Rapid Prototyping models of foetuses built from Ultrasound 3D and Magnetic Resonance files

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The project focuses on the construction of three-dimensional physical models of foetuses from the first, second and third trimesters, from data files obtained from Ultrasound 3D and Magnetic Resonance Imaging scans, along with Rapid Prototyping systems, with the objective of reproducing physical models of live foetuses inside the womb. It is suggested that the use of USG 3D exams and Magnetic resonance when segmented and applied separately or combined in the construction of 3D virtual and physical models, may improve our understanding and demonstration of foetal characteristics for medical educational purposes and also for parents visualization.

Introduction

The research was developed with medical practitioners in London and Rio de Janeiro, in order to understand the difficulties encountered in the visualization of imaging examinations during gestation, and how the production of 3D models might be useful in terms of didactic purposes. Through the witnessing of various scans and detailed survey on other non invasive projects, it was possible to define the procedures in order to transform the results of the scans into 3D virtual and physical models, a process made possible by the capture, segmentation and conversion of the existing two-dimensional views of medical examinations.

Since the technologies for the imaging examinations described previously usually provide a two-dimensional format (layers) and sometimes in 3D viewing programs on the computer screen , (without 3D volume data) it was necessary to transform these scan files into 3D CAD models, not just for visualization purposes on screen, but also to add mathematical data in the form of spatial coordinates, in order to make it possible to transform this data into a physical representation.

The key concerns of the experiment were associated with finding a way to obtain high-quality images to be manipulated in 3D software without losing their accuracy. These difficulties occur particularly when dealing with the poor quality of Ultrasonography images and the movement of the foetus, which happens regularly with Magnetic Resonance scans. It is important to observe that the quality of the image is directly associated with the precision of the final 3D virtual mathematical data, which will also be transferred to the Rapid Prototype.

Rapid Prototyping systems (RP) allow a three-dimensional virtual model to become a physical model in a process that is fast, easy and dimensionally accurate. The construction process in RP is realized by transferring a three-dimensional data file, specifying surfaces and solids, to the RP equipment, which will construct models through the superimposition of thin layers of various raw materials according to the technology being used.

Essentially, the technological processes of medical imaging acquisition and RP systems are very similar in terms of their logical procedure: the acquiring images from medical scans is based on “slicing” the physical body being scanned through the capture of several slices, for later construction of a virtual 3D model, through the superimposition of those same layers. The RP process begins with the virtual 3D CAD model which is “sliced” in layers in order to later deposit various materials, layer on layer, resulting in a physical 3D model.

Technical process

When working with Magnetic Resonance exams, the difficulty lies in getting the greatest number of images with a high-quality outline; the quality of the image is best in the final stages of pregnancy, since the foetus has little space to move and the capture time is short - the images have better quality when the foetus is immobile during the sweep.

Generally, when using MRI images, once the examinations are complete and the quality of the image is verified, the next step in the 3D reconstruction is the segmentation of the body by outlining the necessary areas (visually separating the foetus from the womb of the mother) in order to later superimpose these layers, allowing the creation of a 3D CAD representation of the foetus. This task is carried out manually in each image slice with the help of digital stylus pen used directly on computer screen, on which it is possible to open the images of the layers and separate the areas required.

Having obtained the required number of images to complete the desired volume, the next step is the 3D virtual model reconstruction (Figure 2), which is made by using software which converts medical images into numerical models (Mimics v.12).

The USG 3D scanning process allows the medical doctor to perform a faster sweep to visualize the image of the foetus, which is automatically transformed in real time in 3D virtual images on the screen. Depending on the size of the foetus, this process permits the visualization of the complete body only during part of the second trimester, since in the late stages of pregnancy it is not possible to obtain entire images of the foetus, as it is only possible to capture separate sequences.

The software used to capture USG slices from the 3D volume was either the 4D View (GE) or the Sonoview-Pro (Medison), that are widely used by medical practitioners in obstetrics.

Having captured the whole sequence of slices related to the complete aimed area (e.g. the face of the foetus), the next step is to export to the software (Mimics 12) all the slices obtained, to analyse medical images in order to reconstruct the 3D image, keeping the accuracy and reliability. From this point on, the same procedures as the preceding experiment were adopted.

Having both 3D CAD files ready (USG 3D and MRI) and obtained on the same day, it is possible to merge them by working with 3D modelling software (e.g. Alias), through coinciding axial registers in order to keep the accuracy and preserve the scale (Figures 3 and 4).

Conclusion

The innovative procedures made through the combining of MRI and USG 3D, demonstrates to be very useful on represent foetuses, mainly on the third semester being possible to create 3D models exhibiting the whole physical characteristics of the foetus (figures 5,6 and 7).

Since the Magnetic resonance is usually a sequential procedure to the USG to be conducted on the same day, when some visual question was raised on the USG scans, it means that they have the same volume dimension, being necessary to ‘visually adjust’ the images, since the positions of the foetus inside the womb changes constantly between the procedures.

This combination of virtually join two different 3D virtual models is made in order to generate a final model having as an example the facial and the body characteristics inserted on the same 3D model. Having both files (MRI and USG 3D) obtained on the same day, it is possible to combine detailed characteristics of the body, such as the face, hands or feet (USG 3D) and the body (MRI), keeping the distances through the obtaining of several measures on both technologies.

Another path successfully tested is related to the procedure made through different USG 3D views from the same sequence of scans. By combining distinct images of the same foetus on the same moment, the result, will exhibit at the end of the process, more than one characteristic obtained on the same USG sequence. With this experiment, different images have to be segmented and transformed in 3D virtual models; the next step is the 3D over-imposition of the different files, virtually applied on the same 3D model, in order to have at the final stage a more defined figure of the foetus represented in a 3D physical model.

To understand better this implication it is important to explain that during the Ultrasonography scan, due to the size of the foetus (particularly on the second and third trimester) only some image of the parts of the body can be obtained in a sequential capture. As an example, in a scan performed, the left side of the face of a foetus including the left arm was captured (figures 8, 9 and 10); on the next sweep it was possible to capture the right arm with also the right side of the face (figure 11). The final model constructed exhibits the whole face with both arms since attested the visual integrity by the medical doctor responsible (figures 12 and 13).

Although these experiments combining different images cannot be considered biomechanical accurate, since the images are joined by visual positioning approximation on the spatial virtual ambiance of the computer screen, they can produce very interesting results of the appearance of the foetuses, once the final combined 3D models are accompanied and attested by the medical doctor responsible.

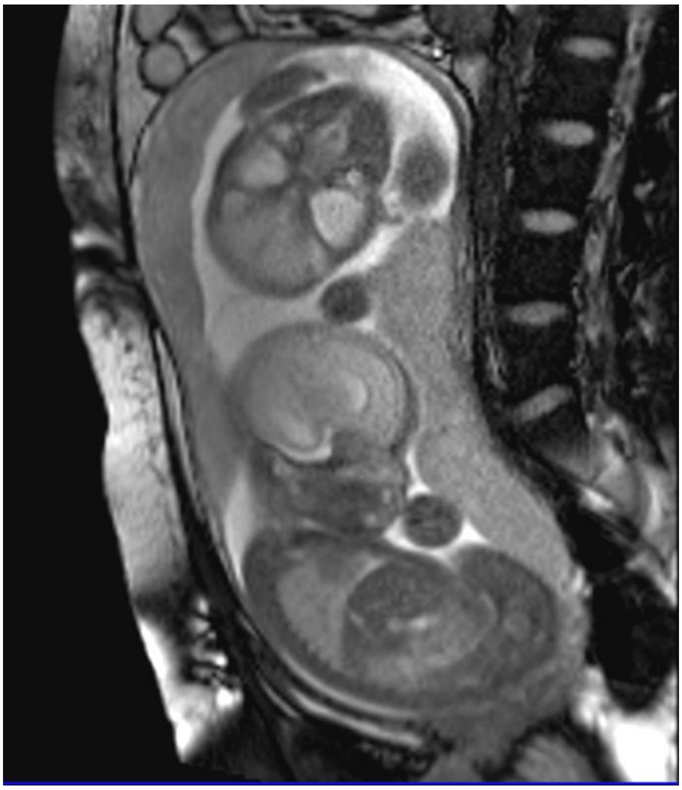


Figure 1 - MRI image of the twins inside the womb.

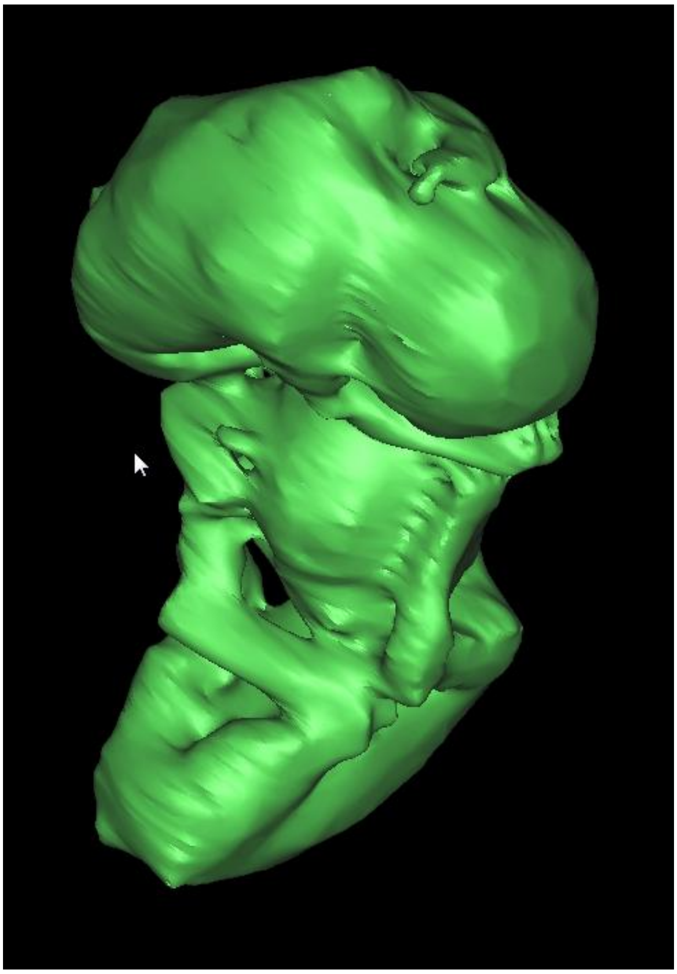
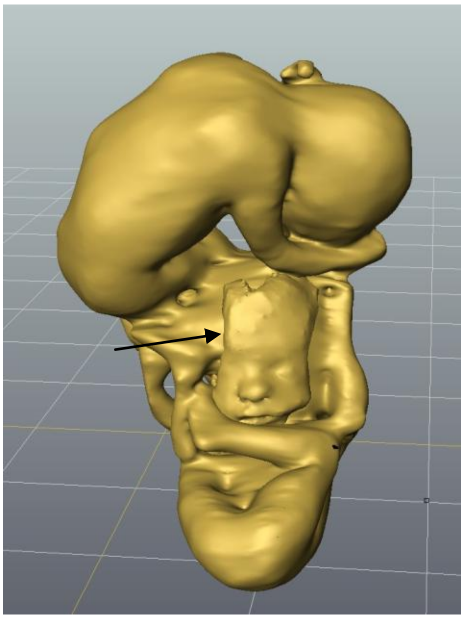
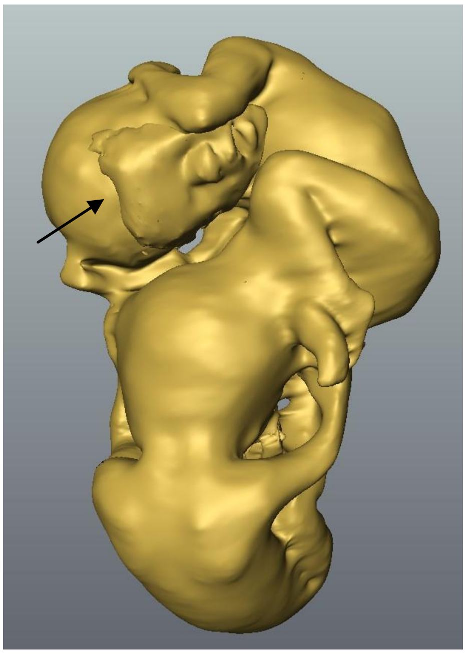
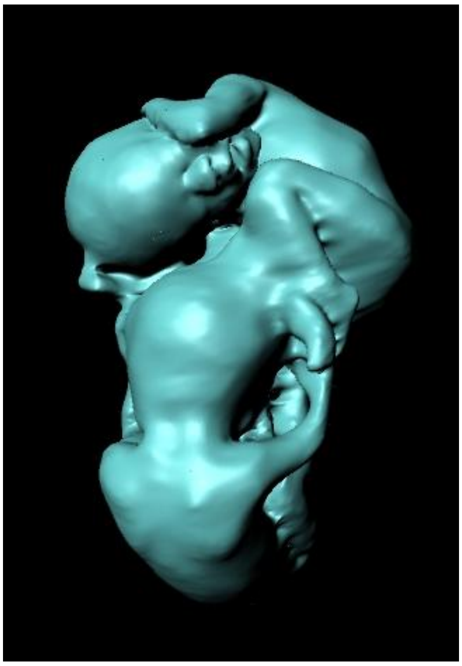


Figure 2 – First rough 3D model generated from MRI on Mimics v.12







Figures 3, 4 and 5 (From the top) - The process to merge the face detail (USG 3D) on the bodies (MRI), and the final virtual CAD model combining MRI and USD 3D images.

Figures 6 and 7– Rapid prototype models of foetuses built on Z- Corp equipment at Rapid Form laboratory.
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Figures 8 - Ultrasound 3D image exhibiting only the left arm.

Figure 11 – Ultrasound 3D image exhibiting only the right arm.

Figure 9 – 3D CAD model exhibiting only the left arm.

Figure 12 – 3D CAD model exhibiting both arms.

Figure 10- First Rapid prototype model, exhibiting only the left arm, built on Z-Corp equipment at LAMOT- Laboratory, Instituto Nacional de Tecnologia - Rio de Janeiro, Brazil.

Figure 13- Final Rapid prototype model, exhibiting both arms, built on Z-Corp equipment at LAMOT- Laboratory, Instituto Nacional de Tecnologia - Rio de Janeiro, Brazil

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