYING

Building today is characterised by an ever increasing proportion of building measures within existing built contexts. Precise building documentation is a prerequisite in order to plan effectively in such environments. In most cases this is not available or has not been kept up to date with the current situation. As a result a building survey is necessary, either as an extension or validation of existing building documentation or to provide new documentation. A building survey which fulfils the needs of a planning task will be described as a planning-oriented building survey.

In a general sense the planning-oriented building survey can be seen as the construction of a model. The surveyor generates a model, a representation of the existing building, with a specific purpose in mind. It is neither possible nor necessary to capture everything about the building. Instead, it is the surveyor's task to capture and represent all information necessary for future planning tasks. The capture of additional information not required for planning leads to redundant information, increased costs and longer surveying duration. In contrast, when too little information is captured, planning requirements could make it necessary to survey additional information at a later date. A planning-oriented building survey should therefore be undertaken or directed by someone with appropriate knowledge of the demands of planning practice. He or she is then able to identify what is relevant, how it should be captured and to what degree of detail.

1.2. THE DEFICITS OF COMMERCIALLY AVAILABLE SURVEYING SYSTEMS

The computer is a useful tool for supporting the planning-oriented building survey. Whereas humans are able to draw upon enormous reserves of background knowledge with which to interpret their surroundings, the computer is able to accumulate large amounts of data and to apply algorithms to these without showing any signs of fatigue. From this point of view man and computer complement one another ideally.

By comparison, it is sobering to examine currently available software solutions for planning-oriented building surveying. For the most part the system approaches concern themselves almost exclusively with the geometric representation of the building. Typically the applications have been developed for a specific technology. To make the most of their different advantages they need to be used in combination. This is currently possible with commercially available solutions, e.g. as program modules in a CAAD environment, however the use of different techniques still involves a process of manual combination. The programs therefore dictate the approach of the surveyor. Some programs, particularly for manual surveying, even dictate the step by step procedure of measuring itself.

The task of building surveying is not limited purely to capturing geometric information. Rather, the surveyor captures a variety of data related to specific objects. In the IT environment, product models—in the architectural environment building models—are used to represent object-oriented data. Complex systems such as IFC are already available in the field of new building; however there is still a considerable deficit in the field of planning for existing buildings. Product models from new building cannot simply be applied to existing buildings. The high degree of variance in existing buildings means that static structures and standardized parameters can rarely accurately represent an existing built structure.

1.3. APPROACHES FOR FUTURE SOFTWARE SOLUTIONS FOR PLANNING-ORIENTED BUILDING SURVEYING

To reduce the described deficits or to remove them entirely a number of approaches are proposed:

- The use of a dynamic building model based upon a model administration system
- Representation of formal and informal data, of geometric and relational data

- A process of surveying oriented towards the working method and pattern of perception of the surveyor rather than the system
- A step-by-step approach to capturing geometric detail, e.g. “from the sketch to the detail”
- The use of inexact geometry in the representation until such time as precise measurements have been obtained.

This paper focuses on the step-by-step capture of geometry and its level of detail. Further information is also available in Thurow (2004) and InfAR (2005).

2. A concept for the step-by-step capture and representation of building geometry

The following is a description of concepts which address some of the difficulties mentioned earlier and concentrates on a concept for the step-by-step capture and representation of building geometry. For the moment the current implementation makes two assumptions:

- The surfaces to be surveyed are planar.
- The building is upright, i.e. based upon a system of vertical walls.

Surveying techniques which have been tested include:

- Manual surveying
- Tacheometry
- Photogrammetry.

Likewise we assume a non-destructive surveying process, i.e. the surveyor need not break open or damage parts of the building to obtain data.

2.1. THE LIMITS OF PERCEPTION AND MEASURING BUILDING GEOMETRY

When surveying without damaging building structure, the surveyor is limited to measuring what he or she can see, i.e. surfaces of rooms and exposed building elements. The surfaces represent both the division and the connection between room space and built substance. By contrast, the connections or divisions between structural building elements cannot usually be ascertained by eye and in many cases there is no surface separating different structural elements. By way of example, Figure 1 shows a plan of a building: an attempt to describe how the building elements connect with or are separated from one another could be interpreted differently—it is a matter of speculation.

The examples (b) and (c) show two equally possible definitions. This is just one reason why the representation of the geometry of a building element should

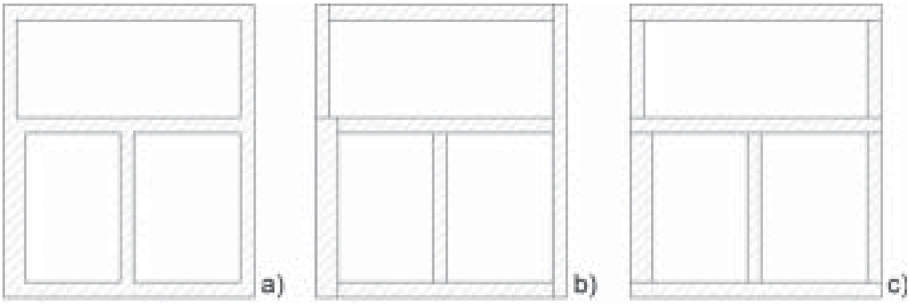

Figure 1. Floor plan and different interpretations of the wall structure.

not be forced when insufficient information is available to describe it. Instead a number of different surfaces should be attributable to a building element, i.e. what the surveyor can see. This approach ensures that the resulting representation does not contain more information than has actually been obtained.

2.2. ORIENTING DATA CAPTURE AROUND THE PERCEPTION AND WORK METHOD OF THE SURVEYOR

A building survey is usually undertaken step by step. In the first stages of a survey (initial site visit, etc.) the surveyor perceives the identity of visible elements of the building, e.g. rooms and elements thereof such as doors, windows and openings. For the purposes of geometry the information describes the topological relationship between the elements. The view of the entire building is localised, i.e. room for room. The surveyor captures information about the limiting surfaces of the room in which he is standing—the space and its limiting surfaces are experienced as one and the same.

As the building survey progresses, more and more qualitative properties of the building elements are captured. This also includes ascertaining the exact geometric dimensions of visible surfaces and objects. As the surveyor works in close proximity to the building he or she also perceives more detail in the geometry of the building than is possible from further away. Existing geometric data can be enriched with more detail and the quality of the model representation of the building improves accordingly.

Through a combination of an overall view of the model of the building and indications ascertained locally, a sufficiently knowledgeable surveyor is able to deductively break down the building into its constituent building elements (i.e. to interpret the model) and to attribute captured data to these. The actual geometric description of these elements may be incomplete as indicated earlier, however certain geometric parameters such as wall thickness, door openings, etc. can be deduced.

3. A concept for a software system for the step-by-step capture and representation of geometric data

Based upon the considerations mentioned earlier, there are three principle stages to capturing and representing geometric data:

(a) Creation of geometric data
(b) Adaptation of geometric data
(c) Extraction of building elements.

The creation of geometric data means the sketch-like generation of an approximate geometric representation not to scale. This model is then successively adapted to the real situation as precise information becomes available. Once sufficient information is available individual building elements can then be defined (extracted from the model) and their geometric parameters determined.

The following section concentrates on the adaptation of the geometric model. More information about the creation of geometric data and building element extraction can be found in Thurow (2004).

3.1. COMBINING DIFFERENT SURVEYING TECHNIQUES

As previously described, the surveyor should be able to use a variety of different surveying techniques. The most common techniques employed are manual measuring by hand, tacheometry and photogrammetry. Each of these surveying methods has their own advantages and disadvantages. All are able to determine the geometric location of a particular point (or series of points) in relation to another point with slightly different degrees of precision. In order to reconstruct the geometry of a building from these series of measured distances certain geometric abstractions must be applied. For example, wall surfaces are generally regarded as being flat or planar. The use of such abstraction means that the geometric model will inherently contain an element of error in comparison with the original building. This should be differentiated from errors resulting from low precision surveying techniques. It is the surveyor’s responsibility to take sufficient and intelligently chosen measurements (diagonals, skews, perceived bends in walls etc.) in order to minimise model inaccuracies through geometric abstraction. As a result the survey itself can be regarded as a process of modelling the building.

Geometric abstractions also help to speed up the surveying process and therefore to keep costs down. The pay-off is a reduction in geometric precision. The surveying of window jambs serves as a good example. Depending upon the level of accuracy required and the form of the window, many window jambs can be regarded as being parallel. This level of abstraction means that only the dimension of the opening, the distance between the jambs, need be measured. This is usually undertaken in the middle of the wall depth to keep model inaccuracies to a minimum. The same principle of geometric abstraction of dependencies applies for other elements in a building. These include:

- Parallel and orthogonal orientation of surfaces
- Horizontal and vertical surfaces
- Symmetry
- Geometric similarity (repetition) of particular elements, e.g. windows, columns, etc.

To combine measurements from different surveying techniques and geometric abstractions a computational adjustment model from the field of geodetics is applied. This allows the conscious 'enrichment' or validation of the model with a view to improving the model's accuracy. All measured dimensions and abstractions are recorded in a formalised form in a database and their representation in the form of a geometric model can be recalculated periodically as required.

The basic principle of adjustment of a geometric representation is relatively straightforward. The geometric representation is described using a surface model. Measurements and abstractions are "introduced" into the surface model. These change the dimensions of the representation. Computational adjust attempts to resolve conflicts between the representation in the model and the actual measured data in such a way as these are minimised and the model need be changed as little as possible. Using this approach it is possible to begin with a high level of geometric abstraction and only a few measurements and to gradually add further measurements and reduce the geometric abstraction to increase the accuracy of the model.

A detailed description of the mathematical approach used can be found in Thurow (2004) and Thurow and Donath (2003).

3.2. DESCRIPTION OF THE SOFTWARE SYSTEM FROM THE USER'S POINT OF VIEW

This section details the technical realisation of the software concept for adapting geometric information using the capture of a 2D rectangular room by way of example (see Figures 2, 3 and 4).

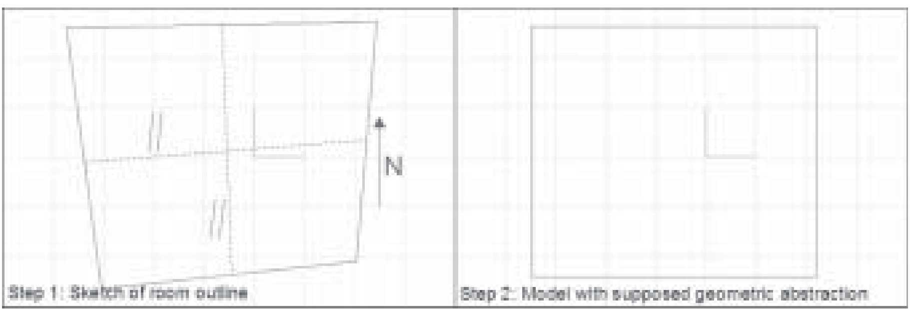

Figure 2. Step-by-step capture of the geometry of a rectangular floor plan, part 1.

The user begins by creating a sketch-like geometric representation of the room (Figure 2, Step 1). The computer examines the approximate representation for typical geometric abstractions such as parallel walls, orthogonality, etc. This process can be directed by the user who may choose which dependencies apply and their limits of application. The semi-automatically determined dependencies are entered into the model and the geometric representation adapted accordingly (Figure 2, Step 2).

After the geometric representation has been created, additional data such as measured dimensions can be introduced into the model at any time. The user indicates the kind of measurement, the elements between which the measurement was taken, the value and its accuracy. In Figure 3, Step 3 shows this using two distances measured between two surfaces opposite one another. The computer program provides a visualization of the adapted geometric model together with a colour representation of the deviations between the real measured values and the virtual representation.

As further measurements are introduced the model is successively adapted in such a way that the deviations between the model and reality are kept to the minimum possible (Figure 3, Step 4). This process can be repeated as often as necessary and the user may enter them in any order and whenever he or she wishes.

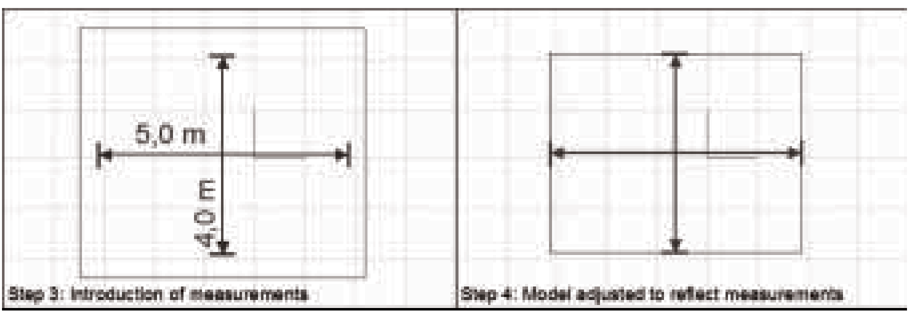

Figure 3. Step-by-step capture of the geometry of a rectangular floor plan, part 2.

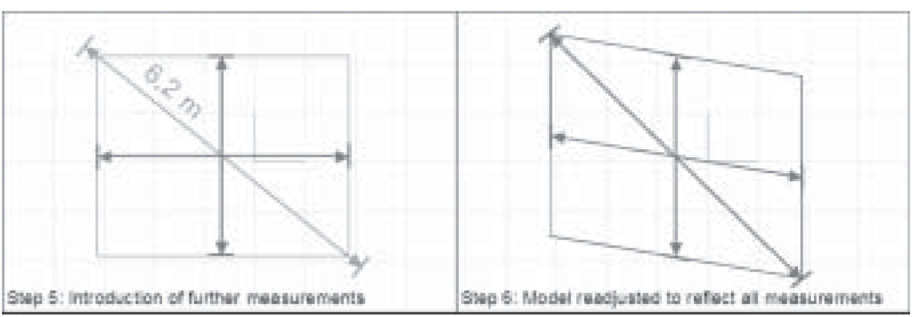

Figure 4. Step-by-step capture of the geometry of a rectangular floor plan, part 3.

In Figure 4, Step 5 the distance between two edges of a room are introduced which the computer has suggested are at right angles to one another. The measurements contradict this assumed geometric abstraction and the user can decide how the computer should react to such inconsistencies. In general the computer is set to discard abstractions in favour of the real conditions. Step 6 shows the results of the automatic geometric adaptation of the model.

3.3. PROTOTYPICAL REALISATION

Selected aspects of the concept as described have been realised in a prototypical system. The prototype with the name “experimental platform FREAK” consists of a series of extendable tools which access and work with the same database. Implementation has at present concentrated upon aspects pertaining to the building survey itself.

The tools allow the sketch-based, plan-oriented creation of simple building geometries and their adaptation to fit taken measurements. After the building geometry has been entered in sketch form the system looks for likely geometric abstractions. Using various different tools manual measurements or measurements obtained with tacheometry or photogrammetry can be introduced into the model. The geometry is then adapted accordingly.

Through the use of a motorised tacheometer with visible laser beam it is possible to compare model and reality in real-scale. The tacheometer rotates to show the location of points in the geometrical model as a laser-beam point in the real building. Another method is the visual comparison between a distortion-corrected photo and the geometry model.

3.4. RESULTS OF THE PROTOTYPICAL REALISATION

The verification phase of the research project is currently underway and therefore the following are preliminary observations.

The prototype has been used to undertake test surveys in laboratory conditions. The current concept is presently only suited to buildings with planar surfaces. Figure 5 shows the result of a manual 3D survey of a floor of an office building. Figure 6 shows the results from a combination of tacheometry, manual survey and photogrammetry.

The quality of the geometric representation is heavily dependent upon the geometric abstractions applied. For this it was necessary to mathematically formulate typical geometric abstractions and dependencies within buildings.

The computational adjustment involved in the adaptation of the geometric model proved to be particularly difficult and needs further improvement in order to reduce resolution speeds to an acceptable level for on-site requirements.

A further aspect in need of more detailed examination is the combination of

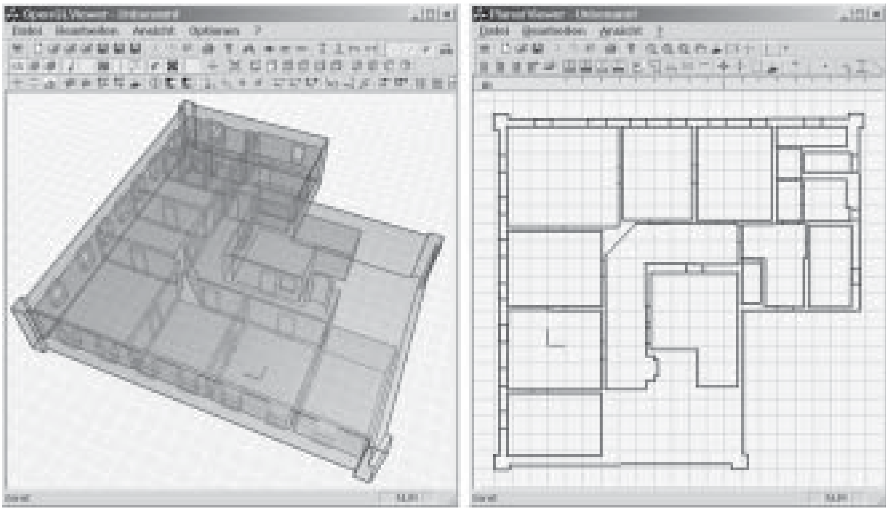

Figure 5. 3D and plan-oriented views of a geometry model using the tools “OpenGLviewer” and “PlanarViewer”, showing an example of a manually measured survey of an office building.

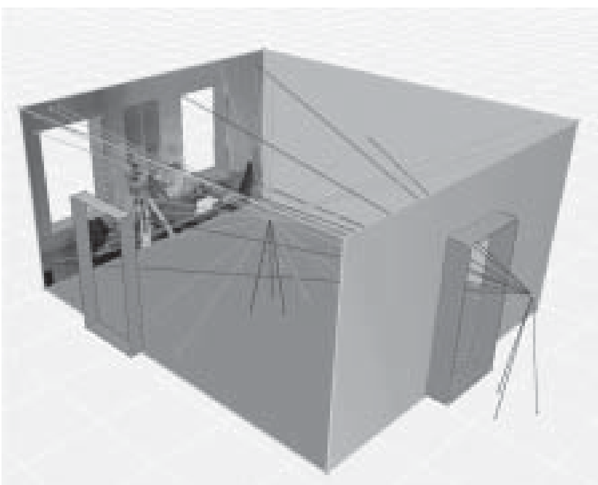

Figure 6. Integrated adjustment : A room containing measurements obtained through manual measuring, tacheometry, photogrammetry and geometric constraints.

similar measurements with widely differing weightings. A means of discrete grouping of measurements would be desirable.

The approach as described above necessitates the parallel existence of geometric elements of differing precision within the same model. Software tools which allow the user to control the level of detail of an element need to be developed.

In contrast to manual or tacheometric measurements it has proved difficult to integrate photogrammetry effectively. One reason for this is the present lack of necessary approximate values.

Tests have shown that the duration of a building survey can be significantly reduced by improving the ergonomics of mobile computer systems and the linking of these to different measuring devices. This area is also currently being developed with the Junior Professor chair of “architectural computer science” (Petzold et al., 2004) together with the underlying supporting software interaction.

The approach as described does contain a number of as yet unresolved but identified and described problems, particularly with regard to increased levels of detail and the creation of parameterized building elements by the user. Current progress does however provide good cause for optimism and the authors intend to pursue and improve the current approach as described.

The attention of interested readers is drawn to the forthcoming InfAR (2005) where we intend to present prototypes and the research results to date.

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4. RaBBiT has been implemented in Java using additional open-source third-party Java libraries such as JGraph, JGraphPad, and JEP.