INTERNATIONAL DESIGN CONFERENCE - DESIGN 2010
Dubrovnik - Croatia, May 17 - 20, 2010.

DESIGN 2010

# STANDARDIZATION OF 3D MODELS CREATION PROCEDURES IN COMPUTER GRAPHICS

Z. Sabati, Z. Novak and A. Bernik

*Keywords: 3D laser scanning, micro scanning, spatial data acquisition method*

## 1. 3D Modeling

A three-dimensional (3D) model is a collection of data used to show an object in a virtual 3D space. Information on virtual object view is available as a collection of data on pixels, coordinates, dimensions, materials, etc. The creation of 3D object mathematical representation is called 3D modeling, and includes using of the polygon or NURBS (Non-Uniformal Rational Bézier Splines) as constituting elements of the object. A polygon is a surface bordered with at least three vertices. The modeling process occurs when the polygons are mutually connected by vertices. The NURBS model is a mathematical description representing Bézier curves. The result is a 3 D model containing data on 3D space vertices, which can be rendered to a 2D image or used as resource in real-time graphic simulation.
A 3D model can also be created using procedural algorithms and 3D digitalization of space and objects. Fractal modeling is a well known technique of procedural modeling, based on the process of generation, and not manual creation of the models. 3D digitizing is a procedure used to build a digital 3D copy of a physical surface. The main difficulty resides in obtaining the actual shape of the surface, that is, the volume the surface occupies in space. The 3D digitalization process is conducted with different types of 3D scanners. Because of recent developments in computer vision and sensor technology, light has been used in a number of ways to measure objects. These measuring techniques can be divided into two categories: active and passive technologies. Passive scanners do not emit any kind of radiation themselves, but instead rely on detecting reflected ambient radiation. Most scanners of this type detect visible light because it is a readily available ambient radiation.

## 2. Measuring Methods and Sources of Light

Passive methods can be very cheap because in most cases they do not need particular hardware other than a digital camera. The accuracy of these methods depends mostly on the resolution of the imaging system and the density of identifiable features in the image. Passive 3D Image Modeling Technologies generally use one of the following three length measuring techniques:
*a) Photogrammetry based measurement.* There are two approaches for surface modeling in the photogrammetry and computer vision. The first approach is active projector technique which uses a specified light pattern projected on the surface and a single camera. The projected light pattern must be sharply focused to obtain reliable measurement on the images took by camera. 3D coordinate of the surface points calculated using the image coordinate of the points and geometrical positioning of the projector and the camera. The photogrammetric orientation algorithms need the known inner orientation of the light projector. The second approach is passive projector technique which is based on finding correspondence between projected light patterns on stereo images. The projected light pattern should be focused to obtain reliable measurement accuracy on the image point. The pattern of light may be a random pattern or a coded structured pattern. The surface model is calculated using triangulation between the corresponded points based on geometrical configuration of the cameras and aerial intersection.
*b) Stereoscopic Technique.* Stereoscopic 3D scanners usually employ two video cameras or mirrors, slightly apart, looking at the same scene. By analyzing the slight differences between the images seen by

each camera/mirror, it is possible to determine the distance at each point in the images. This method is based on human stereoscopic vision. This technique usually use a Photogrammetry based measurement.
*c) Reconstruction Technique.* The point clouds produced by 3D scanners are usually not used directly. Most applications do not use point clouds, but instead use polygonal 3D image models. The process of converting a point cloud into a polygonal 3D model is called reconstruction. Reconstruction involves finding and connecting adjacent points in order to create a continuous surface. Many algorithms are available for this purpose.
Active scanners emit some kind of controlled radiation and detect its reflection in order to probe an object or environment. 3D Laser Scanning is an active, non-contact, non-destructive technology that digitally captures the shape of physical objects using a line of laser light. 3D laser scanners „point cloud" data from the surface of an object. A „Point Cloud" is a set of 3D points or data coordinates which appear as a cloud or cluster. Point clouds are not directly usable in most 3D applications, so they are converted to triangle mesh models, NURBS surface models, or CAD models through a process called reverse engineering to be used as input for design, modeling and measuring. Point clouds collected with laser-based measurement devices may also include characteristics such as intensity and color.

*Microscanning and Scanning of Small Objects*
3D scanners used for microscanning include laser and photogrammetric scanners. There are also devices achieve the same results by combining these technologies and methods. An optimum system is determined considering the type of task. The area of microscanning requires approaching the object at 2 m and data collection accuracy of up to 0.02mm.
Photogrammetric measuring uses the method of stereography, or the possibility of creating 3D models with precise and calibrated movie cameras and cameras which acquire object photographs from different positions. Their mutual position has been precisely determined, and the third dimension is achieved based on the photography stereo pairs taken of different positions. Special algorithms are used to automatically integrate spatial 3D vertices and the final result is a 3D model.

*Medium and Long Range 3D Laser Scanning*
Operation of medium and long range terrestrial 3D laser scanners is based on the LIDAR (Light Detection and Ranging) technology of known speed of light and a narrow bundle of coherent laser beams emitted into space by the device. The beam moves with the speed of light, and bounces from a physical obstacle back to the receiver of the device it had been emitted from. The device measures time the laser beam pulse needs to travel from the obstacle back to the sensor. The output signal from CCD or CMOS sensors is then converted into a digital signal, which is then subjected to digital signal processing. Using details on distance and angle, that is the interval between measured vertices, each vertex can be presented in space with its spatial 3D coordinates. Such method results in a final and precise 3 D model.

## 2.3. Measuring Using Light

### 2.3.1. Triangulation Based Measuring

The triangulation laser range finder used in this 3D capturor shines a laser on the subject and a camera looks at the location of the laser dot. The laser and the camera are placed so that the direction of the laser and the view direction of the camera are not parallel. Depending on how far away the laser strikes a surface, the laser dot appears at different places in the camera's field of view. This technique is called triangulation because the laser dot, the camera and the laser emitter form a triangle. The length of one side of the triangle, the distance between the camera and the laser emitter is known. The angle of the laser emitter corner is also known. The angle of the camera corner can be determined by looking at the location of the laser dot in the camera's field of view.

### 2.3.2. Time-based Measuring

*a) Time of Flight, TOF, 3D Laser Scanner*
Time of Flight laser scanners use a precise time counter to measure time that the laser beam needs from the obstacle back to the device sensor. A laser transmitter sends a short impulse which is split into two parts. The first part is sent to the receiver and starts the time counter. The second part is sent to the measured object. When it reaches the measured object, the laser beam disperses in all directions and only a part of it is sent back to the decoder. The signal in enhanced and sent to time discriminator, which calculates time. Few of such lasers (Optech ILRIS 3D) enable collecting of spatial data of 3 to 1500 m

accuracy within 1 cm. High Density system enables data collection with the speed of 10,000 pixels per second.

*b) Phase Shift 3D Laser Scanner*

Phase shift method uses a continuous bundle of laser beams which serve as a modulated signal support wave, usually as a sine wave or a sinusoid, or a rectangular wave. Length of the signal is determined by comparing the signal sent and received during the phase shift. Phase shift lasers scanners are different from TOF laser scanners because they use higher emission energy, lower laser beam divergence, shorter wave length and higher frequency. The speed of spatial data collection exceeds 500,000 pixels per second, with 100m range and 1.2mm accuracy.

Both scanners use the laser beam to calculate spatial 3D coordinates for each particular vertex based on the distance and the angle.

### 2.3.3. Beam Deflection Methods for time-based measurement system

To be able to measure multiple points from the same scanner point of view, the laser beam needs to be deflected. Instead of moving the laser itself, a deflection unit is used. Most deflection units make use of a mirror because they are much lighter and can thus be rotated much faster and with greater accuracy. A number of methods exist to deflect the laser beam towards a specific direction without having to move the scanner itself. In general, three methods are employed for this purpose: oscillating mirror, rotating polygon, fiber switch.

Devices analysed in this paper use various length measuring methods, which use different light sources:

*a) Laser, coherent monochromatic light source.* A device that is able to generate a wave of light using only a very narrow of the spectrum is called a laser. A typical laser emits light in a narrow, low-divergence beam with a well-defined wavelength (corresponding to a particular colour if the laser is operating in the visible spectrum). This is in contrast to a light source such as the incandescent light club, which emits into a large solid angle and over a wide spectrum of wavelengths. These properties can be summarized in the term coherence.

*b) White halogen light.* Visible halogen light is a form of incandescent white light. The halogen bulbs look like traditional light bulb and are filled with halogen gas that helps extend the lifespan of the light bulb. Halogen and incandescent light bulbs operate by heating a filament, most commonly made of tungsten until it glows. The glowing filament is what creates the light, but it also creates a lot of heat. To keep the filament from burning up an incandescent light bulb is filled with a relatively inert gas like nitrogen or argon. Since the gas inside the light bulb doesn't react with the tungsten, even at a high temperature, the filament doesn't burn.

*c) Structured light.* Structured light is the projection of a known light pattern (plane, grid, or more complex shape) at a known angle onto an object and capturing this with a camera. By looking at the deformation of this pattern we can calculate the shape of the object this pattern is projected upon. There are various ways of deploying this technique. We scan an object using structured light by a moving a stripe pattern across the object or project a series of different patterns on the object. The key problem of 3D vision measurement using triangle method based on structured light is to acquiring projecting angle of projecting light accurately. In order to acquire projecting angle thereby determine the corresponding relationship between sampling point and image point, method for encoding and decoding structured light. This technique can be very useful for imaging and acquiring dimensional information. Scanning the object with the light constructs 3D information about the shape of the object.

### 2.4. Collected Data Analysis and Processing

The main product of 3D laser or photogrammetric scanning is a measurable 3D model taking a form of a point cloud, in which every point has its particular spatial coordinate defined by Cartesian coordinates X, Y, Z. The original point cloud in real colors may be used to connect the points into a system of triangles to make 3D models with surfaces to be used in further analysis, cross sections, creation of 3D replicas or 3D physical models on 3D printers, and in composing simulations or animations.

## 3. Converting Inscription Formats of 3D Computer Graphics

In addition to classical 3D modelling, graphic programs support downloading data from other programs operating in 3D graphics. These input data may include 3D models or scenes generated by modeling or alternative techniques such as 3D scanners. Input data can be used only if saved in a compatible format.

There are numerous specific tools used for generation of 3D models. Each of them develops formats for saving 3D information and is usually of a closed type. Their connecting is possible through plugin files. If plugin is not available special converters are used.
The final 3D model can be stored from the 3D graphic program either as 2D or 3D data. 2D presentation of a three-dimensional model is possible only with image. The method enabling this conversion is called rendering. Rendering can create a single static image or a sequence of images based on which a post production video image is generated. If the completed 3D model is to be further processed with other techniques and in a different environment it should be saved into a compatible 3D format. The predefined/default 3D formats are usually included in the 3D graphic programs but special program solutions may require special 3D formats. In such case, plugin solutions to connect the two programs or alternate converters providing the required compatibility are searched.
An extensive analysis of various types of 3D scanners, 3D print devices, a Sub-Surface Laser Engraving machine (SSLE), 3D scanning and 3D modeling program tools provided important information on the possibilities and procedures for mutual conversion of inscription formats or 3D models. The results are shown in Table 1.
Based on information included in Table 1, a significant deviation relating to compatibility of inscription formats was noticed for different 3D program tools, i.e. possibilities of converting the 3D model into other 3D graphic programs. The most frequent inscription formats enabling mutual compatibility are obj, ply, dxf.
The obj data format is an ASCII format, representing a compatible system for saving and transfer of 3D models where compression is not necessary, and which supports a range of colors and 3D geometry. obj is geometrically defined format which contains information on all polygon elements, coordinates and attributes of NURBS curves. obj information may define and access external MTL information containing definitions of various material types. obj reading and writing routines are based on FORTRAN90 library. Its compatibility makes obj one of the most spread 3D data formats and many programs can convert the obj into another 3D format. 3D models, created in any technique (3D scanning, 3D modeling, generating from photographs, ...), are easily transferable to other specialized application. This results in a wide area of application and advanced manipulation of models providing wide connectivity of 3D computer graphics. The structure of obj format may be explained in seven key parts shown in Table 2.

**Table 2. obj format main parts**

| | |
|---|---|
| Edge points/vertices | Geometric and textual (v, vat)<br>Normal edge (vn)<br>Area edge (vp)<br>Curve edge (cstype) |
| Model key elements | points (p), straight line (l), polygon face (f)<br>curve (curv), 2D curve (curv2)<br>surface (surf) |
| Curves and free form surfaces | Parameter values (parm)<br>External and internal edges (trim, hole)<br>Special curves and points (scrv, sp)<br>End status (end) |
| Connection between curves and free form surfaces | Connection (con) |
| Grouping | Group name (g)<br>Smoothing (s), merged group (mg)<br>Object name (o) |
| Plotting view and attributes | Interpolation of color, bevel (c_interp, bevel)<br>Defraction interpolation (d_interp)<br>Level of details (lod)<br>Material name and details (usemtl, mtllib)<br>Shadows, light beams (shadow_obj, trace_obj ) |
| General inscription | Arguments, .OBJ file name, location. |

**Table 1. Comparison of program tools by application and inscription format compatibility**

| Application | Manufacturer (SSLE) | Equipment Type | 3D camera | Software | Input/output File Format |
|---|---|---|---|---|---|
| Sub-Surface Laser Engraving machine | Hangzhou Shining 3d Tech Co. *www.shining3d.com* | ELD3000C-H | M1/M2 | 3D Vision | 3DS, DXF, OBJ, CAD, ASC, WRL,SDV |
| | Wuhan Syntony Laser Co., Ltd. *www.stnlaser.com* | STNDP-803B4 | inSpeck 3D Mega Capturor | Inspeck EM Software | Softimage, 3DS, Maya ASC, DXF, OBJ, STL, VRML, FBX, HRC |
| | 3d Laser Engraving Systems *www.3dlasermachine.com* | LE-X4000 | Z-L1/Z-M2 | Software OS | STL, OBJ, 3DS, LTM, TGL, WRL, |
| | Wuhan Lead Laser Co. *www.leadlaser.com* | LD-EG-603B | inSpeck Cyclops, 3D Mega | Inspeck EM SSLE/ENT | Softimage, 3DS, Maya ASC, DXF, OBJ, STL, VRML, FBX, HRC |
| | LeLee Laser Tech *www.leleelaser.com* | LE-X-Advance | LE-SC-3d camera | 3D Software Creation | XYX, 3DS, DXF, CAD, STL (BOTH ASCCI and Binary), OBJ, PLY, GSF, CAM, CDM, |
| | Perfect Laser Co *www.perfectlaser.net* | PE-DP-820B3 | MEGA II | 3D Grafical Software | 3DS, DXF, OBJ, 3DV |
| **Application** | **Manufacturer** | **Scanner/Camera** | **Software** | | **Input/Output File Format** |
| Spatial Data Collection | LEICA Geosystems *www.leica-geosystems.com* | Leica HDS 2500 | Leica Cyclone Software | | ZFS, SCAN, SC2; DXF, COE, ASCII, PTZ, |
| | Riegl Laser Measurment Systems *riegl.com* | LMS-Z390i | RiSCAN PRO | | 3DD, DXF, ASCII, SOP, 3PF, ASC, PTC, OBJ, STL, PLY, POL, VRML |
| | Artec Group, Inc. *artec-group.com* | Artec 3D Scanner | Artec Scanning Software | | STL, OBJ, PLY, WRL |
| | DeltaSphere, Inc. *www.deltasphere.com* | DeltaSphere - 3000 | SceneVision | | VRML, ASCII |
| | 3D Dynamics Bvba *www.3ddynamics.eu* | Mephisto Extreme | RapidForm XOS Software | | OBJ, PLY ASCII, PLY binary |
| | Optech Inc. *www.optech.ca* | ILRIS-3D | InnovMetrics/PolyWorks, Mencisoftware Z-map | | Optech pif/ixf, zfs, ptx, 3dd, fls, 3DS, cnrc, dxf, nas,obj, ply, pol, pqk, stl, stl, wrl, ASCII |
| | Zoller+Fröhlich *www.zf-laser.com* | Z+F Imager 5600i | Z+F LaserControl, LFM, Geomagic, 3D Reconstructor | | zfs, xyzim, zfc, ptx, ptz, osc, wrl, ascii, bin, ptc, idx, dxf, xpm |
| | Topcon Positioning Systems, Inc. *www.topconpositioning.com* | GS-1000 | ScanMaster Software | | PTX, OBJ, PLY, ASCII |
| **Application** | **Manufacturer** | **Equipment Type** | **Scanner/Camera** | **Program Tools** | **Input/Output F. Format** |
| 3D printers | Menci Software Srl *www.menci.com* | | | Scan View | Pvtp, vtp, vtk/ ASCII |
| | | | | Z-Map | AutoCAD, DWG, DXF |
| | NextEngine Inc. *www.nextengine.com* | | Desktop 3D scanner | ScanStudio HD&HDPRO | VRML, STL, U3D, PLY, XYZ, OBJ with JPG TEXTURE |
| | Z CORPORATION *www.zcorp.com* | ZPrinter 650 | ZScanner 800 | ZScan; ZPrint | STL, PLY, 3DS |
| | Dimension 3D Printers *www.dimensionprinting.com* | Dimension uPrint Personal 3D Printers | | Catalyst EX 3D Print Software | STL |
| | 3D Systems Corporation *www.3dsystems.com* | ProJet 3D Printing | | V-Flash Desktop Modeler | STL |
| | Objet Geometries Ltd. *www.objet.com* | PolyJet TM | | Objet Studio Software | STL, STC |

Polygonal file format called ply is a format used for saving graphic objects described as a group of polygons. There are two versions of the ply format: simple ASCII and binary, enabling fast saving and downloading. ply format describes an object as a group of points, faces and other elements together with their attributes such as color, direction of normals, etc. This format can store data on only one object. Some features which may be stored together with the object are: color, surface normals, texture coordinates, transparency and other options linked to polygons.

The format does not contain any transformation matrix, hierarchy inside the model or object's sub-parts. It also does not include square surfaces nor operations on hard geometry, polygons with holes or information on the very texture. The ply format structure includes: the heading, the list of points, the list of faces and the list of other elements. The ply file heading is a group of textual data describing the file system and each contained element. The number and the name of the element is saved as well as the list of their features.

dxf (Drawing Interchange Format, or Drawing Exchange Format) is an Autodesk format used to exchange drawing created in different AutoCAD applications. In this format, all information is specially numbered. Every data element in the file is preceded by a whole number called a code group. The code group value determines the data type and the meaning of the data element which follows.

It has been developed as the binary and the ASCII data type, where the ASCII type may be edited in all text editors. Conversion between the dxf and other formats is easy, which makes this format widely useable, especially in CAD, CAM and CAE systems. The inscription structure is very complex and difficult to monitor, particularly due to poor documentation available on the format. The drawback of the dxf is its size and speed of accessing data, which is several times bigger than other formats of the same application.

## 4. Conclusion

The tree-dimensional (3D) model is a group of data used to show an object in the 3D virtual space. Information for virtual object presentation may be in a form of data group on points, coordinates, dimensions, materials, etc. 3D modeling implies the use of polygons or NURBS, as fundamental constituents of objects, the use of procedural algorithms by fractal modeling and 3D digitalization of space and objects.

3D scanning is used for detailed and accurate data collecting and processing in the area of microscanning or scanning of small objects and 3D medium or long range laser scanning. The main product of 3D laser or photogrammetric scanning is a measurable 3D model in the form of a point cloud in which each and every point had its space coordinate defined by Cartesian rectangular coordinations X, Y, Z.

There are numerous highly specific tools used for 3D model generation. Each of them develops own formats for saving 3D information. They are usually of closed type. If more applications are used and they do not have mutually agreed data transfer standard, plugin data should be provided to enable functionality. If there is no direct plugin, converters are used to convert special formats into any of generally accepted formats. If the completed 3D model is to be further processed using other techniques in other environments, it should be saved in a compatible 3D format. Usually, the predefined/default formats fbx, obj, mb, ma, dae, dxf, etc. are already included in the 3D graphic programs. Conducted analysis showed that the .OBJ format is the most widely used conversion format.

## References


http://www.shining3d.com http://www.stnlaser.com http://www.3dlasermachine.com
http://www.leadlaser.com http://www.leleelaser.com http://www.perfectlaser.net
http://www.cerion.biz http://www.leica-geosystems.com http://http://riegl.com
http://artec-group.com http://www.deltasphere.com http://www.3ddynamics.eu
http://www.optech.ca http://www.zf-laser.com http://www.callidus.de http://
www.topconpositioning.com http://www.menci.com http://www.zcorp.com
http://www.konicaminolta.com http://www.nextengine.com http://www.3dsystems.com
http://www.dimensionprinting.com http://www.objet.com
http://www.autodesk.com/techpubs/autocad/acad2000/dxf/ascii_dxf_files_dxf_aa.htm
http://usa.autodesk.com/adsk/servlet/item?siteID=123112&id=12272454&linkID=10809853
http://www.okino.com/conv/exp_ply.htm
http://local.wasp.uwa.edu.au/~pbourke/dataformats/ply/
http://reference.wolfram.com/mathematica/ref/format/PLY.html



doc. dr.sc. Zvonimir Sabati
Fakultet organizacije i informatike Varaždin
Pavlinska 2, Varaždin, Hrvatska
+385 98 267 668
+385 42 690 560 – fax
zvonimir.sabati@foi.hr