

USING 3D LASER SCANNER DATA FOR 3D MODELLING: “EL BORN” IN BARCELONA

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1. IT APPLICATIONS FOR CULTURAL HERITAGE

Intervention within areas of historical and architectural importance, where one finds groupings of monumental and cultural heritage, is a complex task that implies a great responsibility, since a non-appropriate restoration can result in irreversible damage. For this reason, and with the purpose of establishing guidelines for the intervention of Cultural Heritage, it is fundamental to have detailed information, adapted to established goals, as well as the tools and technologies that allow an effective manipulation and operation of the data generated during the complete lifecycle of an historical landscape.

For that reason, a multidisciplinary knowledge base, created from the studies and research about those cultural aspects is fundamental: historical, architectural, archaeological, environmental, social, economic, etc., which reflects in a trustworthy form the organisation of the heritage to be safeguarded, its characteristics, its location and the possible problems related to its conservation, so that it facilitates the development of policies and the later decision making on the part of the owners and managers of the said Cultural Heritage.

Data capture, Data models

In order to have an adequate diagnosis of the Cultural Heritage, it is necessary to describe its buildings and monuments by means of documentation and plans, whether they be historical or newly elaborated, where their more outstanding characteristics are reflected: samples and soundings for undertaking foundation studies, values of sensors that measure the deformations and the movements of the architectural structures (walls, columns, arcs, vaults,...), types of original materials or those used in performances or later restorations, its possible damage and other non-structural pathologies, constructive systems, etc.

Nevertheless, an intervention on Cultural Heritage is inappropriate without taking into consideration that it can have an effect beyond the limits of its own particular area. Facing the proposal of intervention and allocation of possible uses during or after the intervention, it is important to carry out the study in its surroundings and to document those aspects that condition them clearly (environmental, social, economic, landscaping,...). Therefore a two-way interaction exists between the monument and its surroundings. The surroundings condition the possible use of the monument and can affect it directly (for example, noise nuisance originating from nearby emitting centres), but also the area must be in accord with its surroundings and it can even cause a change in the socio-economic activity of the surroundings.

Between the techniques that can provide the necessary plans and cartography for the previous studies, it is possible to mention, amongst others, photogrammetry and laser scanning, for the three dimensional definition of the structures; the systems of design undertaken by computers (CAD) in the elaboration of building plans or of 3D mesh objects; the systems of global positioning GPS/Galileo for the location of devices which characterise 3D surfaces or for the creation of plans associated to the monumental setting; digital images taken from airborne platforms,... In addition to this documentation generated, it would be necessary to add that existing and prevailing in public institution archives, that maintains the relation of the heritage.

Archive and sharing, GIS and related information, Virtual Reality (VR)

Nevertheless, at this point in time the foregoing is considerably far removed from the real situation, since more often than not it is extremely difficult to obtain full documentation and cartography, of an acceptable quality, since the materials, constructive pathologies and systems are often insufficient or deficient (flat that simply reflects levels, isolated photographs,...). Sometimes the information in reality exists, but this fact is not known, or it is not easily accessible, leading to the unnecessary duplication of efforts and resources. The possibility of counting upon catalogues of goods and properties of cultural interest, and their associated meta-data (information relating to their own data), where it is possible to ascertain the possible existence of certain information and to co-ordinate actions between the institutions in charge of safeguarding the heritage, is a key issue. Certain European initiatives, as is the case of INSPIRE [5], aim towards the creation of the infrastructure for the distribution of such data, would represent an important step in the knowledge and the protection of the Heritage. Also, an aspect of special relevance would be the consideration of historical standards for the characterisation of monuments and places, as for example MIDAS [1] that assure the consistency of information and facilitate its flow between all the implied actors (heritage owners, heritage managers, cultural promoters, specialists, technical personnel, researchers, students, tourists, tourist operators, residents,...)

Data maintenance, updating information, conversion, data standards, national databases

One of the greater limitations than takes place at the moment in the management of the Cultural Heritage is that of the integration of the information. It is not only important to have the data, but also that is available in a digital format (the greater part of the present information remains being provided in a paper format), that these formats are compatible with one another, that the data has semantic meaning, that they are inter-connected, so that the usual problems of incoherence of information are avoided, that the duplicity of efforts as far as personnel and economic resources are concerned is avoided and that they can altogether be put under analysis.

Another aspect to consider is that given the important volume of information that exists around an intervention in Heritage, it is necessary to have a solid database management system (SGBD) offering data protection and the integration of documents in a consortium of data, information, technical studies, basic and derived cartography, virtual reality models, multimedia material, etc. This point is of special interest, since at present some SGBDs (such as MySQL, Oracle,...) allow binary type data to be stored in their information tables (BLOB fields), an aspect that, until recently, was only possible to do through local files systems, via web servers. It is necessary to acknowledge that the information levels will be different depending on the user profile and of the use that is going to be made of the data.

In this aspect, GIS allows for the integration of diverse information as that which is generated during the lifecycle of cultural heritage, so that its later operation is simpler and, in many cases, accessible, either through a simple visualisation and recovery of the stored data, or by modelling more complex processes such as those carried out when analysing manifold criteria and study object variables (nD-modelling) [8].

The joint analysis of the information stored in the data bases on cultural heritage facilitates actions such as, for example, establishing tendencies in the movements of structures over time, from measurements arising from sensors and their representation, in a layered information form, in three-dimensional objects generated by applications of 3D or CAD modelling; to generate alarms when values exceed thresholds; to plan and prioritise interventions according to the existing economic resources and based on the state and importance of each building; to anticipate the budget necessary to approach the programmed interventions; to value possible relations between, for example, the degradation of materials and the deformation of structures and the conditions of inherent temperature and humidity of the surroundings or of the building; to economically value the partial cost over time arising from the restoration and maintenance of each element of the monumental set and the sum of these; to simulate performance of the monumental set based upon chosen criteria so that the possible performances are studied without implying a modification or destruction of the original characteristics; to generate documents for the management of administrative files relative to interventions on the patrimony or others that could affect it, etc.

Dissemination and diffusion to citizens

In addition to the aforementioned capabilities that these technologies have in Cultural Heritage to support its management, maintenance and decision making, the possibility which they offer to carry out the promotion and diffusion of the monumental groupings, something which until recently was difficult to value, is remarkable. Heritage diffusion is possible thanks to; virtual visits that can include as diverse aspects as animations through the history of the monumental groupings; walks on the land with the possibility of interaction with the virtual surroundings on the part of the user; bird's eye view visualisations on the cultural landscape; thematic tourist routes based on personal interests or on the time available for future "on-site" visits; games for children where the possibility is offered of discovering certain historical atmospheres, and even disappearing, from a playful point of view etc.

Also, it is very important that the public institutions inform the resident population of what is in existence and is anticipated to happen in the matter of heritage, so that, far from being a simple means of cultural knowledge, allows the citizen to take part in the processes arising from the planning of the city, and more concretely in those interventions that can be taken on historical groupings. In addition, this fact allows the citizen to consider him- or herself to feel involved in the process of facing the protection and conservation of the heritage he and she enjoys, but also the rest of visitors who, logically, are important in the maintenance and economic reactivation of the place.

Many cultural heritage applications require 3D reconstruction of real world objects and scenes. The motives are numerous:

To document historic buildings, sites, and objects for reconstruction or restoration if they are ever destroyed.

To create education resources for students and researchers of history and culture.

To reconstruct historic monuments that no longer exist, or partially exist.

To visualise scenes from viewpoints that are impossible in the real world due to size or surrounding objects.

To interact with objects without risk of damage.

Virtual tourism and virtual museum.

2. THE 3D LASER SCANNER TECHNOLOGY

CONCEPT AND DEFINITIONS

Terrestrial laser scanning is the use of a ground based device that uses a laser to measure the three dimensional coordinates of a given region of an objects surface automatically, in a systematic order at a high rate in near real time. It is also referred to as close range laser scanning [1].

The scanner is targeted to the physical objects to be scanned and the laser beam is directed over the object in a closely spaced grid of points. By measuring the time of laser flight, which is the time of travel of the laser from the scanner to the physical objects and back to the scanner, the position in three-dimensional space of each scanned point on the object is established. The result is a "cloud of points" which consists in thousands of points in 3-dimensional space that are a dimensionally accurate representation of the existing object [2]. This information can then be converted in a 3D CAD model that can be manipulated using CAD software, and to which the design of new equipment can be added.



Figure 1: CYRAX 2500

This innovation is significant because it has potential to solve the problems that are always associated with design and construction of existing buildings for reuse goals. For example, it can provide faster, better quality and more precise analysis and feature detection for building survey.

Point Clouds

The XYZ co-ordinates of points in a common co-ordinate system portrays an understanding of the spatial distribution of objects on the earth. It also includes additional information such as intensity or RGB value. Generally a point cloud contains a relatively large number of co-ordinates according to the volume of the point cloud occupies, rather than a few widely distributed points.

Point clouds are suitable for use on a wide variety of subjects including small objects, details of architectural design, building facades and whole sites. The variety of laser scanning systems is available and their differing design and operation of the exact procedures used to perform a survey will differ from system to system.

Overview and Detail Scans

A combination of overview and detail scans provides a clear description of the interested area. In addition, they enable the acquisition of detailed information of selected parts of the area or buildings. It is likely that scanning process on field requires the combination of a mixture of scans.

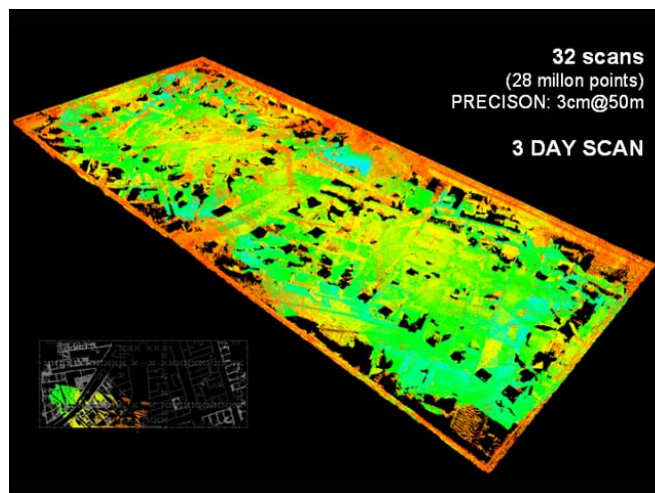


Figure 2: Overview and single scans with the CYRAX scanner

Overlapping Scans

Overlapping scans are generally required to ensure a full record of an object is collected. Overlapping data can also provide users with confirmation that the registration process has been successful [1].

It is possible to filter overlapping scan data in order to reduce the point density in the final registered point cloud and hence reduce file sizes and strain on software systems during processing.

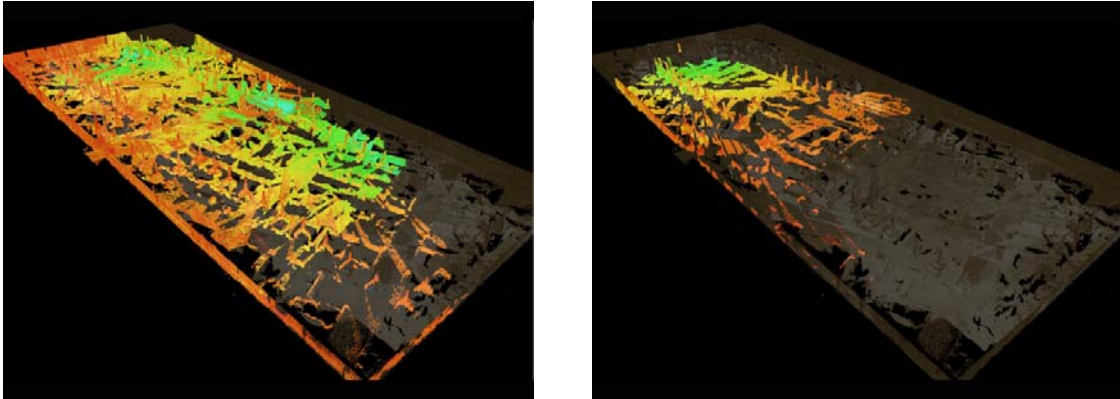


Figure 3: Overlapping Scans

Data Voids

Since data, which is collected during the scanning survey, will form part of the record of that site or the building, it is necessary to make sure that the data collected is complete. Data voids should therefore be minimised during the scanning process on field through selection of appropriate scanning positions (overlapping if necessary) and minimising temporary obstructions to the scanner during operation such as vehicles and pedestrians. Data voids due to occlusions to the line of sight can normally only be eliminated by using multiple scans. Data voids due to temporary obstructions such as pedestrians or vehicles should be limited by appropriate positioning of the scanner or restriction of such obstructions.

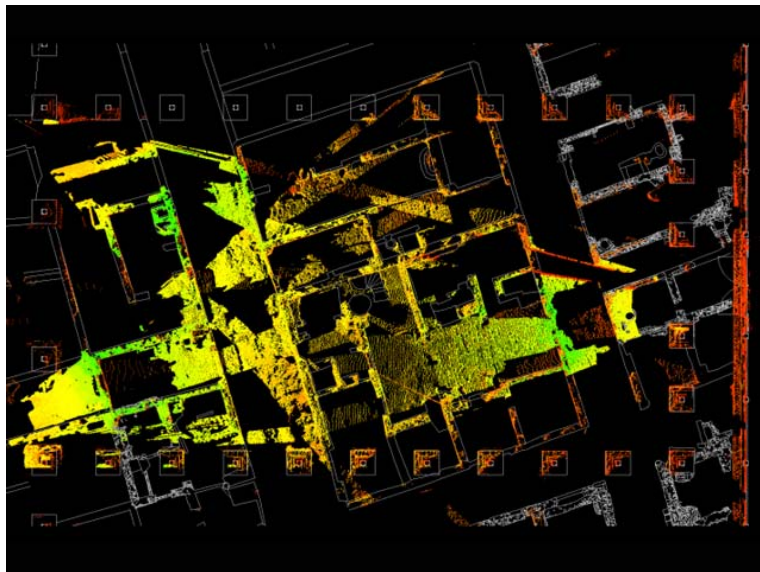


Figure 4: Lack of data, due to columns

Survey Control, Co-ordinate systems and Registration

In the majority of surveys dealing with fixed objects, such as buildings and monuments, a site co-ordinate system will be available to which to reference the data. Where a previous co-ordinate system does not exist therefore a new system may need to be established. In order to ease the processing of point cloud in CAD packages, the Z axis should be defined as the vertical axis [1].

Although a single scan may be sufficient to fully record certain scenes, multiple scans are likely to be required, especially when dealing with a large site or buildings. It is likely to be necessary to transform the collected point clouds to the local site co-ordinate system. The process of registration can be performed using four methods [1]:

Data collection can be performed from a station with known co-ordinates and known orientation such as using a GPS system mounted on top of the scanner system

Targets such as cylindrical reflectors can be used to transform the data onto common co-ordinate systems

Surface matching algorithms for alignment of the individual scans can be used to transform data onto common co-ordinate systems. The use of surface matching algorithms alone would normally involve the use of an arbitrary co-ordinate system

A combination of the previous methods may be used to improve the speed and ease of the registration process

Generally speaking, each method will provide an indication on the quality of the registration process. Data collection from a known station and known orientation will be reliant upon the precision to which the control information is known. In the case of using reflectors as control points the quality of the registration process is best indicated by the residuals of the transformation process and the estimated precision for each transformation parameter. In the case of surface matching alone the quality of the registration would be indicated by the residuals of surface matching algorithms, along with the estimated precision of the transformation parameters. It is unlikely that surface matching algorithms alone would be suitable for metric survey applications and that some targeted points should be defined during the post-processing.

Intensity/Colour Information and Additional Data

The majority of systems provide intensity information, in addition to XYZ position as well as a colour value for each point. Additional image data such as those obtained by camera mounted on top of the scanner can be collected to provide an overview of the subject being scanned, in addition to providing imagery for narrative purposes. This imagery should be of a high resolution and clearly portray the building or objects in the interested area.

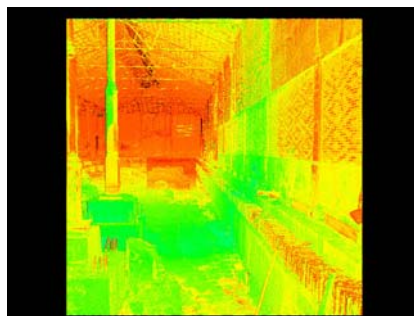


Figure 5: Cyrax 2500 (Range colour image)

This additional data will help to reduce scan artefacts caused by poor framing of the scanner. For example, it can be used for interpretation of actual geometric edges, even though scans may simply have been created by poor positioning of the scanner. Furthermore, additional image data can help to interpret the effect of different materials on the scanning measurement [1].

Weather

Weather can have an impact on the quality of data collected. For example, scanning in heavy rain may give rise to data voids due to falling raindrops or erroneous data points due to return from airborne raindrops or erroneous range measurement due to refraction of the measurement beam.

Data Format

Currently there are no standard formats for the distribution of scan data [1]. This leads to issues relating to compatibility, exchange of information and data archiving and preservation of data access. It is likely that the most desired or appropriate data formats relates to the software system to be used. In these cases, it is possible that a particular format can be specified. However, in cases where the data is to be preserved as an archive data source, the required data format may not be well defined.

To assist in the future management of scan data, all data is required to be delivered in a pre-specified format with emphasis on the transferability of data between software systems.

WORKFLOW FOR THE SCANNING SURVEY

A CYRAX 2500 laser scanner with Rapidform's software was used for handling the 3d data processing. The high-speed scanners have the following specifications:

LASER SCANNER	LEICA
Characteristics	CYRAX HDS 2500
Range:	
ρ□80%	75m
ρ□10%	35m
Minimum	2m
Spot size/ beamwith	6mm @ 50m
Precision	6mm
Max resolution	2,5mm
Capture	6.000 pts/sec
<hr/>	
SCAN	
Vertical	0°-40°
angular resolution	
horizontal	0°-40°
angular resolution	
Weight	20.5 Kg
Software	Cyclone 3.2
Camera	
resolution	480x480 pixels

Figure 6: Cyrax 2500 specifications [7].

A workflow is presented with the current software used to achieve the first goal: a CAD model from laser scanner data. Due to problems in the precision of the registration process of 32 scan positions in one single model. It was decided to redraw CAD information out of the cloudpoint model using Cyclone's Cloudworx module, and adding mesh data generated via Rapidform's software.

During data acquisition, the Cyclone software is used. It allows the operator to perform a large number of tasks including sensor configuration, data acquisition, data visualization, data manipulation, and data archiving. Numerous export functions allow the scanned data to be passed to post-processing data packages for, e.g., feature extraction or volume estimation.

A field methodology has been developed to rapidly capture data for a building survey. The CYRAX scanner has a limitation of 40°x40° field of view, and each scan to full resolution (one million points) takes about 14 minutes. So a good planning is needed for a full building survey. CYCLONE software [7] allows user-specified scan area and density, data filtering, scan scripting, and automatic recognition and extraction of targets. This methodology is being extended to incorporate GPS positioning of the scanner.

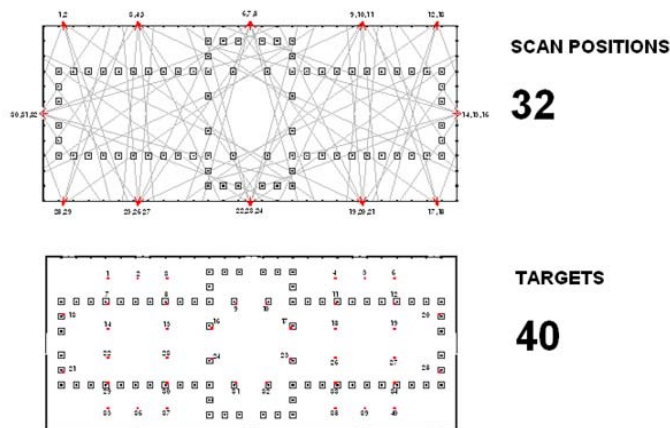


Figure 7: 40° Planning

Once back in the office, Cyclone software is used to clean up each scan separately and for the registration process. The module CloudWorx [9] is also used for integration with CAD systems. CAD users can work efficiently with large point clouds directly using CAD tools and commands. The Cyclone CloudWorx application adds simple tools for viewing and working with slices of point cloud data to speed up 2D drawing creation. However this process is not automatic and depends highly on the ability of the user to redraw from the cloudpoint data CAD information. On the other hand, Rapidform software (produced by INNUS Technology) provides comprehensive set of tools for quickly processing 3D scanned data [6]. This software has traditionally been used in the manufacturing industries with very short range scanners, but the advent of longer range laser scanners, it has seen widespread use in surveying and architecture, especially within North America. The software can handle many millions of data points while still retaining the ability to model very fine details very accurately.

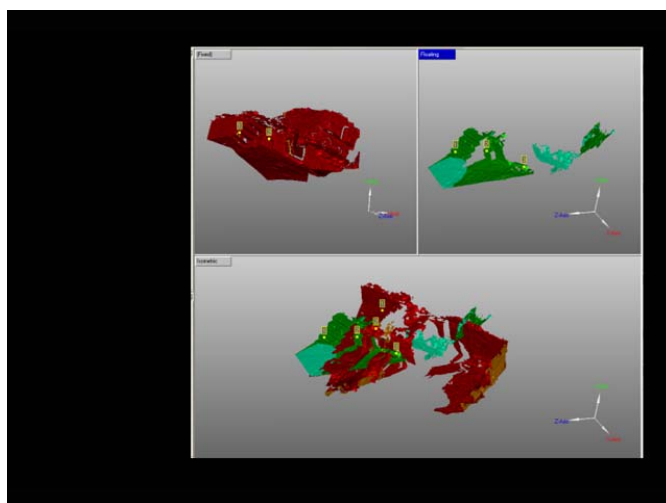


Figure 8: 2 scans align via 3 common points in Rapidform

This will allow scans from each scanner position to be merged together in space. The software will compare geometric features in overlapping areas of adjacent scans to calculate the correct alignment of each scan. This is a very accurate method of aligning laser scan data as it is using many thousands of measurements to make a comparison rather than a few observations that would be made in a conventional surveying scenario.

Next, the 3D mesh model (sometimes termed a wireframe) is created. This 3D mesh uses all the measured data points without applying any dangerous point sampling techniques. In its approach, it uses tolerance-based smoothing and tolerance-based adaptive meshing which provide a robust industrial strength process [6].

The 3D model can then be viewed, analysed and edited as necessary. It is also possible to use an intelligent simplification algorithm on the model to reduce the number of triangle vertices while retaining as much information as possible.

Finally, it is exported via *.wrl to 3dmax studio where the textures, previously worked in Adobe Photoshop, are applied. The result is an accurate 3d model with more than 3 millions polygons which was simplify to 750,000 polygons, to be used in standard 3d softwares.

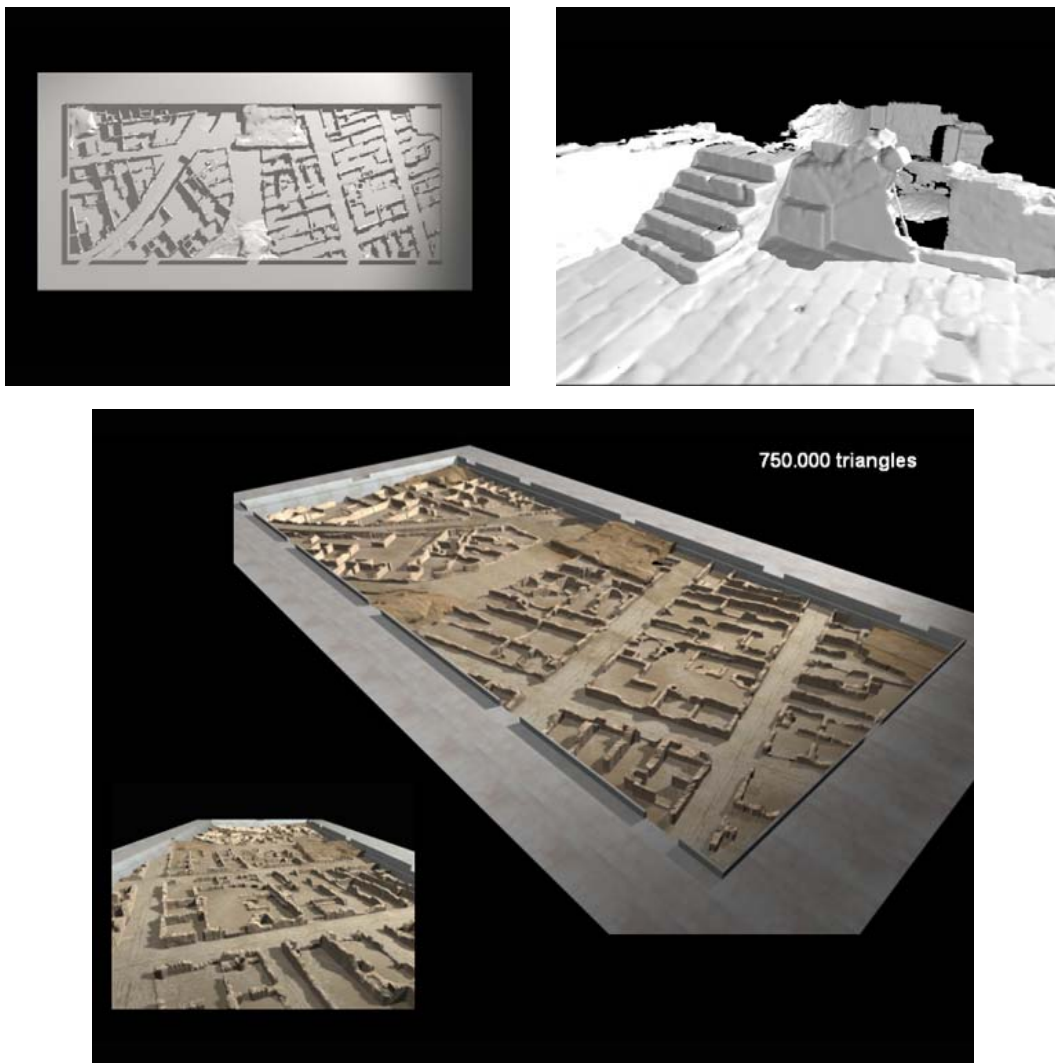


Figure 9: CAD model, Detail and Final Textured Model

DATA ISSUES AND LIMITATIONS

Currently, there are no standard formats for the distribution of scan data. This leads to issues relating to data archiving and preservation of data access. It is likely that the most desired or appropriate data format relates to the software system to be used. In these cases, it is possible that a particular format can be specified. However, in cases where the data is to be preserved as an archive data source the required data format may not be well defined.

Firstly, the development process is illustrated in figure 10 below to address the limitations and data issues at certain stages of the process.

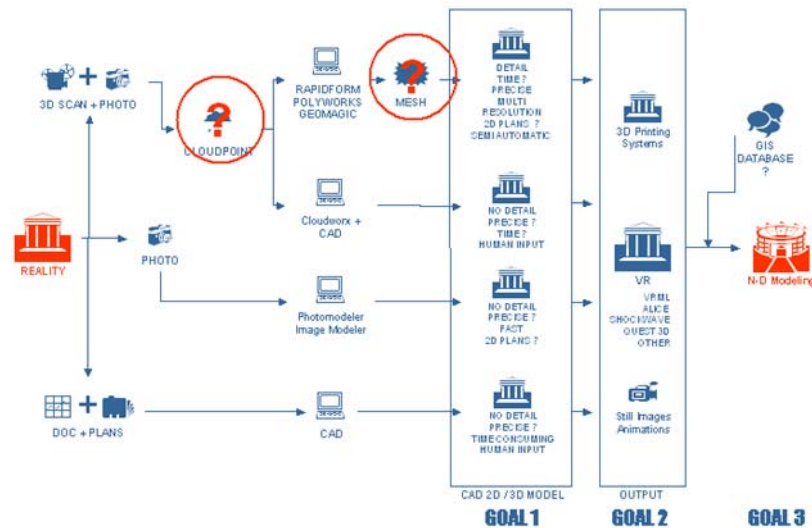


Figure 10: The development process in the 3D laser scanner system

In the use of the 3D laser scanner system according to the above process, the followings advantages and disadvantages of the system are explored.

3D Laser Scanning	
Advantages	Disadvantages
Applicable to all 2D and 3D surfaces	Some systems do not work in sun or rain
Rapid 3D data collection-near real time- requiring substantially less site time	Large, high resolution 3D data sets require post-processing to produce a useable output
Very effective due to large volumes of data collected at a predictable precision	Difficulty in extracting the edges examples from indistinct data clouds
Ideal for all 3D modelling and visualisation purposes	Output requires manipulation to achieve acceptable recording quality
Both 3D position and surface reflectance generated which, when processed, can be viewed as an image	No common data exchange format-such as DXF- currently in use to allow ease of processing by third parts
Rapidly developing survey technology	Difficult to stay up-to-date with developments
Extensive world-wide research and development currently undertaken on both the hardware and software tools	With hardware still expensive and sophisticated software required to process data, cost is prohibitive for many projects

Table 1: The advantages and disadvantages of this technology is shown in the below table [8].

Barriers and Limitations in the development Process

The limitations experienced in the process are depicted in the diagram below:

Point Cloud: Too many points to handle in Planes

Mesh postprocessing: Mesh editing takes long time

2D/3D CAD Models: CAD output is not as good quality as required

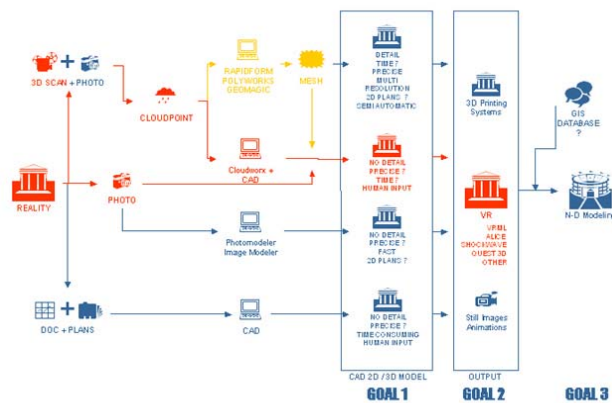


Figure 11: Barriers and limitations experienced in the Process

Strategies to Overcome the Barriers

In line with the strategies, the tactics depicted in figure 11 are identified.

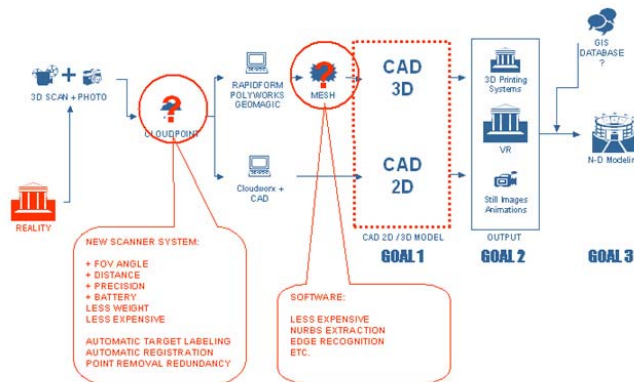


Figure 12: tactics to recover the limitations in the process

CONCLUSIONS AND FUTURE WORK

Through the attempt for integration with CAD system and 3D printing system, the main limitation is the extracting the information from the 3D model produced through 3D laser scanning system. This is because the laser scanner acquires millions of point data of the existing objects. As a result, it brings about the difficulty in extracting significant information accurately and fast from “point clouds” data such as feature lines for 2D and 3D CAD plans and models. Otherwise, use of the post-processed model of the laser scanning system is not easy to handle for the other systems.

Integration with the CAD systems

The laser scanner system enables to produce a polygonal mesh model of the existing buildings and provides export facilities in various CAD oriented data formats. However, this model is not directly useful for developing the 2D and 3D CAD models, which is aimed at using for building refurbishment process. This is because the polygonal model is formed by a large number of triangles, which needs extracting the features lines for CAD modelling.

However, it is not sufficiently accurate to extract the feature lines using the cross-sections and curves, which do not provide straight lines as an output. There is not yet fast, fully automated and accurate process is identified for the extraction of feature lines. Cross sectioning can be considered for extraction of 2D bird-eye view CAD plans using a mode of indoor scans. However, it is not sufficient for an ideal bird-eye view CAD plan because wall thickness cannot be obtained accurately unless reflectors are used during the scanning process.

In order for fully automated and accurate extraction of feature lines for CAD modelling, a specific approach is identified, which includes use of planes and cross-sections. In the approach, the planes are inserted through each surface in the model. All the vertices deviated from the plane are projected to the plane, which result in a very smooth surface before cross-sectioning. This activity is applied to every surface, when this activity completed, cross-sections are applied through the same planes to each surface. All cross-sections are exported in dxf or IGES formats for analysis in CAD software such as AutoCAD. The output in AutoCAD will be a 2D or 3D CAD models with straight lines.

However, this approach requires long time for editing in the Cyclone software and currently it is investigated to reduce the editing period by improving the quality of the models during the process.

Integration with the 3D Printing System

The 3D printing system only accepts files in STL format and it uses wax and plastic to make the shape of the model. Therefore, the model should be closed shape or the surfaces should have thickness for a complete and accurate printing.

On the other hand, the polygonal model produced in the laser scanning system has very thin surfaces. It is easy to produce the STL format of the same model. However, it is not appropriate for 3D printing because of the thin surfaces in the model. In order to overcome this limitation, after completing the editing process in Rapidform's software, the model is exported in dxf format to the autoCAD software to extrude the model in the third dimension to create thickness in the model. However, exporting the extruded model from AutoCAD sometimes is not sufficient because the STL export of the extruded model has irrelevant holes in the model, which makes the model incomplete for 3D printing. This is attributable to the arbitrary triangles make up the model.

3. REFERENCES

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