Lecture 12:

3D printing based on imaging data: review of medical applications Rengier et al

COMP 30025J

Dr. Abraham Campbell

Abstract

- Medical paper so breaks down the abstract into **Purpose**, **Materials and Methods** , **Results** and **conclusions**.
- Generation of graspable three-dimensional objects applied for surgical planning, prosthetics and related applications using 3D printing or rapid prototyping is summarized and evaluated

Conclusions

- Rapid prototyping is an emerging technique
- Enormous potential
- Development of new applications in the fields of individual patient care, as well as academic and research activities

Introduction

- Rapid evolvement of Medical imaging in last 30 years
- 3D visualization, multiplanar reformation and image navigation help radiology to be pivotal for many clinical discipline
- They maybe very well integrated but in general are limited by the use of flat screens for the visualization of three-dimensional imaging data
- This paper addresses this issue by illustrating how 3D objects can generated based on radiological image data
- It also review its application and limitations in the medical field

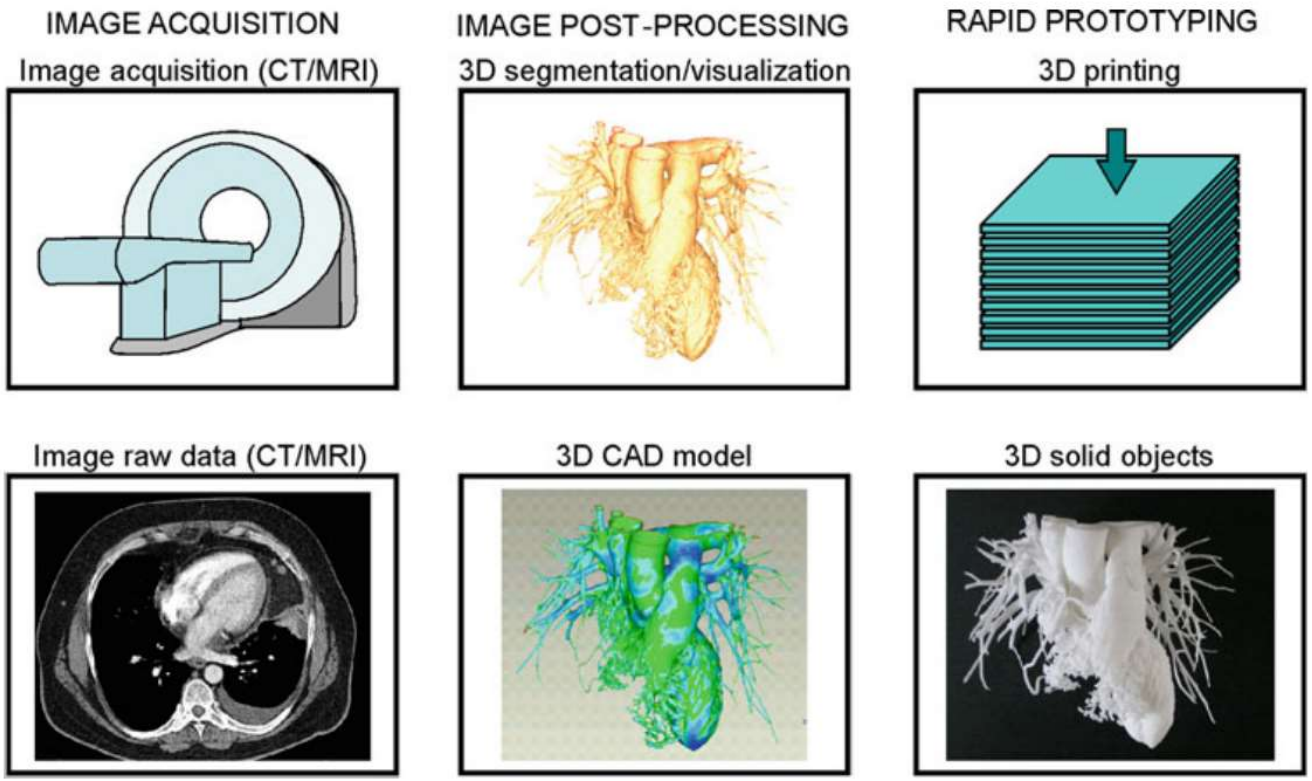
Generation of 3D objects

- Image acquisition
  - ultra-high spatial resolution (400–600 microns) using MDCT and MRI
  - DICOM format (Digital Imaging and Communications in Medicine)
  - (Important standard to know , even just for your own health)
- Image post-processing
  - 3D post-processing tools common in practice include segmentation tools often based on simple region growing as well as visualization tools such as surface/volume rendering, maximal/minimal intensity projection and multiplanar reformation
  - STL (Surface Tesselation language) final format in most cases (actually the paper is wrong it is actually (**STereoLithography)**

Generation of 3D objects (continued)

- 3D printing is a methodology using three-dimensional CAD data sets for producing 3D haptic physical model
- With additive fabrication, the machine reads in data from a CAD drawing and lays down successive layers of liquid, powder, or the sheet material, and in this way builds up the model from a series of cross sections
- Opposite to this would be CNC (Computer Numerical Control) cutting machines that remove material for example a milling machine.

Diagram of the process from Image to 3D print



Types of 3D printing

Table 1 Overview of established rapid prototyping techniques used in the medical arena

	Accuracy	Cost	Advantages	Disadvantages
Stereolithography (SLA)	+++	$$	Large part size	Moderate strength
Selective Laser Sintering (SLS)	++	$$$	Large part size, variety of materials, good strength	High cost, powdery surface
Fused Deposition Modeling (FDM)	++	$	Low cost, good strength	Low speed
Laminated Object Manufacturing (LOM)	+	$	Low cost, large part size	Limited materials
Inkjet printing techniques	+	$	Low cost, high speed, multimaterial capability	Moderate strength

The characteristics can vary depending on the specific printing system used

Medical applications of 3D objects

- Individual patient care
  - Surgical planning
  - Implant and tissue designing
- Medical research
- Educational and training tool

Surgical planning

- Rapid prototyping has recently been introduced into the surgical arena as a tool for better understanding of complex underlying anomaly. This can improve and facilitate the diagnostic quality and help in pre-surgical planning
- Simulating all complicated surgical steps in advance using prototype models can help to foresee intra-operative complications.
- Generating individual radiation shield, this is a huge step as many times , people sadly need potential double or more amounts of material removed due to a large area of the body been irradiated than necessary.

Visualization to help plan surgery

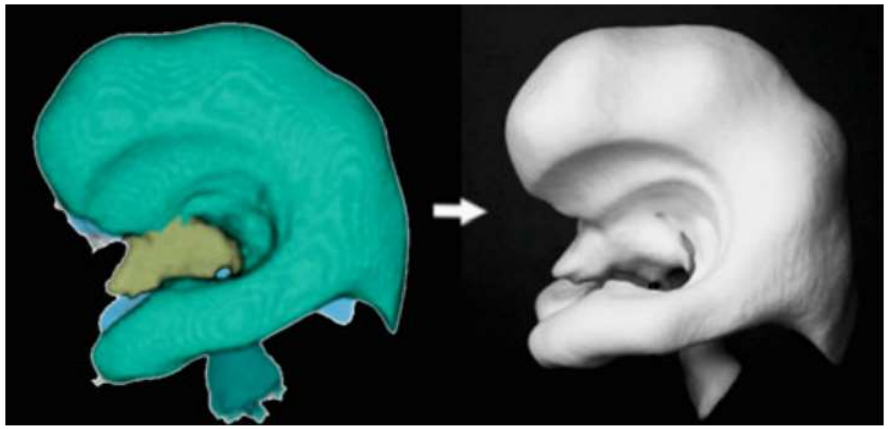


Fig. 2 MRT image data set of the ventricular system of a child with Dandy–Walker malformation was transferred to a dedicated workstation. The software on the workstation provided a 3D visualization and segmentation. The exported segmentation could be used by a rapid prototyping printer to create a 3D print of the 3D ventricular system. Such a print offers the unique possibility of a truly 3D appreciation and palpation of the complex ventricular morphology. Both 3D visualization and 3D print can help the parents and clinicians to understand the exact nature of child's anatomical abnormalities

Ospidéal Mhuire na Leanaí, Cromghlinn
Our Lady's Children's Hospital, Crumlin

UCD is working with Our Lady's Children's Hospital to explore similar techniques that mention in this Paper. We hope that as an intermediate step, that VR HMD's like the VIVE can be used when 3D printing a heart would take to long

Implant and tissue designing

- Medical prosthesis and Implant designing
- Reasons emphasizing the need of customized implants are
  1. patients outside the standard range with respect to implant size- or disease-specific special requirements
  2. improved surgical outcome because of individual fitting and adequate match with individual anatomical needs
- Application of rapid prototyping in creating tissue scaffolds for cellular growth is also widely explored .
- Future applications may include generation of whole artificial organs adapted to the individual patient anatomy (Everyone Gets a new Heart

Medical research

- Research with phantoms (fake 3D printed copies of Human organs) produced by rapid prototyping can help to elucidate physiological processes that are not yet fully understood.
- Complex morphologies may be better depicted on 3D solid models in hand rather than on 2D or 3D visualizations tools
- Potential new insight into how Air and Blood flow inside our bodies.

Experimental Tool

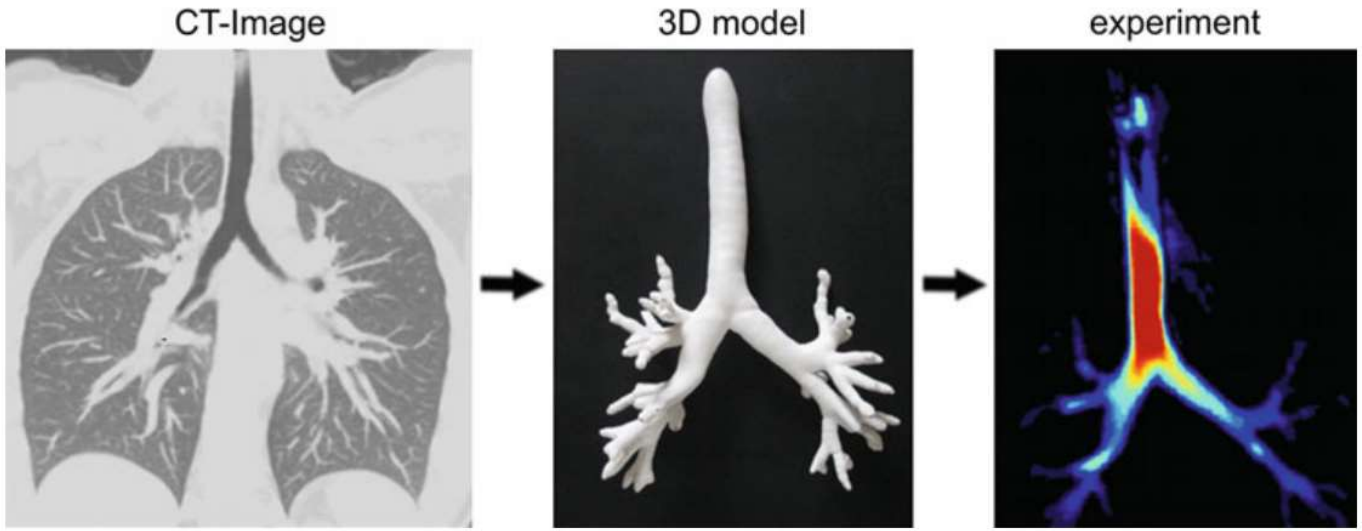


Fig. 3 Rapid prototyping can be used in medical research for creating 3D models of living organs. In this work, a CT image data set of the bronchial tree was processed for rapid prototyping. A 3D model of the human trachea and bronchial tree was produced. The model was then used as a flow phantom for gas flow experiments with hyperpolarised helium (3He) MRI to study the flow pattern through trachea and bronchial tree

Medical Education and Training

- Surgical procedures require a thorough knowledge of human anatomy and topographical relations of various anatomical structures.
- Rapid prototyping objects enhance 3D learning especially in challenging anatomical and pathological conditions
- By training on models surgeons feel more confident while going to the operating room for actual surgery
- This training can also provide a unique opportunity to employ surgical steps in order to determine the best operating strategy

Training tool

- 3D visualization and 3D rapid prototyping of the aorta in a patient with thoracic aortic aneurysm (arrow). 3D models are helpful in demonstrating complex pathologies.
- Vascular surgeons may find models useful for evaluation of the best treatment strategy as well as for training.
- Help Patients and trainees understand

Discussion

- Although medical application of rapid prototyping is still in an early phase its potential has already been demonstrated in several studies
- There is a need for close association and collaboration between radiologists, clinicians, computer scientists and material scientists together.
- The application of rapid prototyping in surgery is valuable for diagnosis, treatment planning and intra-operative surgical navigation especially for complex cases
- Rapid prototyping can serve as the medium to bring the anatomical variations from clinics into the preclinical studies in order to improve the understanding of anatomy

Limitations

- 3D objects usually do not adequately simulate human tissue and surrounding structures
- Rapid prototyping can only be applied to structure not exceeding certain dimension as 3D printers are not able to produce extremely large, e.g., whole body, models
- Rapid prototyping lies within time and cost spent in generation of 3D object. (each Heart for Crumlin children's hospital takes 6 hours or so)
- Unsuitable in emergency cases (That’s were VR can help)

References

- Since it's a Medical paper so I have no idea ☺ about these references , remember no one knows everything .
- Lots of good references to all the techniques mentioned though which is why this paper was suggested to me.
- Great starting point to look for 3D medical research

Next week

- The final Paper will be on Telepresence for VR/AR

  3D LIVE HUMANS IN MIXED REALITY

  ENTERTAINMENT by Simon J.D. Prince, Adrian David Cheok,Farzam Farbiz,Todd Williamson, Nik Johnson, Mark Billinghurst and Hirokazu Kato

- I will also give you presentation from one of my papers in the area as well.

Mixed Reality Questions

- "What techniques could you use to visualise 3D data ?"
  - Use **Milgram** to explain different displays
  - **Rangier et al** to mention 3D printing and medical imagery.
  - **Krevelen** and **Poelman** for more examples from AR and VR
  - **Cruiz-Neira et al** and **Campbell et al** for CAVE designs