Building Information Model (BIM) and Measuring Techniques

Christian CLEMEN, Robert EHRICH and Christopher van Zyl, Germany

Keywords: BIM, CAD, Parametric Modeling, Laser Scanning

SUMMARY

In CAD software digital drawings are modeled with lines, surfaces or solids in order to specify the dimensions of a building. Layers are used to structure the graphical elements according to appropriate criteria. In contrast to CAD, the BIM method offers a rich semantic model of building elements. Typical object types are wall, door, ceiling, etc. Using BIM, dimensions of building elements are specified by parametric modeling. Parametric modeling hardly uses coordinates, whereas engineering surveyors typically use point coordinates and derive graphic elements of higher dimension (line, face, solid) from measured points, which are imported to the CAD software.

In the case of as-built-documentation the BIM method will change the way measurements are used to derive digital models: In this paper some practical investigations are shown: How to use point-clouds (both structured, e.g. as from a total station, and unstructured, e.g. as from a laser scanner) and manual measurements with the BIM method. Examples are given with Autodesk *Revit*, which is a frequently used BIM program.

Building Information Model (BIM) and Measuring Techniques

Christian CLEMEN and Robert EHRICH, Germany

1. INTRODUCTION

“BIM gets a boost” [Talend 2012] – and engineering surveyors are using this new method. Commercial opportunities for constructors using BIM methodology [Smith 2012] have spread to the designing and planning of large buildings and infrastructural facilities. National and mandatory BIM standards have been established, particularly in the USA [NBIMS 2007], UK, Scandinavia, Hong Kong and Singapore [Zeiss 2013] – a global trend in the construction industry. On the other hand there are small and medium sized enterprises which do not as yet have much knowledge of BIM. Surveyors – as they learned in school and university – are likely to be accustomed to CAD (and tradition is not the only reason).

“Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.”[NIBIMS 2014]

The use of BIM software implies using a consistent data base for the entire duration of a building project, including planning, construction, operation and demolition. Surveyors also offer services for all construction phases: GIS analysis for investment decisions, land management, site plan for concept and production design, advice on complicated geometric problems, staking out, machine guidance on the construction site, as-built surveying for the acceptance of work (or refurbishment), and many services for the operation and maintenance of the building (construction monitoring, CAD services, CAFM), The point is that the BIM method suits the surveyors’ way of working, because both, the BIM Method and the surveyor, serve all professionals involved over the entire period of the project.

This paper gives some practical examples on how to deliver the above-mentioned services in such a way that the product is suitable for a BIM. In the section “BIM vs. CAD” a comparison of the methods from a survey point of view is presented. The following section describes the ordinary data flow from manual measurement to BIM for both handheld devices and tacheometry. The last section presents some practical work done with laser scanning and BIM [Ehrich 2013]. Autodesk *Revit* was used for this practical work; no comparative studies with BIM solutions, such as *Allplan* (Nemetschek AG), *ArchiCAD* (GRAPHISOFT SE) or *Tekla Structures* (Tekla Corporation) were undertaken.

2. BIM vs. CAD

Engineering surveyors are used to working with CAD, when a site or building has to be modeled. In the following section three essential differences between CAD and BIM are presented: project management, semantic model and spatial model.

2.1 Project Management

Most CAD documents are natively stored as files. It has been known for years from the GIS domain that databases are very useful for collecting, checking and sharing spatial data. BIM uses a similar approach: A single model instance (database) serves as a central information pool. The BIM software is able to create and update views of the model. Views can be:

- Graphical data (site plan, floor plan, sections and views),
- Alphanumeric data (many types of tables, lists and reports),
- Data in a specialized format for applications software (structural analysis, etc.), or
- Virtual (or physical) 3D models, which may be used as a basis for design discussions, or for marketing and promotion.

How does this change the surveyor's work? Rather than deliver CAD files, the surveyor has to *check in* the as-built surveys to the central information pool. The BIM server reports conflicts immediately. For staking out, parts of the model are *checked out* (using e.g. Autodesk *Point Layout*) and, in turn, reports (successfully constructed) have to be *checked in* after further measurement.

Another important question is the method of open data exchange between different kinds of software and project partners. As in GIS, each software package has an internal data structure that has to be transformed to an open standard. Autodesk *Revit* and other BIM systems are able to transform the internal object types to the IFC-Model [Liebich 2007] and export IFC-files. "The Industry Foundation Classes (IFC) data model developed by buildingSMART is an open, international and standardized specification Building Information Modelling (BIM) data that is exchanged and shared among software applications used by the various participants in a building, construction or facilities management project" [IAI 2014].

The impression of the authors is that with each new software version of the commercial and proprietary BIM software *Revit* IFC support gets better. However data exchange is a problem. Configuring the internal mapping from software objects to IFC elements is not trivial.

Besides these technical questions, the surveyor must keep in mind that the BIM method allows the inclusion of the dimensions of time and cost in the 3D model to. For as-built documentation this means that all measured building elements can be attributed with a specific time period (phase).

2.2 Semantic Model

The BIM data model is object oriented. The overall information frame of object structuring is the building element – not the geometry of drawing elements or layers. For example in In Autodesk *Revit* each building element is classified and connected to other model or datum elements. The group of *datum elements* is very important from a surveying point of view. Rather than using control points the geometrical project context is expressed in terms of system of grids, levels and reference planes. (see section spatial modelling)

All elements that are placed in the model or on a drawing sheet are classified in Autodesk Revit in three levels of specialization: category, family, type (see Fig.1):

- The *category* of an object describes the general function it has for the building (wall, column, window), the way it is visualized and describes a set of references the object can have with other objects in the BIM.
- The next level of specialization is the *family*. The *family* serves as a "drawing" template. The *family* specifies a set of variables for specific parameters (width, length, height, lower bounding, upper bounding ...)
- The most specific level is the *type*. The *type* specifies the value of some parameters (length, width) and leaves some variable (height).

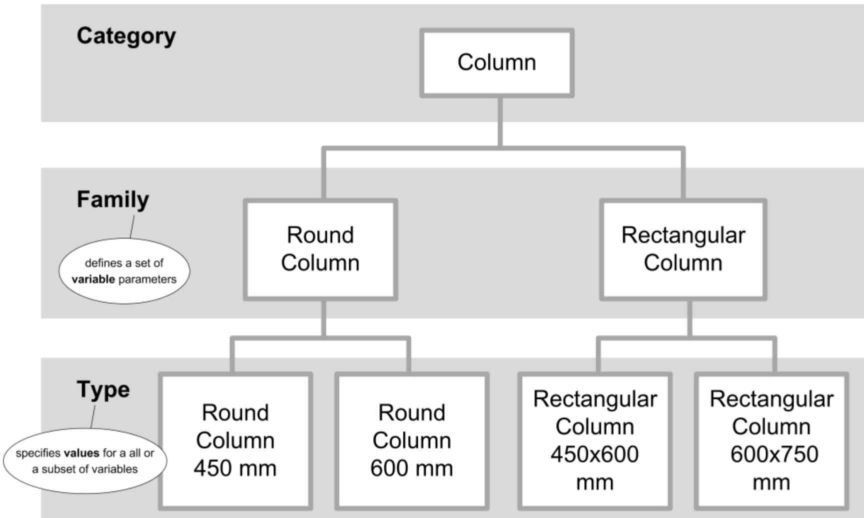


Fig.: 1 Autodesk *Revit* classification of building element instances [Autodesk14]

CAD systems do not generally offer this form of semantic model.

2.3 Spatial Model

In CAD dimensions are derived from the drawing as *relative* information between geometry objects (lines, circle …). Usually the dimensions are associated with a geometry object and thus change in value, when the geometry object changes in size. Geometry objects are placed with *absolute* coordinates (WCS, UCS).

In **Parametric Modeling** the emphasis is reversed: The value of the *relative* dimensions (length, height, width, parallel distance to center line, vertical distance to plane) defines the *absolute* shape and placement of geometry objects. The method of parametric modeling is not unique to BIM Software. CAD Software is also able to parameterize drawing elements with relations such as connected, collinear, parallel, orthogonal, horizontal, vertical or tangential. In BIM software, however, building elements are modeled mainly with parametric modeling. Furthermore, the difference to CAD is that the semantic model defines the set of geometric variables, and the functional relationships.

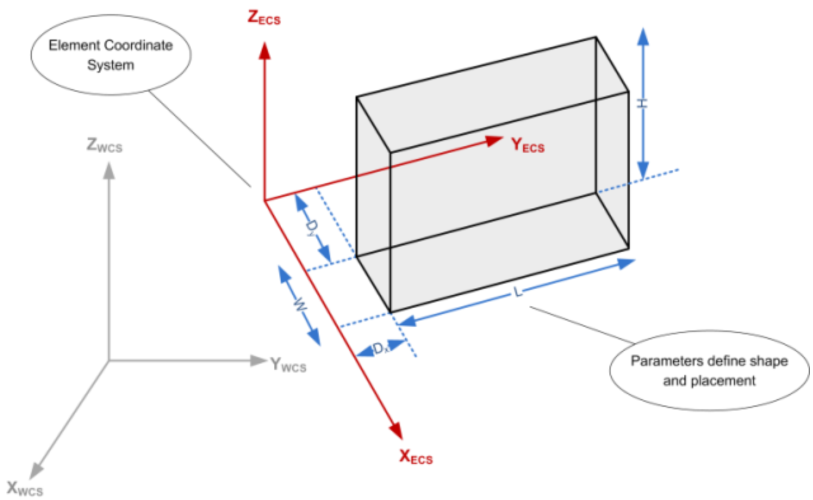


Fig.: 2 Parametric Modeling

Surveyors are used to working with point coordinates. Since BIM does not use any point coordinates for building elements, importing measurement data and exporting set out data are not natively supported. Additional import/export software (e.g. Autodesk *Point Layout*) is needed, that transforms point coordinates and field measurements to BIM parameters.

3. MANUAL MEASUREMENT AND TACHEOMETRY

3.1 Manual Measurements

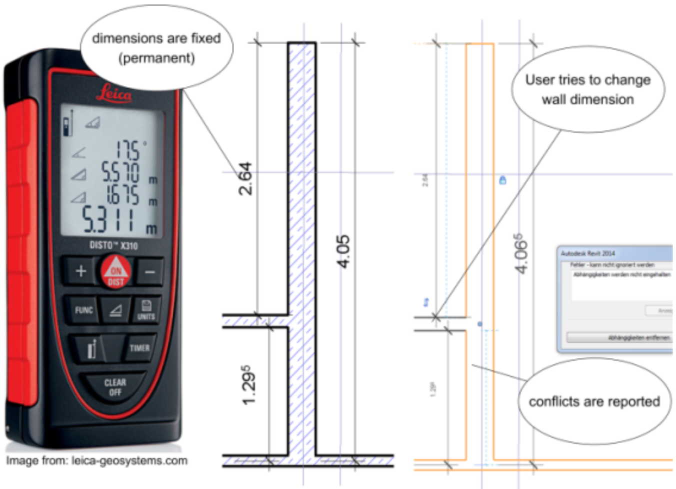
Horizontal and vertical distances are measured with a tape or a laser distance meter and used in the model as:

- Distance between elements (wall - wall, sill - floor)
- Measured object dimensions (width, length)

The measurements are used as direct input to the model (primary data). In the view of the authors, BIM changes the way distance measurements are handled in three significant ways:

— The modeling process starts with a 3D sketch that defines elements and relation between elements. Relative geometry is *checked in* to the model in a successive manner.

- Less intermediate coordinate geometry (COGO) is necessary, because *relative measurements* are primary data in parametric modeling.
- *Conflicts* are reported immediately, but are not resolved. An adjustment tool which



minimizes the misclosure between model and measurements is an unresolved research issue.

Fig.: 3 Laser Distance Meter and BIM: Conflicts are reported immediately

3.2 Tacheometry

Tacheometry delivers measurements to discrete points. Simple relative dimensions like roof slope, column height, etc., can be measured in the instrument coordinate system, without being transformed to any external coordinate reference frame. Reflectorless distance measurement is very useful when objects are inaccessible.

The main advantage of tacheometry becomes apparent once the discrete points are coordinated within an external coordinate reference frame. Autodesk *Revit* is able to link several building coordinate systems to a (single) shared coordinate system. Points measured with total station or GPS can be imported as benchmarks or object points in a shared coordinate system. With these points digital terrain model (DTM) and site plan are modeled as in CAD.

For large surveys, Surveying/Civil Engineering CAD software is still very useful, because BIM misses e.g. the following features:

- Import of raw surveying data.
- Tools for on-line measurements with tacheometry.
- COGO for polar surveys.
- Semantic point-code handling.

Parametric modeling requires the surveying data to fit into an ideal geometry (collinear, planar…) – as long as the deviations between model und measurement are acceptable. Some

Surveying CAD systems (e.g. *TachyCAD* from kubit GmbH, *Vitas* from Vitruvius GmbH) solve these conflicts by fitting planes to the appropriate sets of measured points using least squares, then calculating intersections of the adjusted planes with each other and/or with measured directions in order to determine the bounds and other elements of objects (e.g. rooms) in the model (see Fig.4).

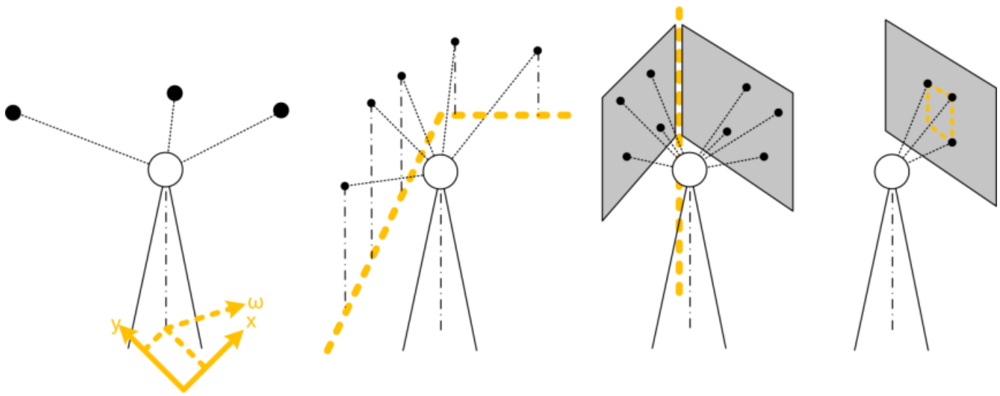


Fig.: 4 Examples of using tacheometry with kubits TachyCAD :
Instrument stationing, creation of floor planes with projected points, use of adjusted planes for intersection, calculation of window corners as the intersection of the line of sight with an adjusted plane.

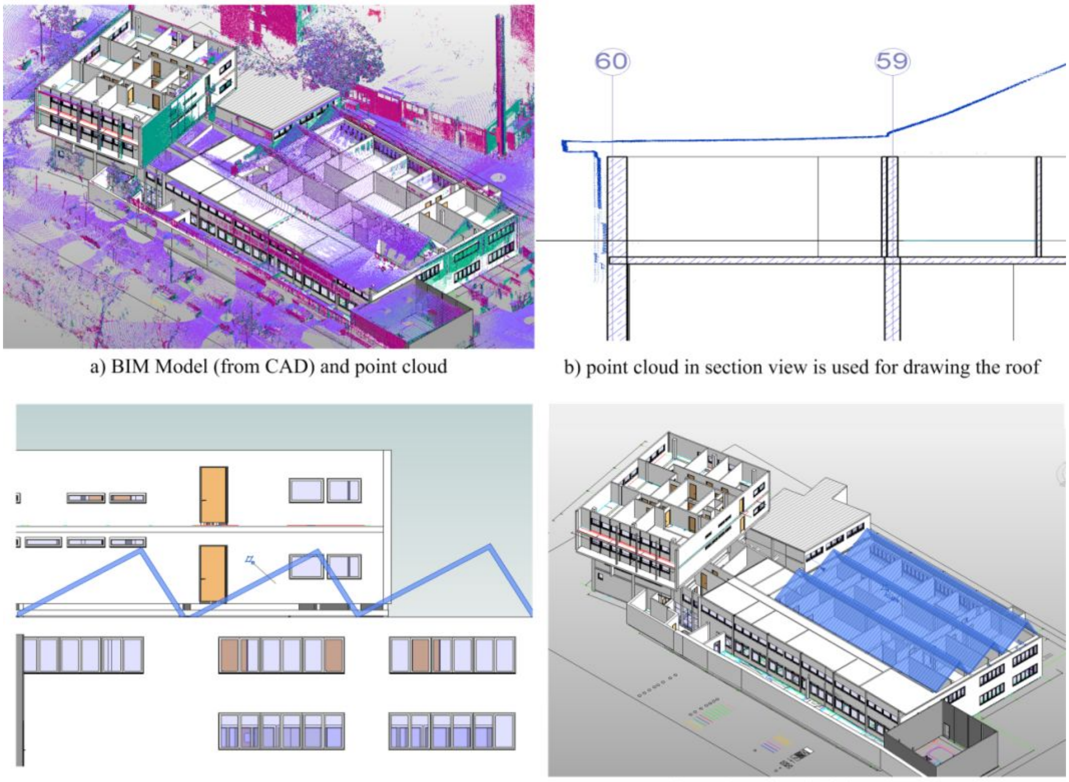
4. LASER SCANNING

The last section presents some practical work done with laser scanning and BIM [Ehrich 2013]. In the course of a student research project factory premises of Beiersdorf Manufacturing Berlin GmbH were surveyed and modeled.

4.1 Native support for point clouds

Autodesk *Revit* is natively able to link and import point clouds. The import format is *.rcp (Autodesk *Recap*). Many other formats can be converted for Autodesk *Revit*. Figure 5a shows a registered (*SCANTRA*, technet GmbH) point cloud after import. The roof profile is then drawn in the section view and used to create the roof surface (figures 5b and 5c). Here the BIM Model (including raster and building elements) and point cloud are clearly laid out. Measurements can easily be taken and/or construction elements derived from the scans in the view.

Revit natively supports planar snapping and direct point snapping when working with point clouds and proper working planes. Another very important use for laser scanning and BIM is to check whether the building is constructed as designed. A simple visualization can be done with native *Revit* tools. For a proper analysis some extra tools (e.g. Autodesk *Point Layout*) are needed.



a) BIM Model (from CAD) and point cloud
b) point cloud in section view is used for drawing the roof
c) construct solids with sweep, dimensions from point cloud
d) result: roof as building element

Fig.: 5 Native support for point clouds in Autodesk *Revit*

4.2 Specialized Laser Scanning software

Several Plug-ins and stand-alone software packages are available for the evaluation of laser scan measurements. E.g.: *Scan to BIM* (IMAGINiT Technologies), *Cloudworx* (Leica) or *Scalypso* (Ingenieurbüro Dr.-Ing. R. König) were developed or upgraded with BIM-specific features. The software packages *VirtuSurv* from kubit GmbH and *SCANTRA* from technet GmbH (for registration) were used in the student research project.

The software *VirtuSurv* does not need to import the entire point cloud to the CAD/BIM software. The user works in 'easy to use' two-dimensional panoramic views of registered scans. *VirtuSurv* has a direct *Revit* interface. In the process shown in Fig. 5 a Faro Laser scanner (*Focus3D*) and the registration software *SCANTRA* were used. *SCANTRA* calculates the transformation parameters for each single scan very quickly without the need for artificial targets to connect the scans. Just a few coordinated control points are used for georeferencing. *VirtuSurv* was then used to place the building object in the model space. *VirtuSurv* offers simple tools to adjust planes und calculate intersections. Hidden edges can be constructed by intersecting planes. Topology and semantics are specified with the BIM software. Both software applications work on the same model instance. Changes are synchronized.

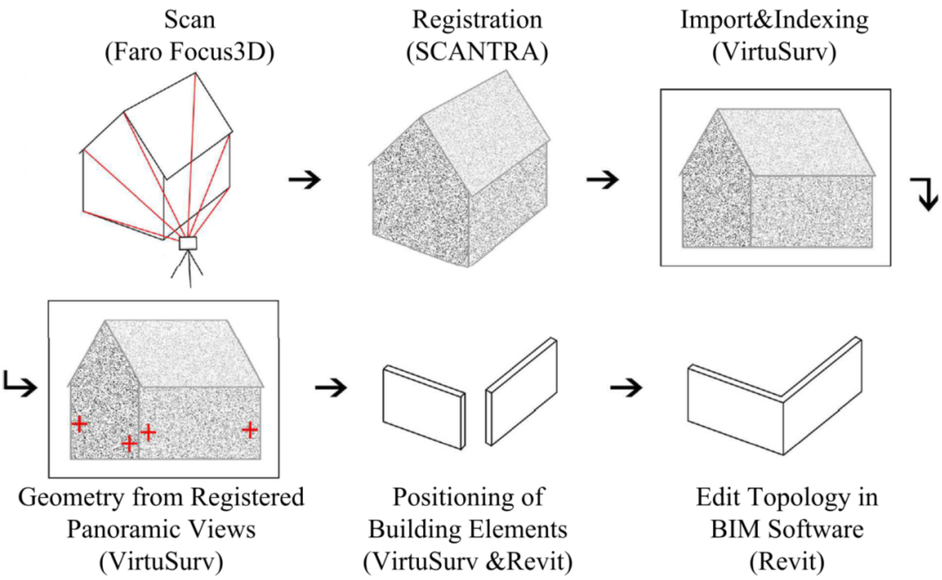


Fig.: 6 Workflow with Faro Scanner, *SCANTRA* (technet), *VirtuSurv* (kubit) and Autodesk *Revit [Ehrich 2013]*

5. OUTLOOK

It is recognized that BIM is very well known in large companies and universities. Most land- and building surveyors work in small engineering enterprises, however, and are unlikely to have knowledge of BIM concepts or software.

It has been shown that the evaluation of measurement data (laser distance meter, tacheometry, laser scanning) is different for BIM as compared to CAD modeling, due to the parametric modeling. Surveying is essential to BIM, because high quality models reduce the costs and completion time of any construction project [Agele 2012].

Students in the Bachelor of Surveying degree course at the HTW Dresden University of Applied Sciences study BIM together with CAD, focusing on data acquisition. As surveying professionals they are able to offer new products and services for BIM methods and create new business segments.

REFERENCES

Smith J.A., 2012, *BIM – A Contractors Perspective*, International Federation of Surveyors Article of the Month – June 2012, FIG

Agele J. A., 2012, *Adoption Of Building Information Modeling And Nigeria's Quest For Project Cost Management*, FIG Working Week, Rome, 2012

Autodesk 2014, Revit *Architecture 2010 User's Guide*, San Rafael, CA, US 2014

Ehrich R., 2013, *Untersuchung zum geodätischen Einsatz von Autodesk Revit und VirtuSurv für die digitale Bestandsdokumentation von Gebäuden*. Unpublished Thesis, HTW Dresden, Germany 2013.

IAI-buildingsmart website, *Industry Foundation Classes (IFC) data model*, 2014: http://www.buildingsmart.org/standards/ifc (last accessed on 01/03/2014)

Liebich T., 2007, *IFC2x Edition 3Technical Corrigendum 1*, 2007: http://www.buildingsmart-tech.org/ifc/IFC2x3/TC1/html/index.htm (last accessed on 01/03/2014)

NBIMS - National Institute of Building Sciences, 2007: *National Building Information Modeling Standard – Version 1 – Part1: Overview, Principles, and Methodologies*. Washington, DC, USA

NIBIMS - National Institute of Building Sciences, 2014: Frequently Asked Questions About the National BIM Standard-United States http://www.nationalbimstandard.org/faq.php#faq1 (last accessed on 01/03/2014)

Talend D., 2014, *BIM gets a boost*, In: *The American Surveyor* Vol. 9, No 1, January 2014 Cheves Media, Frederick, MD, USA

Zeiss G., 2013, *Widespread adoption of BIM by national governments*, geospatial blog, geospatial.blogs.com/geospatial/2013/07/widespread-adoption-of-bim-by-national-governments.html (last accessed on 01/03/2014)

BIOGRAPHICAL NOTES

Christian Clemen, born 1976. Graduated in 2004 as a Dipl.-Ing. in Surveying from the Technical University of Berlin. From 2004 to 2010 he was an Assistant at the Department of Geodesy and Geoinformation, Technical University of Berlin. He then worked as a GNSS software engineer for Alberding GmbH, Wildau. Since 2013 he has been a full professor at the HTW Dresden, University of Applied Sciences..

Robert Ehrich graduated 2013 as a Dipl.-Ing. (FH) in Surveying from the HTW Dresden, University of Applied Sciences.. He works for the town planning office, Hannover, Germany.

Christopher van Zyl was born and brought up in South Africa. After qualifying as a Land Surveyor there he practiced in the Cape Province and in Germany until 1980. He lectured at the University of Fort Hare in Alice until 1986 and then moved to the University of Otago in Dunedin. He was appointed as a professor at the University of Applied Science in Dresden in 1994, where he is responsible for teaching full- and part-time students computer survey applications and is foreign liaison officer for the Department of Surveying and Cartography. His interests include cadastral surveying, the field collection of semantic data and teaching quality. Professor van Zyl retired in 2013.

CONTACTS

Prof. Dr. - Ing. Christian Clemen
Chair of CAD and Virtual Reality, Faculty of Geoinformation
HTW Dresden, University of Applied Sciences
Friedrich-List-Platz 1, D-01069 Dresden, Germany
Tel: +49 351 462-3199
Fax: +49 351 462-2191
E-Mail: clemen@htw-dresden.de
Web site: http://www.htw-dresden.de/