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A Flexible Web Based Learning Tool for Construction and Surveying Students Using Building Information Modelling and Laser Scanning

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A FLEXIBLE WEB BASED LEARNING TOOL FOR CONSTRUCTION AND SURVEYING STUDENTS USING BUILDING INFORMATION MODELLING AND LASER SCANNING

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Teaching and training construction and surveying students using computer simulations of buildings although recently developed is not new. In the case of this project a novel aspect is introduced through applying advanced recording and building modelling techniques developed in the Faculty of the Built Environment in the Dublin Institute of Technology. In summary this learning software uses parametric objects representing intelligent building components which are brought together virtually by the student to create or form an entire building. The library of parametric objects contain the real world geometry, texture and specification of building parts allowing the student to virtually analyse and experience different forms of architecture and structure, this system is referred to as Building Information Modelling (BIM). The BIM can automatically create cut sections, details and schedules in addition to the orthographic projections and 3D models (wire frame or textured). The parametric building objects are not defined singularly but as systems using interaction with other objects and their own values (shape, texture etc.) within a BIM. A terrestrial laser scanner will be used to assist the capture and modelling of existing buildings and environments for use in the project. The learning software and virtual building models will be accessed by the student on the internet through PC, laptop and hand held devices allowing participation and support for traditional and non-traditional learners. This will also allow for progress at the student's own pace, encouraging learning by doing practice.

Keywords Innovation, technology, research projects

1. SUMMARY AND OVERVIEW OF PAPER

The learning software described in this paper uses parametric objects representing intelligent building components which are brought together virtually by the student to create or form an entire building. A terrestrial laser scanner will be used to assist the capture and modelling of existing buildings and environments for use in the project, this is outlined in section 2 of this paper. A library of parametric objects which contain the real world geometry, texture and specification of building parts will allow the student to virtually analyse and experience different forms of architecture and structure. This system is referred to as Building Information Modelling (BIM) and is described in section 3. The BIM can automatically create cut sections, details and schedules in addition to the orthographic projections and 3D models (wire frame or textured). The parametric objects are constructed using GDL (Geometric Description Language); GDL is an open scriptable language that can be used to create new objects. The learning software and virtual building models will be accessed by the student on the internet through PC, laptop and hand held devices allowing participation and support for traditional and non-traditional learners. This will also allow for progress at the student's own pace, encouraging learning by doing practice. The final part of this paper (section 4) describes the design of the learning platform which will be used to deliver the learning software to the students.

2. LASER AND PHOTO-MODELLING RECORDING SYSTEMS

2.1. Terrestrial laser scanners

The terrestrial laser scanner is a device that automatically measures the three dimensional co-ordinates of a given region of an object's surface, in a systematic pattern and at a high capture rate in near real time. The laser ranger is directed towards an object by reflective surfaces that are encoded so that their angular orientation can be determined for each range measurement. The entire instrument and/or the recorded object are rotated to achieve, where possible, complete 3D point coverage [1].

There are three types of scanners suitable for metric surveys for cultural heritage: triangulation, phase comparison and time of flight scanners. Triangulation scanners calculate 3D co-ordinate measurements by triangulation of the spot or stripe of a laser beam on an object's surface that is recorded by one or more CCD (charge-coupled device) cameras. Phase comparison systems calculate range based on the difference in phase between emitted and returning wavelengths. Time of flight scanners (Figure 1) calculate range, or distance, from the time taken for a laser pulse to travel from its source to an object and be reflected back to a receiving detector [2]. Time of flight scanners are most suitable for the metric survey of historic structures because of their long range which is between 2m to 2500m as opposed to triangulation and phase comparison systems which are more suitable for recording smaller objects [3].

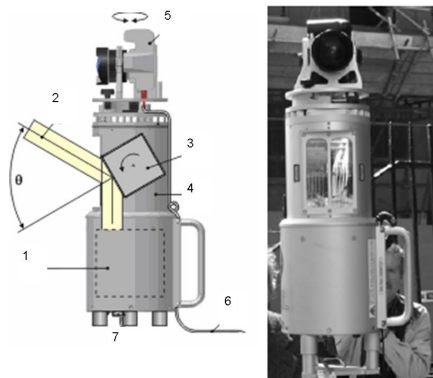


Figure 1: Riegl, time of flight terrestrial laser scanner [4]

Details of the Riegl laser scanner and combined camera system are illustrated in figure 1. The Range finder electronics are indicated at (1) in the main body of the scanner. The vertical deflection of the laser beam shown at (2) is directed towards an object by a polygon (3) which is made up of a number of reflective surfaces. The horizontal scan is achieved by rotating the complete optical head (4) up to 360°. The scan-data which consists of range, angle, and signal amplitude is transmitted to a processor through data cables (6). A camera (5) is located on the same vertical axis as the scanner and the data is fed by a separate cable (7) into the processor. The right hand side of the image shows the scanner in operation in Henrietta Street Dublin.

3. BUILDING INFORMATION MODELLING

3.1. Parametric Modelling

The basic parameters which describe vector objects are shape and volume expressed as coordinates and its orientation as an angular value. For example, a cube can be defined with only two sets of coordinates, one for each of two diagonally opposite corners. The definition also requires three angular specifications, one to indicate the angle of the base side in the x-y plane, one the base angle in the x-z plane, and one the base angle in the y-z plane. The specification for the materials and colour can accompany the numerical data. The cube as a parametric model can then be edited to change any or all of its parameters of construction and orientation [5]. Eastman (2006) defines parametric modelling as 3D or 2D solid object shapes, which are described according to parameters some of which are user defined and others, which relate to position in a 3D environment relative to other shape objects.

3.2. Building Information Modelling

Where parametric objects are brought together as building components to create or form the entire building, this system is referred to as Building Information Modelling (BIM). The BIM can automatically create cut sections, details and schedules in addition to the orthographic projections and 3D models (wire frame or textured). The parametric building objects are not defined singularly but as systems using interaction with other objects and their own values (shape, texture etc.) within a BIM [6]. In building parametric objects, the problem of file format and exchange of data has been overcome within the ArchiCAD software platform by using a geometric descriptive language (GDL). The scripting in GDL allows for sharing and editing of the parametric objects at different levels. In figure 2 below an example of a column with a capital and base is constructed using a GDL script [7].

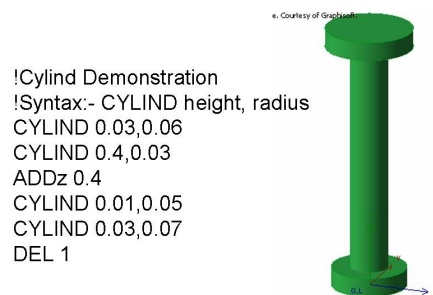


Figure 2: Example of GDL object and script.

ArchiCAD software divides parametric objects into built construction elements (walls, columns, beams etc) and GDL (Geometric Description Language) objects which are specifically constructed for one or many uses. GDL is an open scriptable language that can be used to create new objects with the required parametric information for the object's function. Before placing a construction element, or GDL object, in a BIM, the default parameters can be edited by the software changing parameters of shape, size or other properties as opposed to re-scripting in a GDL editor [8].

3.3. Plotting Parametric Models from Laser Survey Data

Mapping parametric vector objects on to the point cloud can overcome the slow task of plotting and locating every vector onto the cloud surface. Parametric models can also introduce the opportunity to develop detail behind the object's surface concerning its methods of construction and material makeup.

In figure 3 a section of a textured point cloud of a brick wall with an opening is illustrated, the dimensions and co-ordinates of the wall and opening are calculated using RiScanpro software [4]. The dialogue box, which calculates the dimensions, is shown in A and the point cloud is observed in B. These dimensions can then be transferred into parametric modelling software, in this case ArchiCAD.

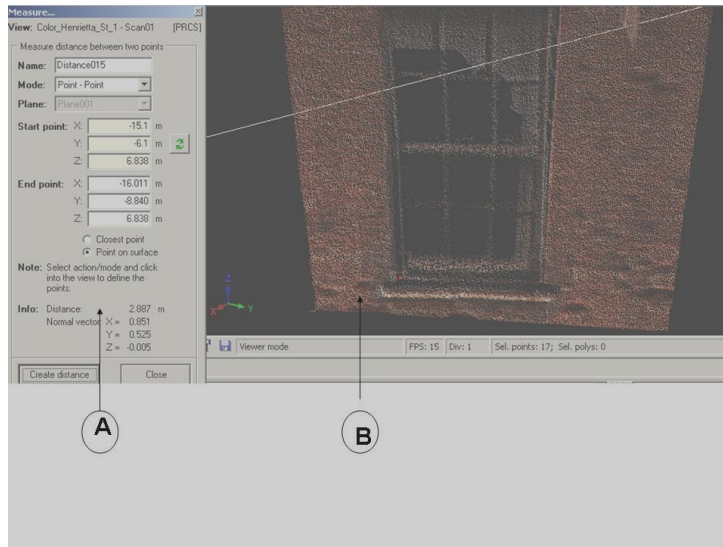


Figure 3: Texture point cloud of a brick wall.

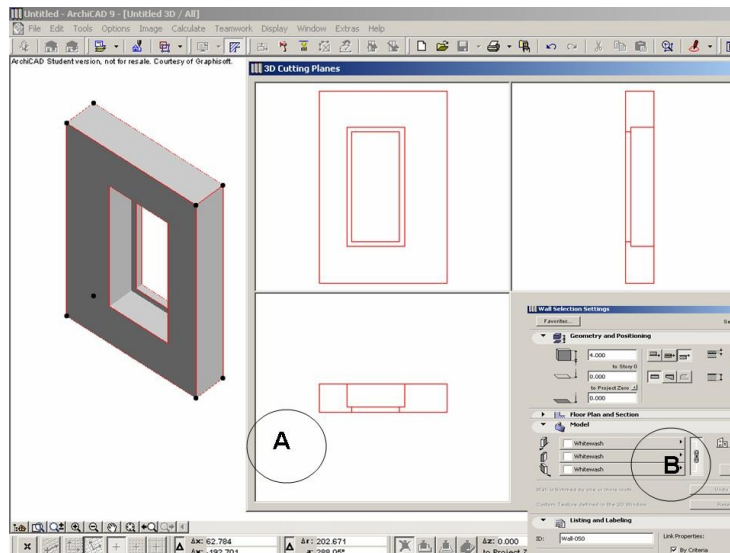


Figure 4: Parametric Representation of the Wall.

Figure 4 above illustrates the parametric representation of the wall built from the point cloud data as:
Detail A – Illustrates the 3D model and the orthographic plan, elevation and section which is automatically created.

Detail B – Illustrates a section of the dialogue box which describes a section of the parameters of the wall and its opening.

The dimensions of the wall (height, width and length) and its position in a co-ordinate system were calculated using the point cloud in RiScanpro. The thickness of the wall and its composite construction were measured separately from the laser survey in this case. The materials and techniques that make up the walls construction can be determined from image data and the model can be textured with the position image data. The opening sizes and positions of the windows were also calculated from the point cloud and are represented by a separate set of parameters.

3.4 Building the pediment as a parametric object

The following parametric objects, constructed using the software platform ArchiCAD were built from GDL script as detailed in the example in figure 11. Initially the pediment is modelled as a 2D vector object, as detailed in figure 16, detail 2. The historic data is used to build the profile of the 2D vector object. The main modular components the architraves and entablature are used to model the object, the level of detail can be added to at later stages. Once the 2D vector data (see detail 2, figure 5) is completed, the 3D model can then be built first as a primitive. The result of the first stage is shown in figure 5; detail 1, illustrates part of the scripting. These are then joined to a rectangular block which represents the entablature with the protruding triglyphs as shown in detail 3 as a wire frame object and shaded in detail 4.

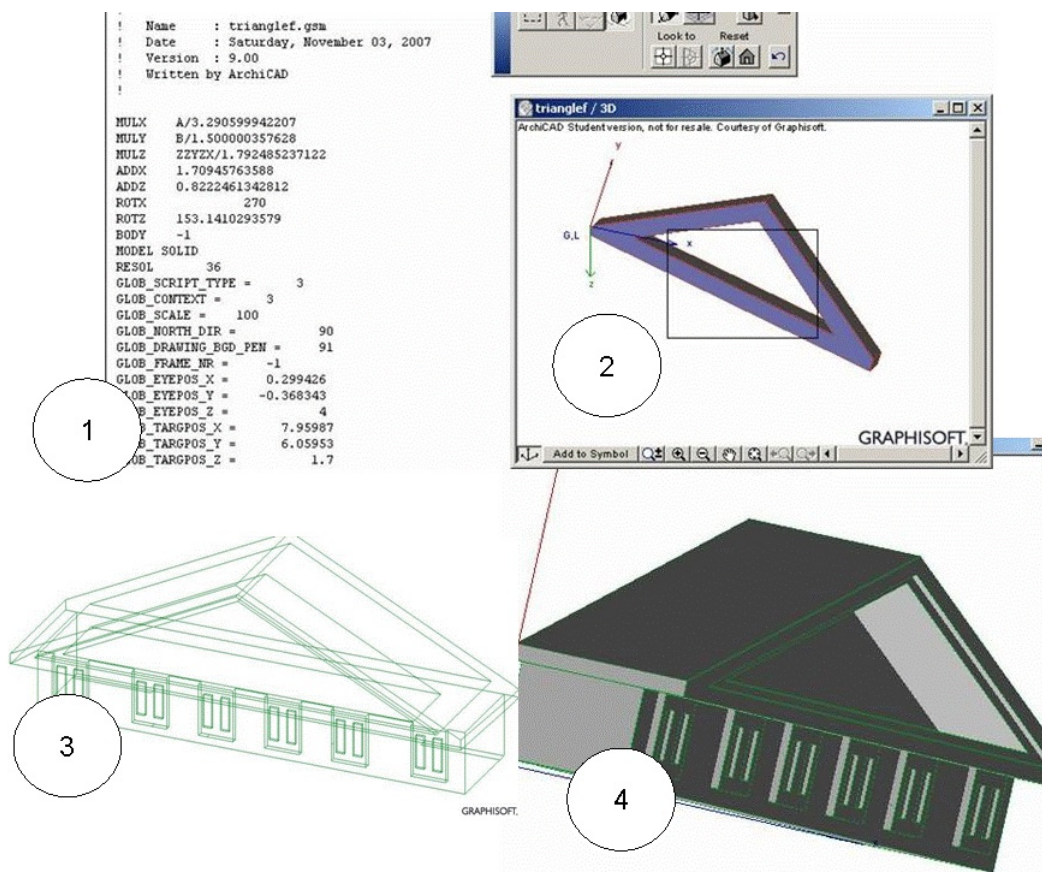


Figure 5: Building a parametric model of the pediment.

3.5. Building the columns from existing library objects

If variations of the component objects already exist as a whole or as primitive objects in a library or database, they can be edited to match the historic data. The 3D parametric objects for the Doric columns that include the capitol and base are created from the 2D vectors from the descriptive geometry of the historic texts [9], [10]. In figure 6: detail 1 shows the historic data; detail 2 illustrates the Doric column as an editable library part. The capitol and base merged with column through Boolean operations from library parts are shown in detail 3 as wire frame objects. Part of the dialogue

box for editing the parameters of the object is shown in detail 4. Finally the shaded Doric column is detailed in 4.

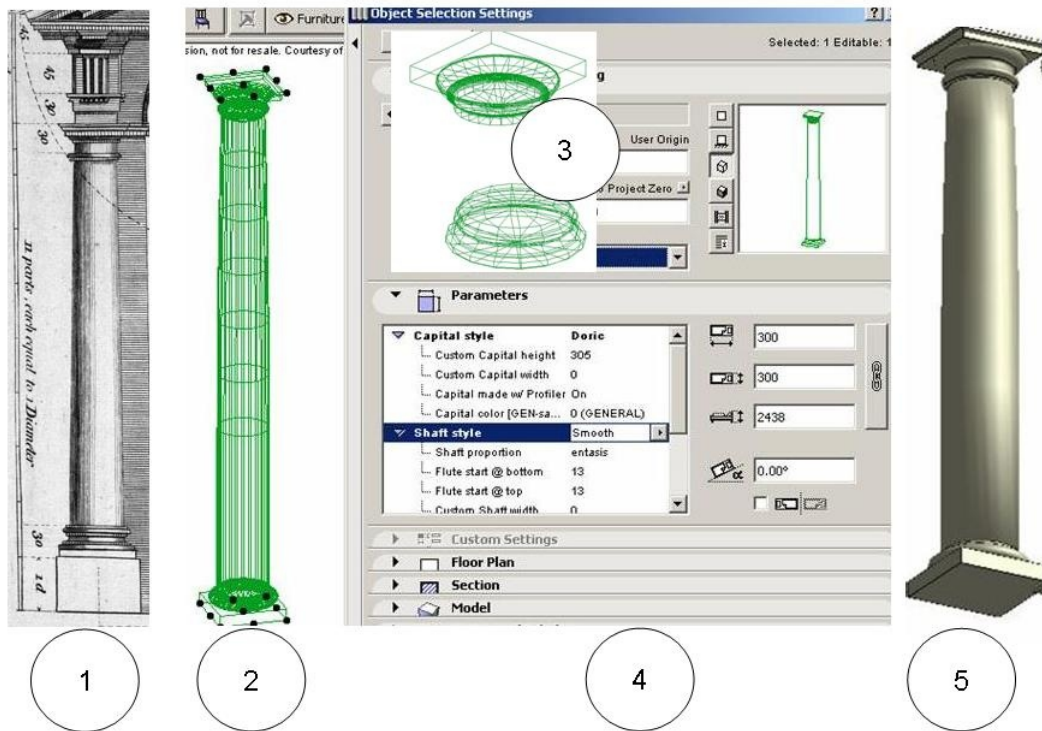


Figure 6: Building a parametric model of the columns.

3.6. Mapping of the parametric objects

The following laser scan survey (figure 7) of a classical door-case in Henrietta street in Dublin (constructed in circa 1730-1740) is taken as an example to illustrate the steps involved in plotting of the parametric objects based on classical detail and proportional geometry from historic texts. It is important to note at this stage that the parametric objects are modelled on the historic data first and later edited to fit the point cloud surveys as they appear in many variations on the survey. This is illustrated in the variation in classical detail of the facades of the buildings in Henrietta Street.

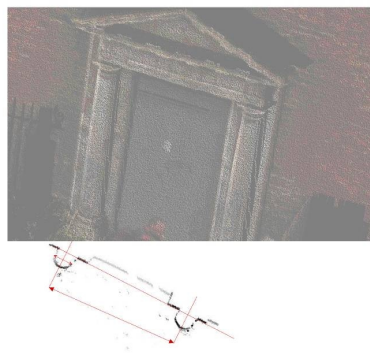


Figure 7: Point Cloud of Door-Case 1730.

The parametric vector objects are brought together to form the partially completed object as illustrated in figure 9 below. The component parametric objects detail 1 (figure 8) which contain details of direction, x, y, z co-ordinate values and construction components (i.e. the capital, base and column can be separated) are modified to suit accurately the geometry, scale and rotation of the point cloud survey. The newly formed parametric object is placed in the wall with the accompanying opening for the door. As a new object it can be contained within a database or library to be placed in the complete model of the building or as components within the elements of the building.

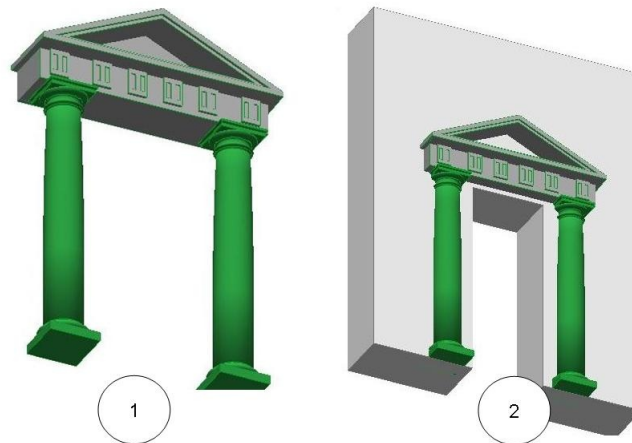


Figure 8: Partially completed plotted parametric objects.

3.6. Automated Production of Orthographic Drawings

The object in this case is an element of a historic structure of an 18th century door case. The object is brought through the design process in the opposite direction, from the laser scan survey to the blueprint, revealing information about the original design and construction. The final process of reverse engineering is illustrated in figure 9; the production of plans, elevations, sections and 3D models is automated from the 3D model.

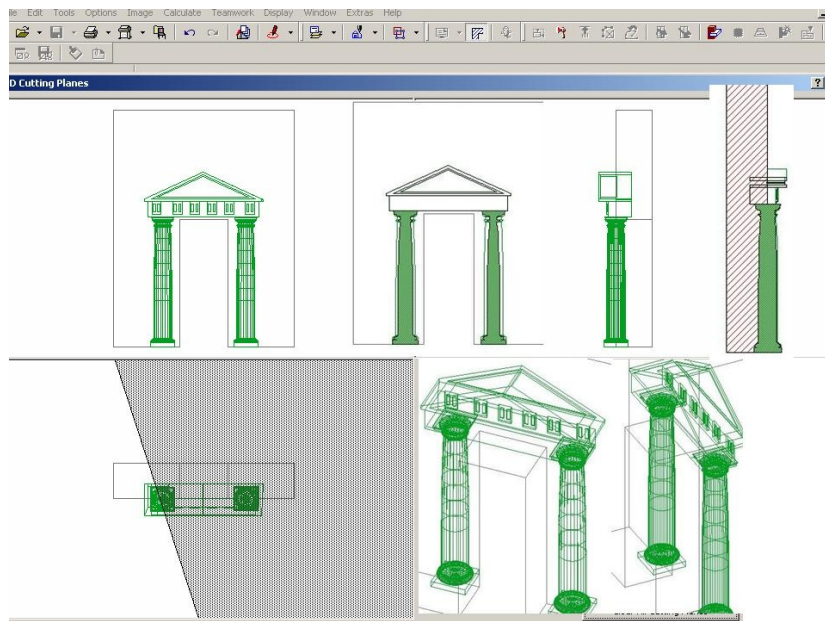


Figure 9: Automated drawings.

4.0 DELIVERY OF LEARNING SOFTWARE

4.1 Instructional design

In the case of this project the objective is to create a learning software platform which will be Web based using PC, laptop and hand held devices, which will enable individual and group based student learning. The learning software will simulate realistic scenarios of the construction process (how buildings are designed and constructed), thus bringing the real world into a virtual classroom.

4.2 Flexible Virtual Learning

The Piloting of the learning software will be delivered as a main element in Construction Technology teaching, delivered virtually alongside some classroom instruction as blended or flexible learning. The E-learning element of any flexible or blended learning module offers a very different experience from classroom-based learning. When interacting online individual students have their own perspective and experiences whereby they construct their own interpretations of the knowledge provided to them. [11]. This can be exploited in the design of the learning software; students will be encouraged to construct their own interpretation from the simulation of realistic scenarios of the construction process thus improving the learning outcomes.

In addition the learning software and mixed delivery platform of PCs and handheld devices (see figure 9) creates a virtual class allowing students to construct their own interpretations against a 'backdrop of shared understanding, practices, language and so forth' [12]. Student members will be encouraged to interact with each other electronically. During the module students will be brought together at various locations to progress their learning. Face to face (f2f) tutorials will be provided and students will be given an opportunity to ask questions, discussion boards will be developed to allow students impart knowledge among each other long after the f2f tutorial has ended. It will be the social makeup and their relationships that determine the possibilities and practices in each case.

As part of the design process it must be ensured that the learning software will effectively exploit the advantages of online teaching. The key ideas that shape the learning software design are; that the learner must be allowed to develop critical thinking and the ability of problem solving. The learning software must operate as an interacting system between the provider and learner [13].

4.3 Theoretical Design Framework

The design is based on a five stage model [14]:

1. **Access and Motivation:** Ability to gain access online quickly and easily is a key issue at step one which is assisted by the delivery on hand-held and PC devices. The second issue of motivation requires the delivery of content to be engaging, thereby encouraging students to spend quality time online and to return willingly over the course of the module.
2. **Online Socialising:** By using mobile devices the students will expand their learning environment into their world of social networking.
3. **Information exchange:** Exchanging information online has the advantage of allowing everyone to explore at their own pace and react to it before hearing the views and interpretation of others. Encouraging the students to use the software library resources providing them with virtual building blocks rather than content will keep the student motivated and encourage them to take charge of their learning.
4. **Knowledge Construction:** The software must provide an area which allows students to give constant feed back of their experience while they are participating on the module, to interpret whether the support systems are working for the student and what aspects of the project can or needs to be improved, [12].
5. **Learning Software Development:** Figure 10, below outlines the process Firstly to build a prototype library and data base of interactive parametric objects and plot these onto laser scans of existing buildings. Secondly create the learning software platform which will be Web based using PC, laptop and hand held devices.

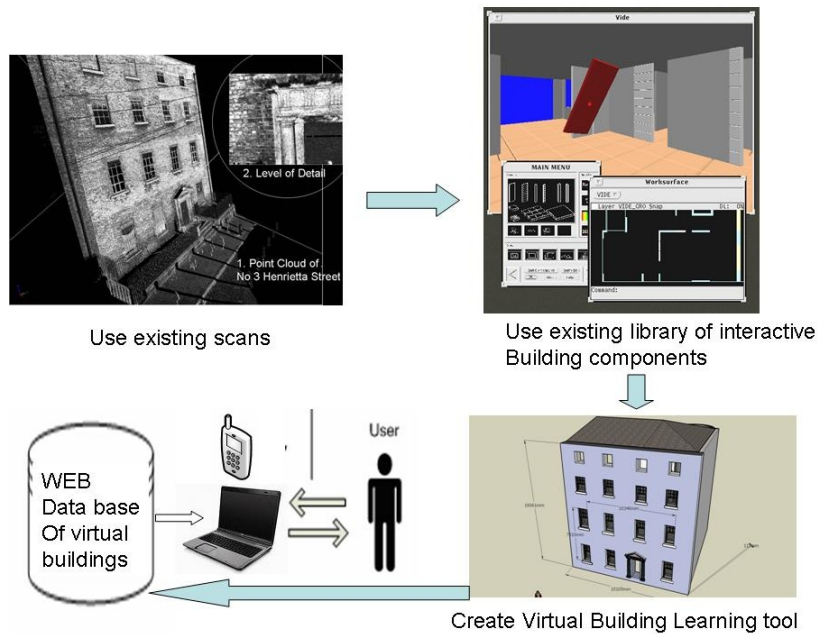


Figure 10: Overview of process

REFERENCES

1. Mills, J.P. and D.M. Barber, *Geomatics techniques for structural surveying*. ASCE Journal of Surveying Engineering, , 2004. 130(2): p. 56-64.
2. Boehler, W., G. Heinz, and A. Marbs. *The potential of non-contact close range laser scanners for cultural heritage recording*. in *CIPA International Symposium*. 2001. Potsdam, Germany CIPA.
3. Blais, F., *Review of 20 years of range sensor development*. Journal of Electronic Imaging, 2004. 13(1): p. 231-240
4. RiegI Laser Scanning, *RiegI laser scanning software manual*. 2006.
5. CSA. (2005) *Parametric modelling in AutoCAD® -- almost*. CSA Newsletter Volume,
6. Eastman, C., *Report on integrated practice university and industry research in support of BIM*, G.I.o.T. American Institute of Architects, Editor. 2006.
7. Graphisoft, *ArciCAD release 10, interactive training guide* 2006, Graphisoft.
8. Tse, T.K., K.A. Wong, and K.F. Wong, *The utilisation of building information models in nD modelling: A study of data interfacing and adoption barriers*. Journal of Information Technology in Construction, ITcon 2005 10.
9. Pain, W., *Pain's British Palladio, or The builder's general assistant*. 1788: London. p. Plate XXXIII.
10. Langley, B., *The city and country builder's and workman's treasury of designs, or, The art of drawing and working the ornamental parts of architecture*, . 1756, S. Harding.: London.
11. Abrami, P.C. and E.M. Bures, *Computer Supported Collaborative Learning And Distance Education* The American Journal of Distance Education, 1996. 10(2): p. 37-42.
12. Schwandt, T.D., *Three epistemological stances for qualitative inquiry: Interpretivism, hermeneutics, and social constructionism*, in *The handbook of qualitative research* Y.S.L. N. K. Denzin, Editor. 2000, Sage.
13. Ramsden, P., *Learning to Teach in Higher Education*, . 1992, London Routledge.
14. Salmon, G., *E-tivities: the key to active online learning*. 2002, London: RoutledgeFalmer