



Review Article

Image-based 3D Modelling: A Simple and Economical Technique to Create 3-D Models of the Face

Shivanand Venkatesh^{1**@}, Sanjay V. Ganeshkar^{2***}, Shreya Ajmera^{2*}

** Assistant Professor, *** Professor and Head, * Post graduate Resident

¹Department of Orthodontics and Dentofacial Orthopedics, M S Ramaiah Dental College, Bangalore, Karnataka

²Department of Orthodontics and Dentofacial Orthopedics, SDM College of Dental Sciences Sattur, Dharwad, Karnataka

@Correspondence Email: shivanand85@gmail.com

Received: 06/08/2012

Revised: 27/08/2012

Accepted: 03/09/2012

ABSTRACT

The goal of diagnosis and treatment planning in orthodontics is to decide a course of treatment based on the evaluation of the initial condition of the patient's anatomy from various types of imaging sources. Imaging of the patient's anatomy has traditionally been evaluated from two-dimensional (2D) imaging sources such as: 2D cephalometric X-rays (lateral, frontal, etc), panoramic and other x-rays, 2D facial and intra-oral photographs, etc. With the availability of 3D imaging, various techniques are available to record the hard tissues (CT, MRI, CBCT) but soft tissue imaging has been limited due to expensive and elaborate equipment requirements (Laser scanning, Moire topography, Stereophotogrammetry). The purpose of this article is to describe a simple and cost effective technique to create 3D models of the face using a 3D modelling software and a series of photographs.

Key words: IBMR, 3D models, Autodesk

INTRODUCTION

Orthodontic diagnosis deals with the systematic recognition of various characteristics of malocclusion. Diagnosis is made based on findings from study models, radiographs and clinical facial photographs. Facial photographs are commonly used to analyse the skeletal and dentofacial deformities of the patient in frontal and

lateral profile view of the patient. They form an essential component of diagnosis and treatment planning. Also they are the most commonly used aid to compare the pre and post orthodontic assessment of dentofacial relationships. But conventional facial photographs are two dimensional pictures of a three-dimensional (3D) structure; they have limitations like poor spatial accuracy,

static in space and time, distortions and information voids. [1] Therefore they have to be supported by a keen and close clinical examination of the face. However for an orthodontist a 3D model of the patient is always useful in incorporating more diagnostic information when the patient is unavailable in the office.

Since the early 1900s researchers' interest has been to create a 3D representation of the face and the dentition. Facial mouldages from plaster were made to maintain 3D record facial changes before and after treatment. [2, 3] Technical difficulties in obtaining facial mouldages and the practical problems of storage prevented most practitioners from adopting the technique. With the advent of 3D imaging in the 1980s, various techniques have been developed that has changed the way facial morphology is recorded. 3D imaging has evolved considerably in the last two decades and has found significant applications in orthodontics. [4-6] One of the applications is creating a 3D model of the face. A 3D model of the face allows a complete evaluation of the treatment outcome, the information of which is unavailable with two dimensional records. [7] There are basically two methods to capture a 3D model of the face: Light based stereo photogrammetric method and Laser scanning method. [8, 9, 10] Though they are popular, the cost of these set ups are high, requires an elaborate set up and a larger office space. Also the safety concern of the lasers is questionable for children. [1]

In recent years, Image-based 3D Modelling and Rendering (IBMR) have gained considerable attention in the graphics community because of their potential to create realistic 3D models. Various IBMR softwares are available in the market: Photomodeler, Photosculpt, Insight3D, 3DSOM pro etc. These applications build geometry and acquire textures from images

by having the user manually identify corresponding features in multiple images. However most of them are paid software with a price range of 900-1400\$. Recently Autodesk™, Inc., has developed a free IBMR application that works on the principle of Cloud Computing. [9] Here the entire construction of the 3D model is done on the cloud, thereby allowing the user to create 3D models even without the knowledge of the complex computing operations involved in creating the model. Therefore the purpose of this article is to present a simple technique to construct a 3D model of the face using IBMR 3D modelling software.

Image-based 3D Modelling and Rendering (IBMR)

3D modelling of an object is a complete process that starts from data acquisition and ends with a 3D virtual model visually interactive on a computer. It involves the conversion of a measured point cloud into a triangulated network ("mesh") or a textured surface. [11, 12] Data for 3D models can be obtained from two methods: Contact methods (coordinate measuring machines, rulers and callipers) and Non-contact methods (X-ray, SAR, photogrammetry, laser scanning). Non-contact systems based on light waves are most commonly used in generation of a 3D model. [13]

Non-contact systems are based on active and passive sensors. [13, 14, 15] Active sensors directly provide range data containing the 3D coordinates necessary for the network (mesh) generation phase e.g., Laser scanner. Passive sensors provide images that need further processing to derive the 3D object coordinates e.g., Photogrammetry, IBMR. After the measurements, the data must be structured and a consistent polygonal surface is then created to build a realistic representation of

the modelled scene. A photorealistic visualisation can afterwards be generated by texturing the virtual model with image information.

Image-based rendering (IBR) refers to a technique which uses images, as opposed to polygons, as modelling and rendering primitives. The goal is to achieve more realistic and faster renderings and to simplify the modelling task. The technique relies on either accurately knowing the camera positions or performing automatic stereomatching that, in the absence of geometric data, requires a large number of closely spaced images to succeed. [13, 16, 17]

Image-based modelling (IBM), on the other hand, refers to the use of images to drive the reconstruction of three-dimensional geometric models. Image-based approaches can potentially eliminate the labor-intensive task usually required for modelling detailed geometric structures. [13, 16, 17]

IBMR works on the principle of “Structure from motion (SfM)”. [18] Structure from motion [19] is a process of finding a 3D structure of an object by analysing local motion signals over time. The general principles of such a system are to exploit the locations and correspondences of image features (points, corners, lines, or other high-level features) in multiple images to infer the 3D feature.

Although 3D scanners are becoming a standard source for input data, Image-based modelling appears to be a complete, economical, portable and flexible alternative to the expensive scanners. [20] Instead of rendering objects or scenes using a traditional polygon-based approach, IBMR uses large amounts of imagery (photographic or synthetic) to achieve a high degree of realism.

Autodesk 123D Catch

Autodesk 123D Catch [21] is an Internet-based IBMR software from Autodesk™, Inc., (San Rafael, California) that uses the power of cloud computing and 3D modelling and rendering capabilities to quickly transform digital photos into photorealistic 3D models. The processor intensive conversion is done entirely with cloud computing. Cloud computing [8] is a marketing term for technologies that provide computation, software, data access and storage services that do not require end-user knowledge of the physical location and configuration of the system that delivers the services (Fig. 1). Autodesk 123D Catch allows anyone capable of using a point and shoot or a digital SLR camera to snap a series of photos of any object to generate 3D models. Once the images are uploaded through the desktop client, the Autodesk cloud based application tries to determine the camera angle of each image and creates geometry of the image and then applies the appropriate texture to the 3D model.

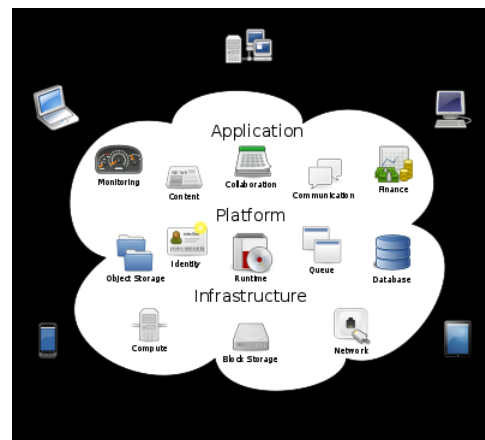


Fig. 1. Cloud computing

How it works

The basic idea behind Autodesk Catch 123 is that by taking a series of photos of an object from different orientations, a 3D modelling program located on the cloud identifies unique points on the surface of the object (provided there's sufficient overlap

and coverage). It can then use photogrammetry to reconstruct the relative positions from which the photographs were taken. From the information obtained, it generates a 3D mesh of points that model the object and projects the images onto that model to create a photorealistic rendering of the model in 3D, which can then be manipulated in a computer graphics program like AutoCAD, 3DS Max or Lightwave software.

Installation

Autodesk 123D Catch™ is a public beta program for Windows OS which is available for free to download. It can be downloaded easily from their official website (<http://www.123dapp.com/catch>). Before downloading the application, the basic system requirements to run the application are to be considered. Autodesk recommends a minimum of 256MB or more video card and Microsoft run time libraries (Microsoft Visual C++ 2008 Redistributable Package) to be installed. A user account needs to be created to download the application. Once registered, the stand-alone application can be downloaded and installed on the system.

Taking photographs

Autodesk 123D catch requires 20-30 photographs, taken from various angles, to create a 3D model of the subject (Fig. 2). A digital SLR or a simple point and shoot camera can be used to take the photographs. The user needs to “walk around” the subject and take snaps at all possible angles. Special care should be taken to ensure good exposure and good focus and in adequate lighting conditions. Autodesk does not require special tools like the calibration mat (3DSOM Pro) or the use of a tripod for the camera to standardize the pictures. The pictures can be snapped randomly at an angle of 5-10° from the previous picture but it should be ensured to get adequate overlap between adjacent photographs. Once the set

of photographs have been taken, they should be saved in a directory for use with Autodesk Catch.

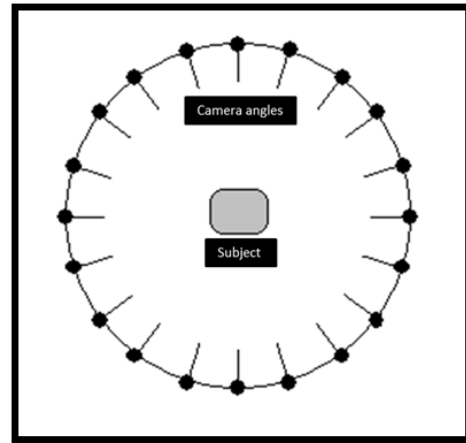


Fig.2. Showing angles with which the photos were captured.

Creating the model

Autodesk Catch requires High speed Internet access to connect to the Autodesk servers in order to compute on the cloud. The application does not start up without a connection. Once the application is started, a new model can be created by clicking on the “Create a New Photo Scene” icon on main UI of the application (Fig. 3). The photographed images are then imported onto to the desktop application using Windows Explorer without any need of manually calibrating or tagging the images with one another. This is one of the biggest advantages of the 123D Catch when compared with other modelling software which requires the use of calibration mats or manually calibrate the images to determine the camera orientation and position. The whole process of determination of the different camera angles is entirely done on the cloud reducing the manual labour of the user (Fig. 3). The program then computes the images and uploads them to the Autodesk’s remote server. After the images are uploaded lot of calculations has to be performed and this done by the Autodesk Cloud application. Once the model is

finished calculating an email will be sent to the user's account, or the progress bars will complete and it will be presented with the main UI of the software. The 3D model can then be rotated, viewed and analysed from

any angle the user desires (Fig. 4). The model can be exported into OBJ or IPM format to be used with CAD software like Maya or Autodesk 123D for further analysis and measurement if required.

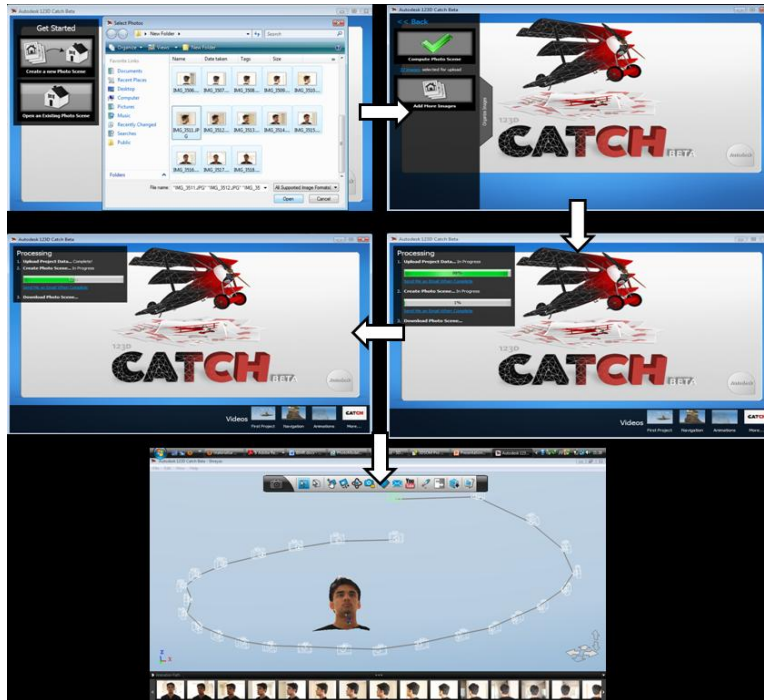


Fig.3. Showing loading of images onto Autodesk software with subsequent computing of the images over the cloud to create a 3D facial model.

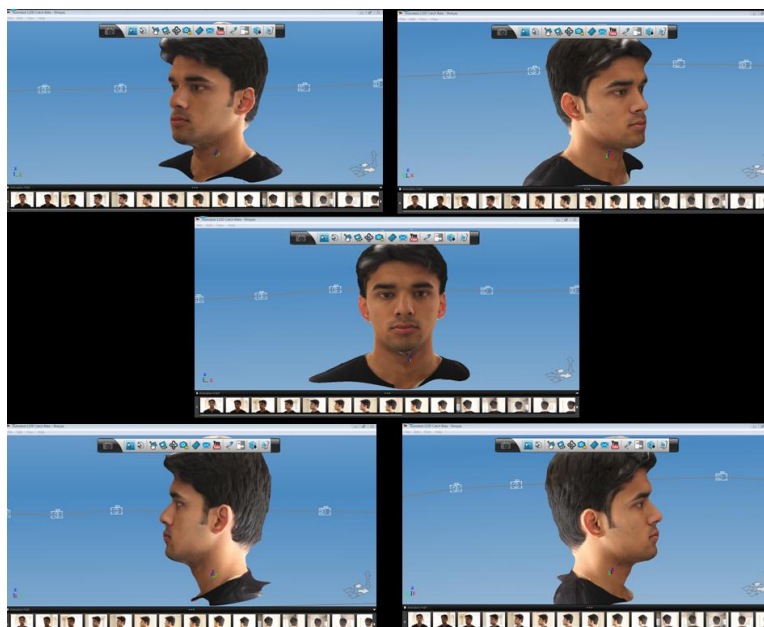


Fig.4. Showing the 3D model that can be rotated, viewed and analysed from any angle.

DISCUSSION

It is clear that a number of new imaging techniques and approaches are available or soon will be available for patient care. The challenge is for the clinician to decide on a particular imaging modality as a function of the information/diagnostic yield vs. patient risk and costbenefit analysis. To make this decision, clinicians need to have a working knowledge of the technology as well as its capabilities. From this perspective, imaging and its related topics need to be included in continuing education of clinicians as well as in the curricula of medical and dental schools.

Autodesk has been well known leader in the computer graphics community for its 3D modelling products (Maya, 3ds etc). This is the first time 3D modelling software like Autodesk Catch has been released as freeware, but the advantage of Catch lies in its ability to do the stereophotogrammetry calculations over the cloud thereby enabling the Orthodontist to be free of the complex modelling calculations required to create a 3D model. Also since it is available as a freeware, it has a bigger advantage over its rival softwares. Some of the applications of the proposed method are as follows:

Applications

- i. Provides a life like model of the head enabling the orthodontist to rotate and enlarge the model to assist in accurate diagnosis and treatment planning.
- ii. A pre and post orthodontic treatment assessment can be made by comparing the models in 3D.
- iii. 2D and 3D measurements can be done using reference points on the model. Using AutoCAD, the manual reference points can be used to do the measurements.

- iv. An excellent patient education tool.
- v. Patient need not be recalled if any of the features were missed during the clinical examination.

CONCLUSION

Autodesk Catch is a cost effective system for 3D modelling of the face. Autodesk Catch technology allows a 3D model of face to be created quickly and economically while requiring far less technical skill or expensive hardware than competing systems.

REFERENCES

1. James Mah J, Bumann A. Technology to Create the Three-Dimensional Patient Record. *Semin Orthod* 2001; 7:251-257.
2. Case CS. *A Practical Treatise on the Techniques and Principles of Dental Orthopedia*. Chicago, IL: Case Company, 1908:34-38.
3. Van Loon. A new method for indicating normal and abnormal relations of the teeth to the facial lines. *Dent Cosmos* 1915; 57:973-83, 1093-1101, 1229-35.
4. Hajeer MY, Ayoub AF, Millett DT *et al*. Three-dimensional imaging in orthognathic surgery: the clinical application of a new method. *Int J Adult Orthodon Orthognath Surg*. 2002; 17(4):318-30.
5. Aboudara C, Hatcher D, Nielsen I *et al*. A three-dimensional evaluation of the upper airway in adolescents. *Orthod & Cranio Res* 2003;6(1):173-175.
6. Mah J, Sachdeva R. Computer-assisted orthodontic treatment: the SureSmile process. *Am J Orthod Dentofacial Orthop* 2001; 120:85-87.
7. Harrel W E. Three-dimensional diagnosis & treatment planning: The use of 3D facial imaging and 3D

- cone beam CT in orthodontics and dentistry. *Australasian Dental Practice* 2007:107-113.
8. Mah J, Hatcher D. Current status and future needs in craniofacial imaging. *Orthod Caniofacial Res* 2003; (Suppl 1):10-16.
 9. Cloud computing. Available at <http://www.wikipedia.org/cloud computing>.
 10. Palomo J M, Yang C Y, Hans M G. Clinical Application of Three-Dimensional Craniofacial Imaging in Orthodontics. *J Med Sci* 2005;25(6):269-278.
 11. Szeliski R. Image and Video-Based Modeling and Rendering. In *Fourth Int. Workshop on Cooperative Distributed Vision*: 1-18.
 12. Burschka D, Cobzas D, Dodds Z *et al*. Recent Methods for Image-based Modeling and Rendering. In *IEEE Virtual Reality*; 2003.
 13. Remondino F. Image-based 3D Modelling: A review. *The Photogrammetric Record* 2006(Sept); 21(115): 269–291.
 14. Gool L V, Defoort F, Hug J *et al*. Image-based 3D modeling: modeling from reality. In *Confluence of Computer Vision and Computer Graphics*: A. Leonardis, F. Solina and R. Bajcsy, Ed. Kluwer, 2000;1-12.
 15. 3D scanner. Available at http://en.wikipedia.org/wiki/3D_scanner.
 16. Oliviera M M. Image-Based Modeling and Rendering Techniques: A Survey. *RITA* 2002; Vol 9(2): 37-66.
 17. Shum H Y, Chan S C, Kang S B. Rendering techniques. *Image-Based Rendering*. Springer publication 2007: 71-90.
 18. Wang Y F. A Comparison Study of Five 3D Modelling Systems Based on the SfM Principles. Technical Report, Visualsize Inc. TR 2011-01, Sept 8: 1-30
 19. Structure from motion. Available at <http://www.wikipedia.org/structure from motion>.
 20. Liu S, Cooper D B. Ray Markov Random Fields for Image-Based 3D Modelling: Model and Efficient Inference. In *Computer Vision and Pattern Recognition (CVPR)*, 2010 IEEE Conference; June 2010.
 21. Autodesk 123D Catch. Available at <http://www.123dapp.com/catch>
