RECOGNITION OF BUILDING PARTS FROM MEASURED DATA

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ABSTRACT: Improvement of the information management of the existing building stock is aimed at more effective use of buildings and design of renovations. Available documentation on old buildings is often inadequate or its information content is out of date. The best way to acquire reliable input data is to measure buildings.

Modern design related to the use and renovation of buildings is based on the modeling of buildings. To serve the needs of the end user, measurement methods should be linked to the building modeling technologies used in design. This article presents a computerized method for creating that link based on the recognition of building parts from measurement data. The main functions of data processing and a rough estimate of the usability of the outputted CAD model are given for the different levels. The four cases reviewed here are: 1) no recognition -> visual model, 2) surface recognition -> surface model, 3) individual building part recognition -> building part model 4) CAD object based recognition -> parametric object model. The suitability of different models for different uses is discussed and the model types are linked to measurement methods. One application of the measuring program for recognizing parametric objects is presented.

KEYWORDS: measurement of a building, CAD, building model, parametric object.

1 INTRODUCTION

Building models have mainly been used in the design of new buildings. A similar model can be produced for the planning of renovations based on old drawings. However, such models do not include the necessary as-built information or possible undocumented changes of structures. If the reliability of drawings is dubious, the model of the existing building should be based on measurements.

Methods originally developed for geodetic surveying have been applied to the measurement of buildings already for a long time. The purpose is to get reliable input data, for example, for the design of renovations. The measurements are often made by sector professionals who may often lack in-depth knowledge of modern modeling-based building design. This is only natural, because measurement and building design are two different fields of expertise. Both are presently highly IT-oriented, which constitutes a third field that should be mastered before a comprehensive approach can be developed. The result may be a situation where the fields do not converse with each other despite the high technology orientation of both. In practice, the worst-case scenario is that a measured building will have to be modeled again from scratch at the design stage.

Buildings can be measured geodetically or photogrammetrically. Independent of the used measuring method, the raw measurement data consist of the positions of points. To generate data suitable for modeling the points must be assigned information about the object from which they have been measured. Objects generated from several points must be the same kind of concepts as those used in building design models. Here these concepts are called building parts.

The assignment of points to building parts must always be done by an interactive computer program. The recognition of building parts cannot be fully automatic. For example rooms normally contain a lot of stuff that is meaningless from the point of view of modeling. Even in an empty room it may be impossible to automatically recognize, for example, the surface of a column intentionally hidden among walls.

2 BACKROUND

2.1 *Building measurement methods*

Photogrammetric measurement methods use overlapping stereo photographs of the object. The method is commonly used for measurements from aerial photographs. When the technology is applied to nearby objects, it is commonly called close-range photogrammetry. This method and its practical application have been described, for example, by Arias et al. (2005) in an article. The article also addresses the selection of a measurement method, and the authors find speed, accuracy and low costs the main advantages of photogrammetry.

Earlier film-based photography has been largely replaced by digital photography. Photographs are mutually oriented by matching common points. Orientation markers are generally attached to the photographed object to facilitate measurement and improve accuracy. Since the position of the camera is usually not known, the global coordinates of the markers are measured by a tacheometer. Known points can be used to calculate the scale and global positioning of the photographs. Actual measurement is performed by storing the positions of the measured points shown in a three-dimensional stereo model image one point at a time. Another alternative is to place three-dimensional objects in the measured image directly based on visual observations. This method requires special workstation software.

Buildings can also be measured directly by a tacheometer using topographic methods. Donath and Thurow (2007) presented an indoor measuring method where a tacheometer can be used to match a sketched space model to reality. However, tacheometric measurements are more often used for improving the accuracy of other methods than as an independent measurement method.

Current tacheometers use a prismless distance meter that can measure the distance to ordinary building materials. The maximum measurable distance depends on the reflective properties of the surface. The stronger the reflection, the longer the maximum observation distance. The distance meters are set to be so sensitive that, for example, a glass surface gives a too strong reflection and cannot be measured. The measured distance and the horizontal and vertical angle can be used to calculate the three-dimensional coordinates of the observed point. This requires that the location of the tacheometer is known, and its positioning is based either on satellite positioning or on measuring a traverse anchored to known points around the object. In some cases a gyroscope can also be used to assist in the measurement. To observe the vertical angle, the device must be aligned carefully in the horizontal direction. To measure the horizontal angle, a reference direction must be measured from a known point.

A measurement device taking digital photographs can be connected directly to a tacheometer. Reiterer A. (2007) described in his article the application of this measurement method to the surveying of buildings. A number of functions have been developed to assist the user in recognizing the objects to be measured. Fully automatic recognition is not possible according to the article.

The tacheometer has also been further developed into a measuring device that automatically observes points between given horizontal and vertical angles. The method is called laser scanning. For example, De Luca et al. (2006) documented the application of this method to the modeling of building facades.

The angle covered by a single scan can be, for instance, 40 degrees. The interval of the scanned points can be varied, but it is usually very small, for instance, 0.001 degrees. The result is a very large point cloud that can be used to calculate surfaces. To establish the coordinates of the observed points, the location and orientation of the scanner must be known, as in the case of a tacheometer. For example, in aerial laser scanning by aeroplane or helicopter, the location of the measuring device is measured continuously by GPS and its orientation by motion sensors. A scanned point cloud can also be processed like a stereo photograph, that is, it can be scaled and placed in a global set of coordinates by individual known points.

The simplest measurement method for buildings is observing the dimensions of building parts manually by a laser distance meter placed by the object. Since any individual measurement is independent of the set of coordinates, it must be assigned directly to the measured building part. In the simplest case the dimensions are written on paper, such as old drawings. However, more complete measurement requires that the measures can be stored directly to a computer. An effective method is to use a measurement program with an image-based user interface for the assignment. Such a method is described, for example, on the Web pages of Nemetschek AG (2007a).

2.2 *The modeling of buildings in design*

The term building information modeling (BIM) has been used since around the mid-1980's to refer to CAD models where the concepts of the construction sector have been combined with coordinate data. For example, BIM integrated such concepts as building parts and their material information. The information content of the used concepts has been similar content to, for instance, those used in product modeling and integrated models. For example, van Nederveen and Tolman (1992) included building information models and product models as keywords of their article dealing with the structures of models usable by different user groups.

Nowadays BIM is the term mainly used to refer to intelligent building models. The possible data content of BIM has also been expanded over time. Cavallero (2006) has described this development in his essay by the terms traditional design-focused BIM and comprehensive BIM. The white paper of Autodesk (2002) provides some kind of a basis for the current understanding of BIM.

Nassar et al. (2003) discussed in their article the development of CAD software for architectural design from drawing to modeling. An important feature of current software is the use of parametric objects to depict building parts. The article presents a method for further development of the interrelations of these objects. No commercial software has implemented constraint-based modeling similar to the presented example.

Predefined objects make the creation of a model fast, as entire building parts can be added with just one command. Objects are linked together so that all adjoining objects adapt automatically to changes made to one. For example, when a wall object is moved, the doors in the wall move along and the length of adjoining walls changes. As object dimensions are indicated by parameters, there is no need to select a new object when a dimension changes. For instance, the same window object can be used to produce different sized windows by changing the length parameters.

The data content of objects may vary. The following three research projects investigated different ways of expanding data content. Qizhen et al. (2002) presented in their report a general design object library (DOL) which can be used by several CAD softwares. The objects are made to include information also for other users of the CAD model than architects and engineers. Ekholm (2001) presented in his article objects which can be used to model activities. The presented method allows generating, for example, a space object which can contain activities with time information. Coyne et al. (2002) presented in their article an environment where the information of objects could be expanded with web-based libraries. They had a database of objects in a server which the users can use to communicate. The objects in the database can contain URL links that allow seeking additional information from the Web.

Commercial architectural design software use slightly different names for objects depicting building parts. The names used on the web sites of the software include:

- *Architectural objects* in Autodesk Architectural Desktop by Autodesk, Inc. (2007a).
- *Parametric components* in Autodesk Revit Building by Autodesk, Inc. (2007b) and in MicroStation by Bentley Systems, Inc. (2007).
- *Intelligent objects* in Archicad by Graphisoft R&D zrt. (2007) and Allplan Architecture by Nemetschek AG (2007b).

3 THE MODELING OF BUILDINGS BY MEASUREMENT

3.1 *Determination of measured model based on users' needs*

If a building owner commissions a survey of his building without detailed specifications, the measurement consultant performs the job using the most economical methods from his viewpoint. Then it cannot be known in advance how well the model will serve its purpose. Moreover, if requirements have not been set and their realization documented, the reliability of the end result is not known. This forfeits the main point of the measurement: to get real measured data on an existing building. In fact, it can be said that a model of dubious reliability is not essentially better than a model based on old drawings.

Figure 1 presents a diagram where the requirements of measured models are determined based on users' needs. Then the method for measuring the model is chosen. The selection is not clear-cut because the same kind of model can be generated by several combinations of a measuring method and processing of measured data. If the measurement becomes too expensive to realize with every possible method, the requirements must be eased.

The particularity of a building model can in practice be improved endlessly, which requires setting limits for the modeling work. The limits apply both to the level of details and the building parts to be modeled. As a general rule, a model should only include data that can be exploited by existing know-how and resources. When making provisions for future needs, variables affecting the general development of automated data processing should also be considered.

The technical definition of a model will not be discussed in more depth here, and no examples of the definition will be given. However, the main aspects of the definition need to be discussed: information content, data storage format and measurement accuracy. Information content primarily specifies the building parts to be measured and their attributes. The data storage format depends on the applications used. A measured model is usually rather rough which makes it is easier to export from one system to another than a model that contains application-dependent features. An important aspect of the storage format is the data structure used for describing the building parts.

The information content of the produced model may also be made to correspond to requirements by computer modeling without measurements. For this reason it is necessary to make a distinction between measured and only modeled data. At a minimum, only a few individual reference points and dimensions are measured. At a maximum, modeling is based entirely on measurement. In practice measurement requires a visual contact with the object, so there are usually some building parts that cannot be measured. These missing objects are added to the model.

Besides the information content the amount of measurement work is essentially affected by the geometry of the building and its environment. Models of different accuracy levels take highly different amounts of work in different buildings. For example, a labyrinthine building, small room size and wall directions deviating from a rectangular set of coordinates increase the workload per square meter of floor area. Valuable old buildings made by hand are usually slow to measure.

The difficulty of measurement has a direct impact on attainable measurement accuracy. A high measurement accuracy requirement in a building that is difficult to measure radically increases measurement costs. Measurement accuracy also depends on whether inside measurements can be tied to exterior measurements of the building. In a long row of successive rooms, measurement errors may accumulate unless the measures can be verified, for example, against the outer surfaces of the exterior walls. For this reason, the measurement accuracy of basements is always lower than that of above-ground floors.

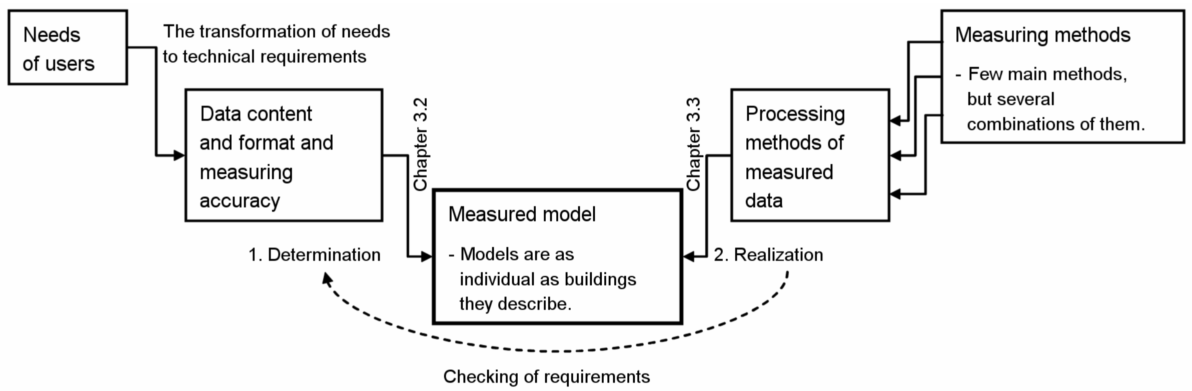

Figure 1. The determination of requirements for a measured model.

Measurement accuracy is a combination of the measurement assumptions made with the used method, the accuracy of individual observations and verification measurements. Only verification measurements allow assigning numerical values for accuracy. Otherwise, the default accuracy of the measurement method has to be used. The default accuracy of the method considers no possible human errors. As a general rule, individual points can seldom be determined at an accuracy of millimeters due, for instance, to different rounding of corners.

In terms of the purpose of the model, measurement accuracy may be described either by global or local coordinates. Global coordinates consider things such as the mutual accuracy of floors. Local coordinates can be defined, for instance, for the interior of a room. If the model is used, for example, for making fixtures or cutting wall-to-wall carpets in advance, high measurement accuracy for the interior of a room is required. Global accuracy, in turn, is needed, for instance, for designing penetrations of ventilation ducts between floors.

CAD programs are quickest to use when the model follows the coordinate axes and copying can be used extensively. In CAD modeling the dimensions and locations of building parts can be expected to correspond to standard measures. For example, the spacing of columns may be assumed to adhere exactly to a 6,000 mm division. The more accurate and more complete the measurements, the more variations from standard measures. In the generation of a model from measurement data, there is a persistent conflict between modeling practice and measurement results.

Because of what was said above, fully uniform measurement accuracy requirements could only be set for buildings that were built in the same way, that have an identical room arrangement and occupancy and are located in a similar environment. In addition, if the purpose of the model and the operating environment, i.e. the parties and used software are the same, a standard procedure for the measured model and its production could be specified. In practice, every case is unique, and no universal specification for the measured model can be given.

3.2 *Connections between needs and general measured model types*

Instead of a universal specification, the following analysis divides measured models into types by their data structure. The visual and surface models do not recognize building parts at all. The appearance of the model can be enhanced by linking surfaces to photographs of the objects. However, the models lack the data actually needed in the planning of renovation and use of buildings. The only useful application for models of this form is as references for CAD modeling.

A building part model contains the building part and space concepts. Its information content can be made to suit most purposes. Utilization of the model in a CAD application requires data transfer where building parts are converted to objects used by the software. In theory this can be achieved, for instance, by using common data exchange formats. In practice the management of different parameters and attributes is difficult, and linkages between the measurement program and the objects of the CAD application must be made by case by case. A procedure where data transfer creates new objects is not recommended, either. The new objects do not necessarily support the user's established conventions that are also compatible with other systems. Table 1 presents the used model types and their general features.

Table 1. Types of measured models and their features.

Model type / Feature	Visual model	Surface model	Building part model	Parametric object model
Raw data format	Photographs or point cloud	Geometric surfaces	Surfaces marking the limits of building parts	Parametric object based 3D building parts
Material information	Not included	Not included	Quantities of surfaces by materials and space information	Fully quantity surveying data
Automatic processing	Triangulated surfaces		3D building part from combination of surfaces	
Manual processing	Background picture for modeling by CAD program	Reference data for modeling by CAD program	The linking of individual building parts to objects of end user programs	Straight data transformation

Table 2 presents applications of models and examples of data in each application. The examples of data represent the minimum requirement for a model type suitable for the intended use. The right-hand column gives the examples a rough measurement accuracy requirement. It is not defined in more detail here but divided into three groups.

Table 2. Examples of the use of different measured models.

The main use and examples of data	Minimum model type	Accuracy
Architectural planning		
- parametric object based building parts	Parametric object model	Medium
- added reality	Surface model	Low
Structural planning		
- load-bearing structures	Parametric object model	High
- elements	Parametric object model	High
Condition data and renovation plan		
- prepared and demolished structures	Parametric object model	Low
HVAC planning and maintenance		
- devices	Building part model	Medium
Fitting		
- carpets, fittings	Building part model	High
- installations	Building part model	High
Facility management		
- space management, fixtures, work points	Building part model	Low
- keys, security, traffic zones	Building part model	Low
Cleaning		
- furniture, materials	Building part model	Low
Signaling, presentation	Visual model	No requirement

With a view to the end use, the best procedure is one where recognition deals directly with the objects defined by the end use. This requires that the objects are initially read as input data for measurement. Thereby data exchange is not a problem because the compatibility of objects is ensured beforehand. A disadvantage is that the operating environment, that is, the software used in the process must be fixed already before the start of measurements. If this is not possible, a linkage-based method must be applied.

Predefined objects may also be useful in defining the needs mentioned in Figure 1. Object parameters and attributes provide a technical specification of the data on the measured building that need to be stored during measurement.

3.3 *Connections between model types and measuring methods*

A model that meets certain requirements can be produced by several different measurement methods. Table 3 shows a rough estimate of the applicability of the main measurement methods for the production of the model types presented in Table 1. In practice, methods can be combined to optimize the amount of work and measurement accuracy.

Table 3. Suitability of measuring methods for producing different model types.

Model type / measuring method	Visual model	Surface model	Building part model	Parametric object model
Measuring program and distance meter or tacheometer	Poor suitability, produces a wire frame model	Is suitable, no building part recognition is needed	Is suitable when building parts are recognized	By input feature of objects of measuring program
Laser scanning	Good suitability	Good suitability	Remodeling by CAD or by adjusting 3D objects	Remodeling by CAD or by adjusting 3D objects and linking
Photogrammetry	Good suitability	Is suitable, border lines from points		

Only methods that directly produce a photograph-like presentation of the structure are suitable for creating visual models. In terms of geometric content, a model consisting of points and surfaces is a wire frame or surface model. A surface model can be created by all methods either directly or by measuring the points that define the boundary lines of the surface.

The software used in the measurement is able to directly produce a building part model. The same method allows producing a parametric object model if objects can be read into the measurement program. In the case of laser scanning and photogrammetry recognition is done at the office. Then is it possible to avoid unnecessary data transfer if measurement results are transferred directly to the end user's CAD application and modeling is performed on top of measurement results.

Laser scanning can be supported by an automatically calculated geometrical surface model based, for instance, on the triangulation of surfaces. In photogrammetry the reference points must be measured whereby the measurements can be used to generate boundary surfaces of building parts. Possible adjustment of 3D objects requires a special application if these data need to be transformed to the end user's CAD.

3.4 *Selection of a measurement method*

As already noted, measurement requires a visual contact with the object. At any given point it is only possible to measure building parts visible from that point. If only a few building parts or points to be measured are visible from a point, the amount of preparatory work before actual measurement is relevant from the viewpoint of the feasibility of using the method. Such preparations include the matching of a pair of stereo photographs and the setting up and positioning of a tacheometer. These tasks must be carried out before any actual measurements of the object can be made.

In the light of the above, methods other than those based on distance measurements are poorly suited to the measurement of the interiors of buildings with small rectangular rooms. Usually a room has only a few points to be measured, but they may not necessarily be visible from one point in the room, especially if the room is in normal use. An exception is the mechanical room where the ducts need to be measured. Then there are a lot of points to be measured, but the limited visibility poses a problem. Measurements are usually made during normal occupancy of the building, because it is not economically feasible to empty the building already during the design stage, especially if the purpose is just to examine the suitability of the building for different uses.

A method based on distance measurement is not at all suited to the measurement of facades, because it requires physically placing the meter by the object to be measured. The only economically feasible alternative are other methods based on non-contact measurement.

The above limitations are not absolute, and the same measurement method can produce different models. Both the information contents and measurement accuracies of the models may vary. The information content can be chosen rather freely irrespective of the method, but in practice some limits may be set on the attainable measurement accuracy depending on the method. Table 4 presents the suitability of different measurement methods for producing models with different measurement accuracies. The accuracy requirement is indicated verbally, as in Table 2.

Table 4. Ability of measuring methods to produce different accuracy levels for models.

Accuracy level/ measuring method	Low	Medium	High
Measuring program and distance meter	Good suitability, quick production	By extra measurement s and known points	By several known points and plane surfaces
Measuring program and tacheometer	Poor suitability	By measured place of measuring device	By a dense traverse
Laser scanning	Good suitability, quick production	By measured place of measuring device	By a tacheometer and a dense traverse
Photogrammetry	Good suitability	By few known points in picture	By several known points in picture

The use of a distance meter always presumes that the surface to be measured is planar. If this assumption is valid, the method is able to produce reasonable accuracy. Accuracy can be improved by extra measurements and known points. The method is not suitable for measuring points located freely in three-dimensional space. With a tacheometer the accuracy of the method can be greatly increased. Because of the preparatory work involved, the method is poorly suited to low accuracy applications, because there the number of points to be measured is small and a similar end result can be attained, for example, with rectangularity assumptions.

The accuracy of methods based on laser scanning and photogrammetry is easiest to adjust. The accuracy of the end result can be improved by increasing the number and accuracy of visible known points. The accuracy of known points can also be improved by additional and independent observations. By reducing the amount of this work, the method can be used quickly and economically if the required measurement accuracy is low.

4 RECOGNITION OF BUILDING PARTS BY A MEASURING PROGRAM

4.1 *Development history*

A measurement method where measurement based on a laser distance meter is controlled by a software application run by a laptop is used as an example of building part recognition. This research environment has been developed at Tampere University of Technology for a long time. Developed methods have been tested on actual buildings.

The first testing environment was implemented in the 1980s linked to a tacheometer. Already in this version, measurement was based on measuring the surfaces of building parts. Laser distance meters introduced to the market in 1994 made use of the present method possible. In this method the recognition of building parts is based on the features of the measurement software. The accuracy of the end results can be varied by different measurement procedures. Used procedures have included additional measurements, reference points measured with a tacheometer and the linking of measured points to facade measurements. The measurement results have been processed using the least squares method.

The next major stage in the development was a procedure where wall surfaces were combined into solid structures. This procedure is documented in the doctoral thesis of Laasonen (2001). The development stage presented in this paper involves the introduction of parametric objects to the measurement and recognition of building parts. This procedure has not been tested extensively in practical applications, because it brings nothing new to actual measurement work. The purpose of the procedure is to serve the further utilization of the model.

4.2 *Use of parametric objects in measuring*

The objects used in the measurement are defined in the end use application, which is usually a CAD application for architectural design. For the definition, the building part types of the building are inventoried and assigned a counterpart among the application's objects. Usually a building contains a limited number of different building part types. The data essential for the measurement of these objects are entered as input to the measurement application. The required information content to be transferred is modest. The main point is that each object is identifiable. In its simplest form this can be achieved by assigning identifying names. In addition, default dimensions are needed to limit the maximum measures of the building part which may be called its bounded box. For instance, in the case of a window usually only the opening in the wall is measured. Measuring other properties of the window such as clear openings does not increase the usefulness of the model enough to make the effort worthwhile. An exception to this rule could be a valuable building with individually dimensioned windows handmade on site.

Table 5 shows an example of a data structure covering the minimum information on a door, where the same door type can appear in different sizes. The data structure includes only a limited number of alternative sizes, although in theory no such limitations are necessary with parametric objects. In practice, however, only doors of certain standard sizes are manufactured industrially. The data structure consists of two tables, and the table on the left contains the names and descriptions of the building parts. These data are linked to alternative default sizes shown in the table DoorMeasures on the right. The linking has been implemented using an internal code, such as DoorT1 on the first row. The file format corresponds to that of Microsoft Visual Basic ini files.

Table 5. Example of a simple definition of a parametric door object.

[DoorType]	[DoorMeasures]
DoorT1=D1, Front_door, Wood	DoorT1=900x2200
DoorT2=D2, Inside_door, Melamine	DoorT2=900x2100
DoorT3=D3, Inside_door, Wood	DoorT2=800x2100
	DoorT3=1200x2200
	DoorT3=900x2100

Structural elements used in construction are manufactured to certain dimensional tolerances. Accurate actualized dimensions can be stored in connection with measurement. The resulting information can be applied in two ways: either the original standard measures or the actual measures can be selected. If dimensional variations of elements are not considered significant information, measurement work can be saved by simply measuring the object in place.

Figure 2 shows the user interface for controlling the measurement of an opening in the measurement software. The menu on the left is used for measuring the location of the lower edge of the opening in relation to a wall corner. The center dialogue box is used for selecting the type of the building part in the opening, in this example a door. The dialogue box on the right allows editing nominal measures to correspond to reality.

In this measurement method direct recognition of objects is possible only with building parts that are sufficiently visible from one location. Such objects usually include windows, doors and fixtures. Beams and columns can generally be assumed to be known objects, even if they continue in another room. If objects are limited to the visible terminals of heating, plumbing, ventilation and electrical equipment, they are also directly recognizable.

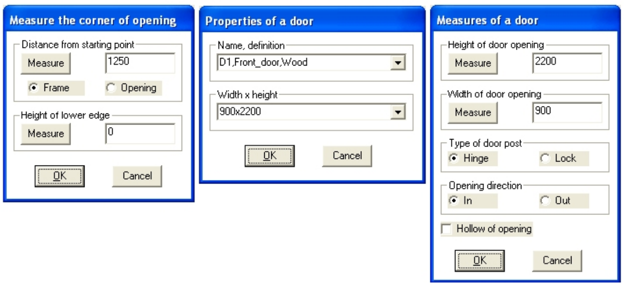

Figure 2. Example of a measurement software user interface for measuring a building part corresponding to a parametric object.

Poorly recognizable building parts include walls and roofing decks and base floors. Their delimitation and thickness pose a problem. For this reason these building parts are usually not recognized until the processing of the measured model. If the surfaces of a structure are treated as objects at the measurement stage, it is possible to attain a similar model structure for these building parts as in direct recognition.

4.3 *Measurement accuracy*

It takes three observations to calculate the three-dimensional coordinates of a single point. For example, a tacheometer observes the horizontal and vertical angle as well as distance at a go. As already noted, measurement accuracy can be improved by additional observations to verify the calculation result. On the other hand, the measurement accuracy requirement can be eased by making assumptions that reduce the number of observations needed. For instance, by assuming a simple room to be rectangular, it can be measured based on three distance observations, that is, the length, width and height of the room. The measurement method is shown on the left in Figure 3.

The right half of Figure 3 shows the measurement of the same room if room surfaces are assumed to be planar and their height to change only linearly. Then, the length and height of every wall is measured separately and the shape of the room is verified by cross measurements. The measurement is more accurate, but the amount of measurement work increases from 3 observations to 10. Moreover, the 3 observations of the assumption-based method can be made more quickly because easier observation points can be chosen. The example of reveals how much the amount of measurement work may increase if the same method is applied to producing more accurate models.

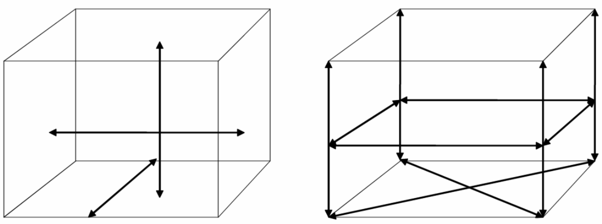

Figure 3. Measurement of a simple room by distance observations.

4.4 *Further development*

The next stage in the further development of the presented measurement method is intended to focus on the rectangularity of the model. An attempt will be made to make the thickness of all walls uniform and aligned with the coordinate axes by calculations. The calculations used to modify the model will not destroy the original measured coordinates. After modification it must be possible to report the difference between the model and measured reality. In addition, it is possible to select the use of either a modified rectangular or the original measured model. The significance of the difference depends on the use of the model. For example, smaller errors are allowed in the design of fittings than in the rental business.

5 CONCLUSIONS

The theoretical section of this article examined how the needs of the end users of buildings can be linked to practical measurement methods. It was found that due to their uniqueness, buildings have to be designed separately in terms of needs and implementation. Needs should be specified in a computer file format to correspond to implementation. The main aspects of such specification are information content, data storage format and measurement accuracy.

In theoretical terms, the presented method arose from the experiences gained from measurements on several test buildings and the processing of measurement data. Practical application of the method has not been documented scientifically which makes it a possible subject for further research.

The test section of the article describes how the method can be applied to measurement work. The technical solution is based on the recognition of the building part concept of CAD modeling software from measurement data. In principle, the presented method is simple, but its implementation still requires a versatile environment. The test environment comprises the measuring apparatus, the measurement program, post-processing of measurement results and transfer of data to a CAD modeling application in the format needed by the end users of the data. The method can be used even with very limited information contents, as shown by the presented example. By limiting data content it is possible to find the most effective method to measure and transform data. In an integrated operating environment based on information exchange, software should have features for both inputting and outputting all information contents automatically. For maximum flexibility, the method should not limit the number of attributes attached to concepts.

The purpose of the recognition of building parts is to produce information as relevant to and compatible with the end use of buildings based on modeling as possible. To be effective, recognition should be done only once and thoroughly enough for the generated model to support building modeling by design software. Consistent methods make the application of measurement results easier and reduce a labor cost which allows the measurement of buildings to become a more routine standard service.

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