RAPID PROTOTYPING USING SELECTIVE LASER SINTERING FOR HUMAN SKELETON TAILORED IMPLANTS

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Abstract. *Bone reconstruction can be customized for every patient with minimum effort and in safety because of the great possibility of computing CT files of DICOM type and transforming data in STL and CAD files that can be visualized and manipulated in 3D. As a plus, the strains and stresses could be simulated through FEM/CFD (Finite Element Analysis/Computer Fluid Dynamics). Thus, the surgeon and the engineer have a real time image of the future implant even before implantation and they can do some vital individualised adjustments to improve it.Building time for a standard implant could be between 2-10 hours, so every geometric shape, even with a very high degree of complexity could be delivered next day after design confirmation. Then, the implant could be mechanically tested, both static and dinamic, and after results, the mechanical properties of the implant can be improved by the manipulation of laser exposure.*

Keywords: *Rapid prototyping, selective laser sintering, 3D CAD, bone reconstruction*

1. INTRODUCTION

A basic task in 3-D image processing is the segmentation of an image which classifies voxels/pixels into objects or groups. 3-D image segmentation makes it possible to create 3-D rendering for multiple objects and perform quantitative analysis for the size, density and other parameters of detected objects.

A raw 3-D image, whether it is CT, MRI or microscopy image, comes as a 3D array of voxels or pixels. Each voxel has a greyscale range from 0 to 65535 in the 16-bit pixel case or 0 to 255 in the 8-bit pixel case. Most medical imaging systems generates images using 16-bit greyscale range. A 3D image typically has a large number of pixels and is very compute intensive for processing such as segmentation and pattern recognition. A segmented image on the other hand provides a much simpler description of objects that allows the creation of 3D surface models or display of volume data.

While the raw image can be readily displayed as 2-D slices, 3-D analysis and visualization requires explicitly defined object boundaries, especially when creating 3D surface models. For example, to create a 3-D rendering of a human brain from a MRI image, the brain needs to be identified first within the image and then its boundary marked and used for 3D rendering. The pixel detection process is called image segmentation, which identifies the attributes of pixels and defines the boundaries for pixels that belong to same group. Additionally, measurements and quantitative analysis for parameters such as area, perimeter, volume and length, can be obtained easily when object boundaries are defined.

Because of the importance of identifying objects from an image, there have been extensive research efforts on image segmentation for the past decades. A number of image segmentation methods have been developed using fully automatic or semi-automatic approaches for medical imaging and other applications.

Computed tomography (CT) is an imaging technique that uses special x-ray equipment to obtain cross-sectional images of the body. A CT image normally has different pixel intensity range for tissues such as bones, organs and other tissues. The threshold-based "Interactive Segmentation" provides an easy way to segment a CT image for 3D modeling. [1]

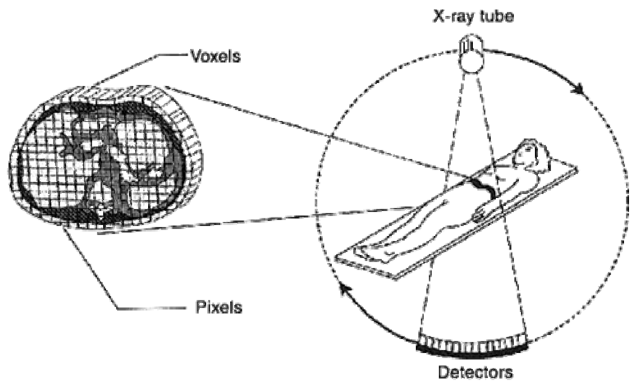

Figure 1. Typical CT scanner; the slices are composed on pixels/voxels basis

A 3D mesh model can be created from a CT image in 3 main steps:

Step 1. Open the CT image. If the image slices come in as separate files, use the "New Stack" command.

Step 2. Use the "Interactive Segmentation" to generate object boundaries. For small size soft tissues, the manual tracing method can also be used. Boundaries can be edited using the boundary editor.

Step 3. Create 3D mesh models using the surface rendering command. The models can be exported to STL (ASCII and Binary), DXF, VRML, 3DS, OBJ, PLY and other formats for 3D measurement, rapid prototyping, simulation, treatment planning and other applications.

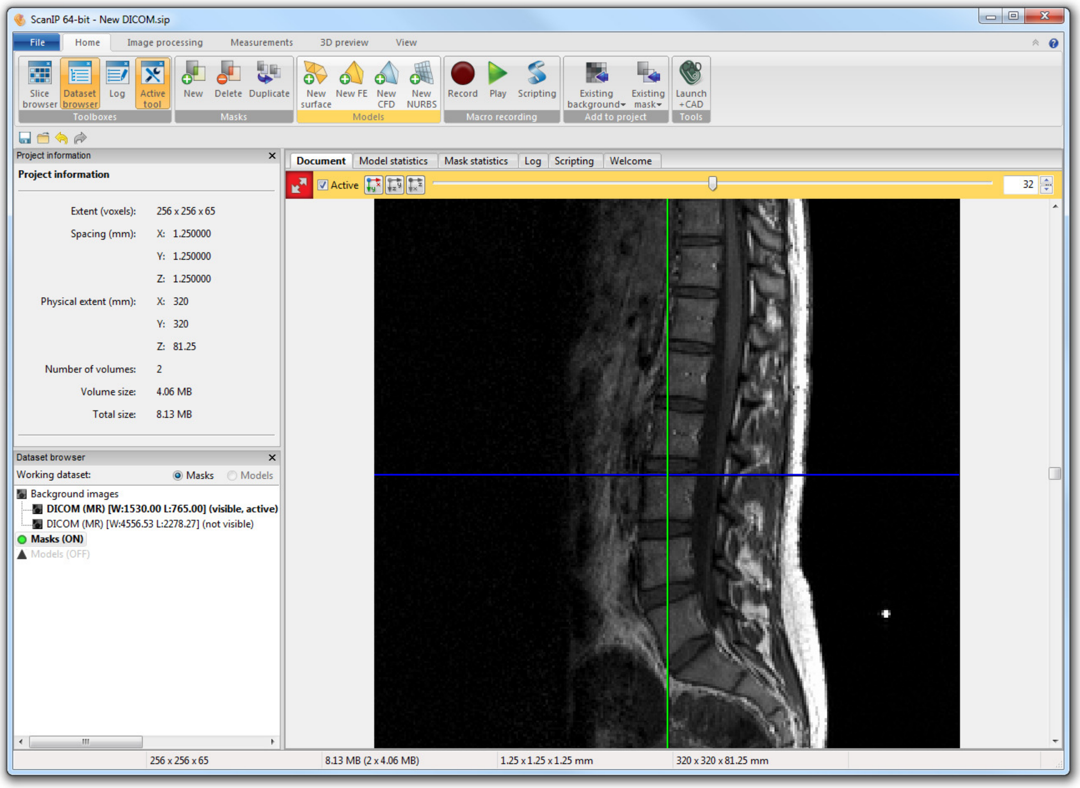

Figure 2. Typical screen of 3D software for CT based reconstruction

2. IMAGE CLARITY – IMPACT ON SEGMENTATION CT (micro/nano CT)

Exposure to X-rays should be avoided if objects with a high and low density need to be scanned together. This is because the high density objects will tend to obscure those with lower density. Use of stronger radiation level can sometimes solve this artefact phenomenon. However, this is not always possible. For radiation doses for living patients must be kept below dangerous or lethal levels. Note that these obscuring phenomena, also called "metal artefacts" (because they often appear when scanning metallic objects at the same time as organic subjects) do not distort the geometry of the parts that are visible; they merely "hide" information.

CT is ideally suited to scanning different objects when they can be distinguished via their absorption coefficient (amount of X-ray absorbed by the object). Very simple threshold based tools can then be used to identify them in the CT image.

It is, however, not efficient at distinguishing between different soft tissues. [2]

MRI - In terms of image quality, metallic objects will usually not influence the generated image, but magnetic objects (such as some teeth implants) can distort the image. The magnets may damage electronic components such as pacemakers.

"Loose" metallic objects should not be carried into the room where a MRI scanner is used since the magnets can make them fly across the room. However, and this has to be checked with the technician running the MRI scanner, internal metallic objects such as hip implants do not in general lead to any problems.

MRI is ideal for visually distinguishing soft tissues, but objects MUST contain hydrogen molecules (e.g. water). However it is possible to get around this problem and scan "dry" objects made of plastic, for example, by immersing them in jelly. The negative of the object is then visible in the MRI data.

Segmentation can be threshold based in some cases. Unfortunately it is quite common for different objects to be easily distinguishable visually, by texture, but not by grey level. In these cases some level of manual segmentation may be required.

MRI images often suffer from signal attenuation and/or noise on the borders of the region of interest. [2]

Figure 3 shows a CT scan, taken around the hip area, where the femur meets the hip bone. You can see that the bone can easily be identified. Although we can distinguish some soft tissues from the fat, all the surrounding tissue seems to be a similar shade of grey. The scanned region is clearly bounded by a sharp circular limit beyond which no value is measured.

Figure 3. CT scan, taken around the hip area

Figure 4 shows an MRI scan taken along the spine. It displays typical MRI features where bone and soft tissues have similar greyscale values but vary in texture, while the fat has high greyscale values (shows as white). On the left of the image, the attenuation phenomenon can also be noticed, as we move away from the centre of the region of interest defined by the coil used for the scanning. Segmentation would not be trivial with this data but, at least, the different structures can be easily identified visually. [2]

Figure 4. MRI scan taken along the spine

3. METAL PARTS DIRECTLY FROM CAD DATA

A number of different materials are available for use with EOSINT M systems, offering a broad range of e-Manufacturing applications. EOS CobaltChrome MP1 is a multi-purpose cobaltchrome-molybdenum-based superalloy powder which has been optimized especially for processing on EOSINT M 270 systems. Other materials are also available for EOSINT M systems, including a special-purpose cobalt-chrome-molybdenum-based superalloy for dental veneering application, and further materials are continuously being developed - please refer to the relevant material data sheets for details.

The ability to produce such parts very quickly enables flexible and economic manufacture of individual parts or batches, which in turn enables design or manufacturing problems to be identified at an early stage of product development and time to market to be shortened.

This new technology is used in top domains of engineering and medicine, both for civil and military purposes. The most advanced engineering entity, National Aeronautics and Space Administration (NASA), use the EOSINT M270 machine, Titanium Version.

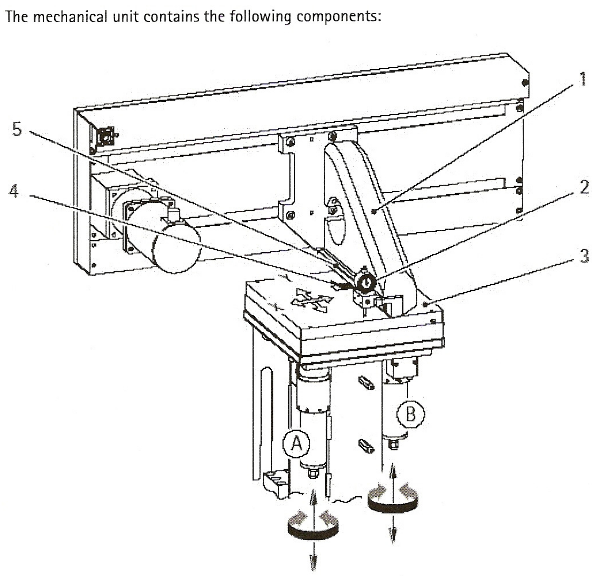

Figure 5. EOSINT M – mechanical unit

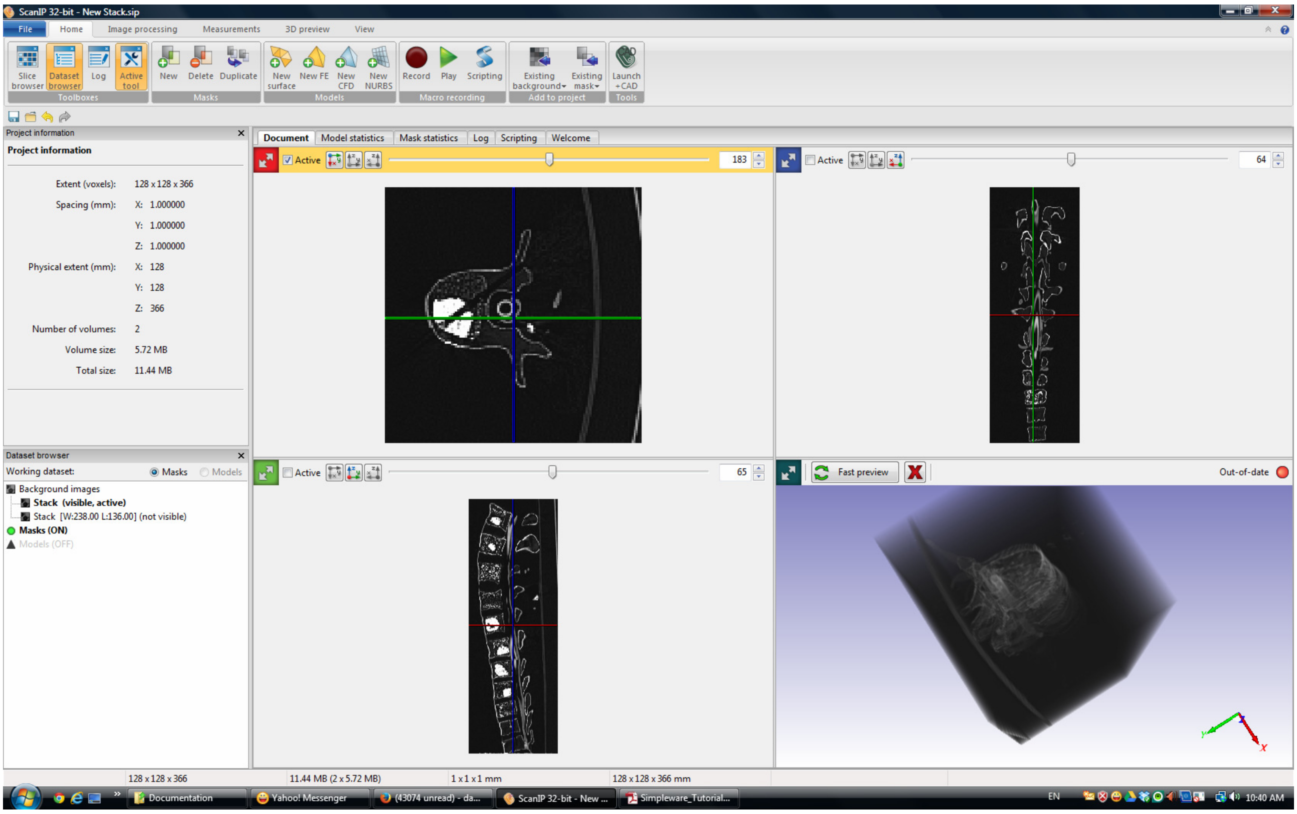

Figure 6. The image is segmented to isolate and trace the boundaries of the object of interest within the image set

4. FROM CT IMAGE TO 3D MODEL

Thanks to new 3D imaging software, surgeons can now create physical models of their patients' inside

As a radiation protection, in order not to further irradiate a patient using an identical replica spine anatomy

The developments in 3D imaging technology over the recent years have been focusing on the goals to not only let the physicians and surgeons to see better inside the body, but also create physical models from CT (Computed Tomography) and MRI (Magnetic Resonance Imaging). Using the model a surgeon is able to perform a "mock" surgery prior to ever entering the operating room. Some surgeons find that minutes or hours of operating time can be saved by careful preparation using the model.[4]

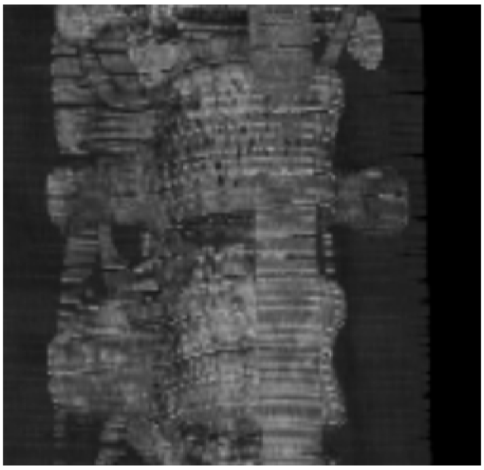

Figure 7. Thanks to the vector-based surface rendering algorithm, a 3D surface model can be created in a few seconds

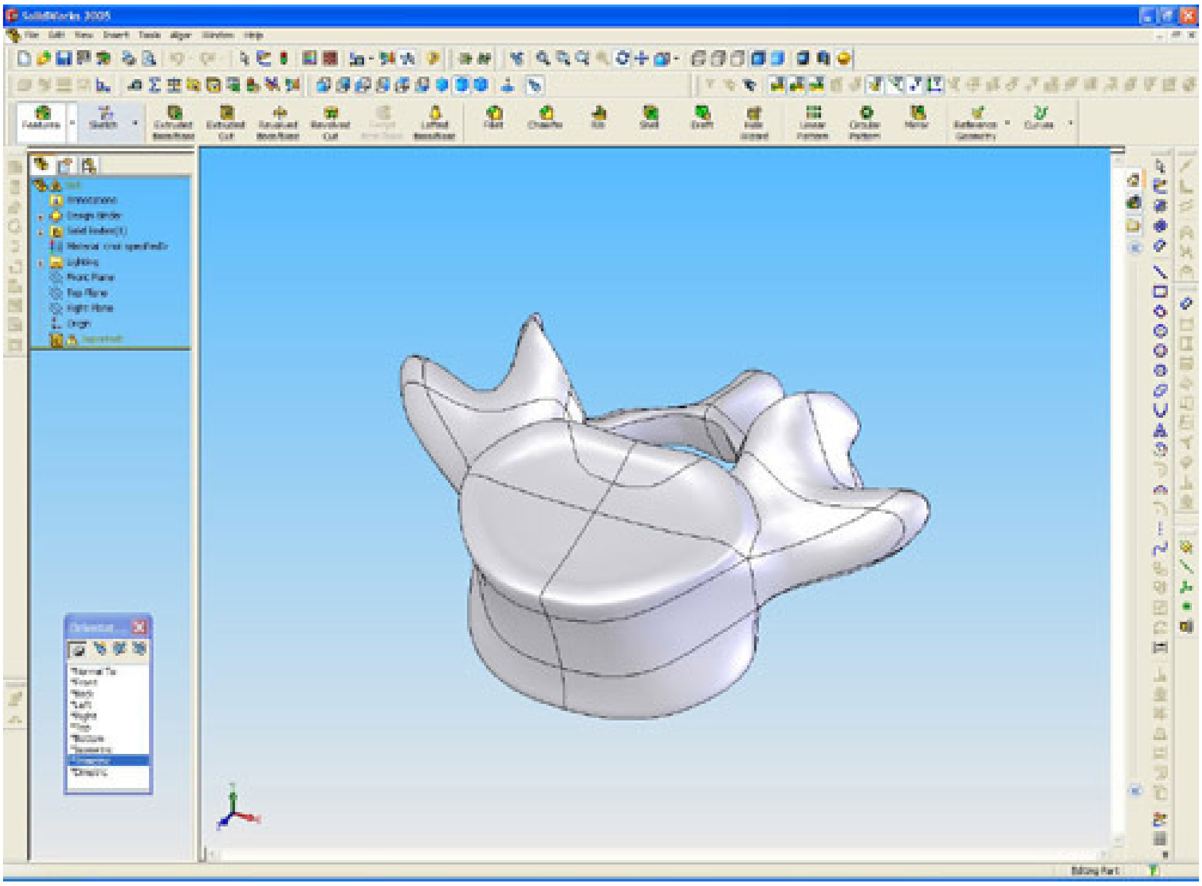

Figure 8. Parametric model in 3D CAD – SolidWorks

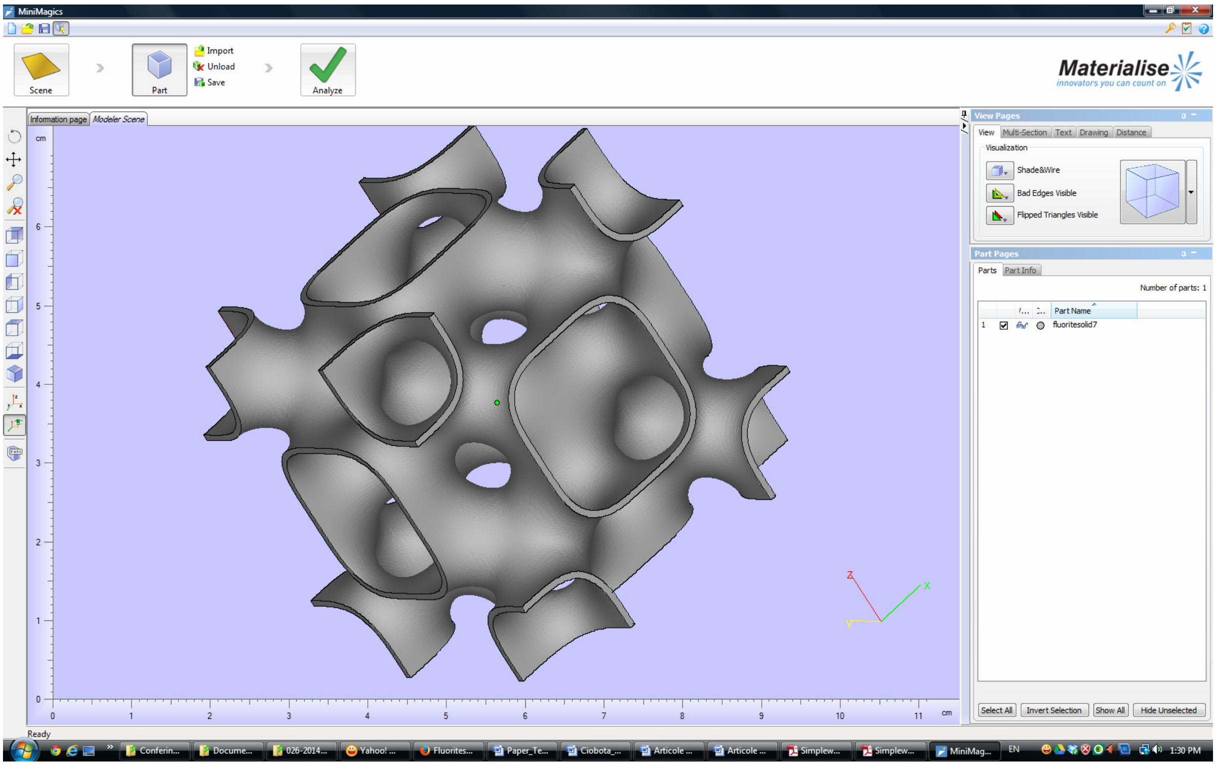

Figure 9. Neovius surface is a triply periodic minimal surface that can be used to fill the interior of a solid volume

5. CREATING THE PHYSICAL MODEL

The CAD models, virtual model of a human body or a part of it can be used to study the problematic area before the actual operation starts. This is especially important in cases where functionality of the body part has to be re-established (orthopaedic surgery). Besides the continuous flow and other FEA methods that are used to calculate required mechanical and physical properties of the implant, the virtual models can also be used to study the surgical procedures, like directions of implantation, required preoperational treatments and preparations, etc.

Vector-based data structure uses lines and points to represent object boundaries, instead of marking each voxel in the 3D volume space. The biggest benefit using vector-based structure for object representation is that it makes 3D image segmentation more flexible and makes editing much easier than raster based methods. Vector-based structure has much less data items to deal with than raster-based structure, and handles topology more efficiently for features like islands, holes and branches and the topological relationship between them.

If the part contains errors and need to be fixed. This can be done automatically in the full version of Magics.[6]

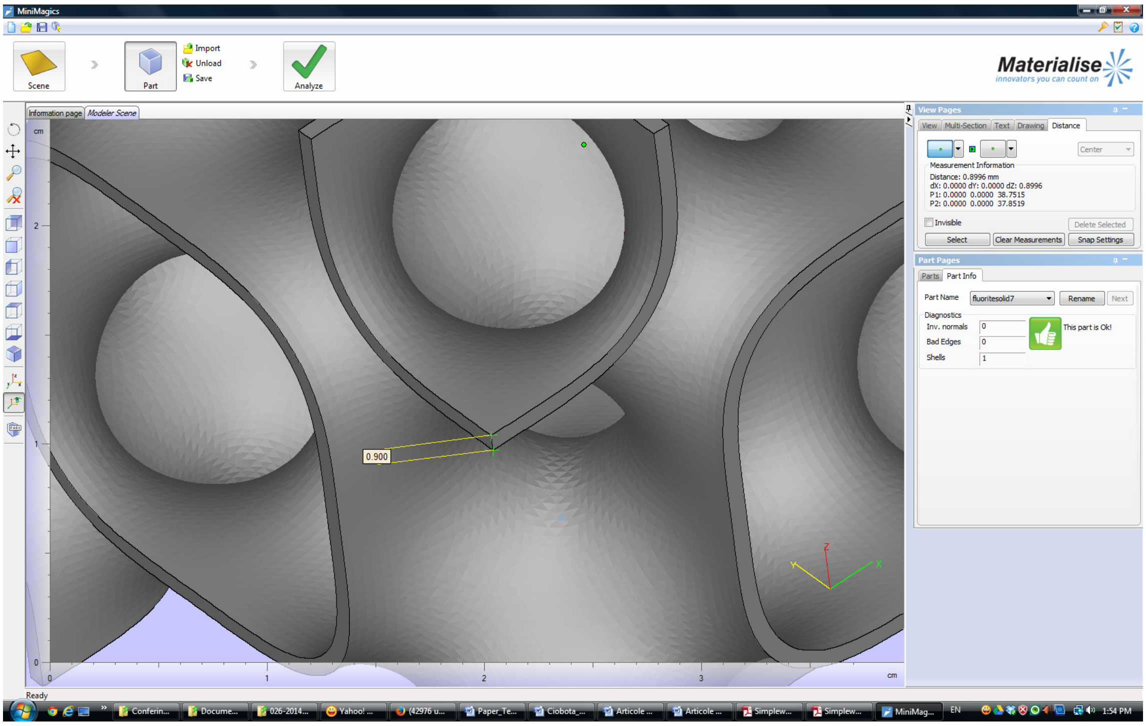

Figure 10. Evaluate file quality: detect bad edges, flipped triangles and multiple shells

ACKNOWLEDGMENTS

In this paper we used demo software and freeware software from various sources.

We mention 3D-DOCTOR, which is a 3D imaging, modeling and measurement software, from Able Software Corp. http://www.ablesw.com.

Also, we use MiniMagics 3 from Materialise, http://www.materialise.com. Materialise is a leader in Additive Manufacturing (also known as 3D Printing).

Another interesting software that can be use in 3D reconstruction is ScanIP software from http://www.simpleware.com/software/scanip

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[7] http://www.simpleware.com/software/scanip