

# 3D Reconstruction of Individual Anatomy From Medical Image Data: Survey

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**1** Introduction

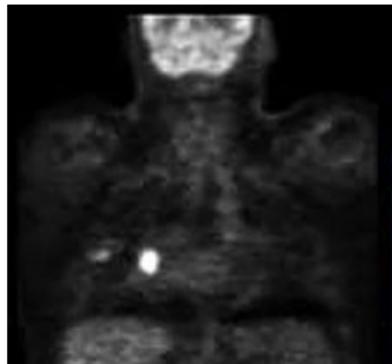
**2** Method

**3** Development

**4** Application

**5** Community

# Introduction



## CT Scan

using X-rays and a computer to take multiple, successive tomographic images.

## MRI

using nuclear magnetic resonance to create images by changing the strength of the magnetic field.

## PET Scans

using isotopes that emit positrons or positively charged electrons to evaluate the chemical activity.

# Achieving the visualization work

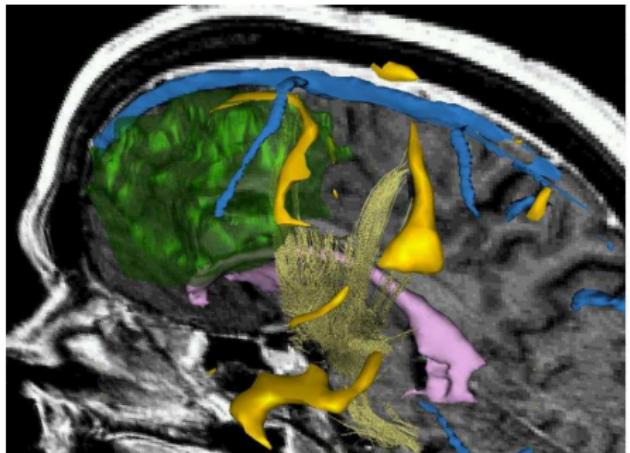


Figure: Three dimensional reconstruction of medical images can provide the direct, real sense for doctors and play an important role in clinical medicine.

# Creating 3D Printable Models

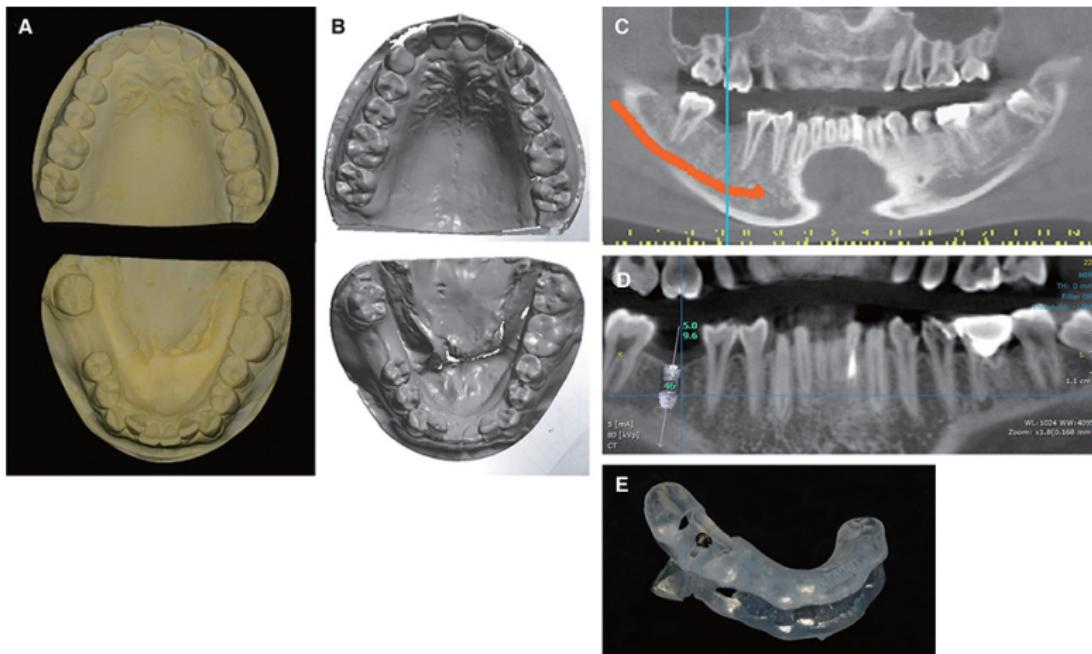


Figure: Three dimensional reconstruction of medical images can generate 3D printable anatomic models from real medical scans.

# Method

# Segment in 3D medical images

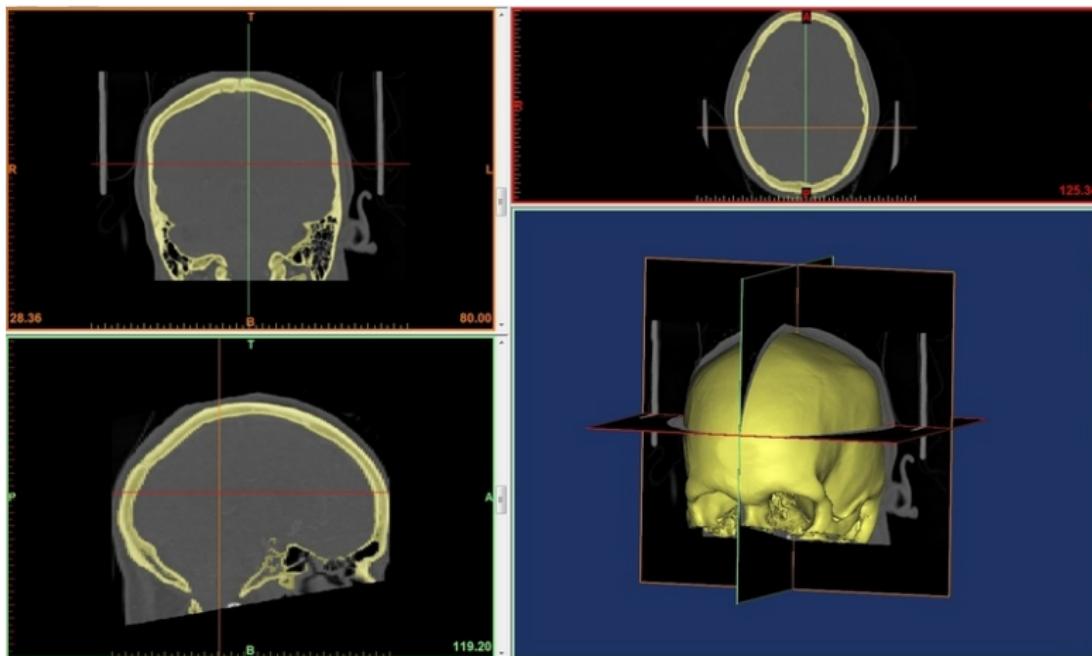
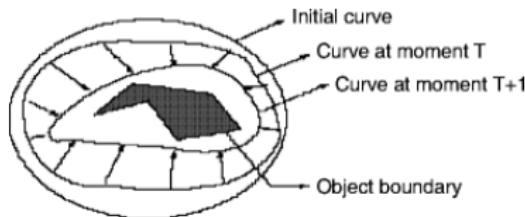


Figure: Firstly, we need to achieve the separation or segregation of information from the required target region per sliced image.

- Active contours, or snakes, are computer-generated curves that move within images to find object boundaries.
- By being a deformable model, snakes can adapt to differences and noise in stereo matching and motion tracking.



## Energy formulation

$$E_{\text{snake}}^* = \int_0^1 E_{\text{snake}}(\mathbf{v}(s)) ds = \int_0^1 (E_{\text{internal}}(\mathbf{v}(s)) + E_{\text{external}}(\mathbf{v}(s)) + E_{\text{con}}(\mathbf{v}(s))) ds$$

- A simple elastic snake is defined by a set of  $n$  points  $\mathbf{v}_i$
- The energy function of the snake is the sum of its external energy  $E_{\text{external}}$ , internal energy  $E_{\text{internal}}$ , and the constraint forces introduced by the user  $E_{\text{con}}$

## Internal energy

- The internal energy of the snake is composed of the continuity of the contour  $E_{\text{cont}}$  and the smoothness of the contour  $E_{\text{curv}}$ .

$$E_{\text{internal}} = E_{\text{cont}} + E_{\text{curv}}$$

- This can be expanded as

$$E_{\text{internal}} = \frac{1}{2} \left( \alpha(s) \left\| \frac{d\bar{v}}{ds}(s) \right\|^2 + \beta(s) \left\| \frac{d^2\bar{v}}{ds^2}(s) \right\|^2 \right)$$

## External energy

$$E_{\text{external}} = w_{\text{line}} E_{\text{line}} + w_{\text{edge}} E_{\text{edge}}$$

- The line functional is the intensity of the image  $E_{\text{line}} = \text{filter}(I(x, y))$ .  $w_{\text{line}}$  will determine whether the line will be attracted to either dark lines or light lines.
- The edge functional is based on the image gradient  $E_{\text{edge}} = -|\nabla I(x, y)|^2$ .

## References

- Wiki: Active Contour Model
- Lec11: Active Contour and Level Set for Medical Image Segmentation
- Active Contours/Snakes: K. Grauman of University of Texas at Austin
- Snakes: Active Contour Models - Michael Kass, Andrew Witkin of Schlumberger Palo Alto Research
- Active Contours, Deformable Models, and Gradient Vector Flow - Chenyang Xu and Jerry L. Prince of The Image Analysis and Communications Lab
- Learning Active Contour Models for Medical Image Segmentation - Department of Eye and Vision Science, Institute of Ageing and Chronic Disease, University of Liverpool

Active contour methods is semi-automatic segmentation algorithms. Can we obtain interactive image segmentation methods more flexible and efficient?

There are two main type of approaches:

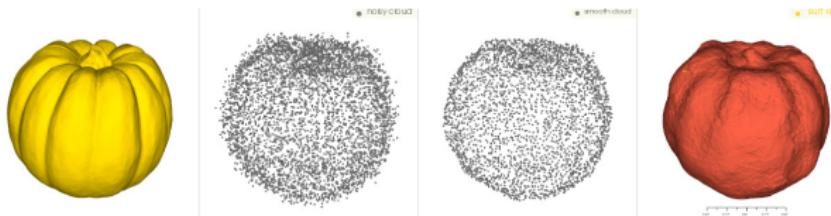
- Deep Learning method based on an active contour framework.  
**DAC, DCAC, DSAC, DACN,...**
- Only deep learning models based on sufficiently large dataset.  
**UNet, DoubleUNet, 3DUnet, Med3D,...**

# Geometry Processing



Figure: A 3d mesh generates from the point cloud associated with the 2D medical images will be used for visualization after the segmentation.

# Geometry Processing



- An object is loaded and noise is added to its vertices.
- The point cloud is smoothed with MLS
- Imposes a minimum distance among mesh points where.
- A triangular mesh is extracted from this set of sparse points.

# Development

- An open-source segmentation and registration toolkit, freely available, cross-platform system for high-performance, N-dimensional image analysis.
- Extensive suite of algorithms for processing, registering, segmenting, analyzing, and quantifying scientific data.

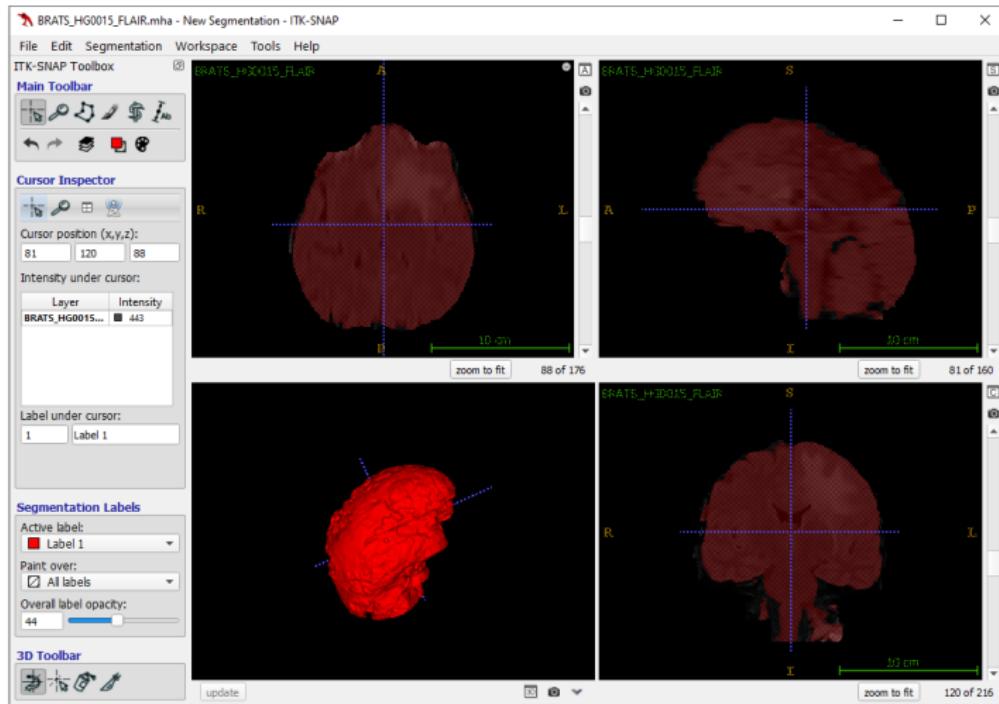


## Pros

- Providing extensive suite of leading-edge algorithms.
- Developing in both Python and C++ packaging, and supporting NumPy, SciPy bridge.
- Supporting cross-platform system.

- An open-source software system for image processing, 3D graphics, volume rendering and visualization.
- Including many advanced algorithms (e.g., surface reconstruction, implicit modelling, decimation) and rendering techniques (e.g., hardware-accelerated volume rendering, LOD control).

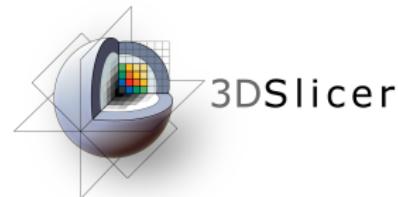




Source: Insight Toolkit-SNAP



- An open source software platform for medical image informatics, image processing, and three-dimensional visualization.
- Built over two decades through support from the National Institutes of Health and a worldwide developer community, Slicer brings free, powerful cross-platform processing tools to physicians, researchers, and the general public.



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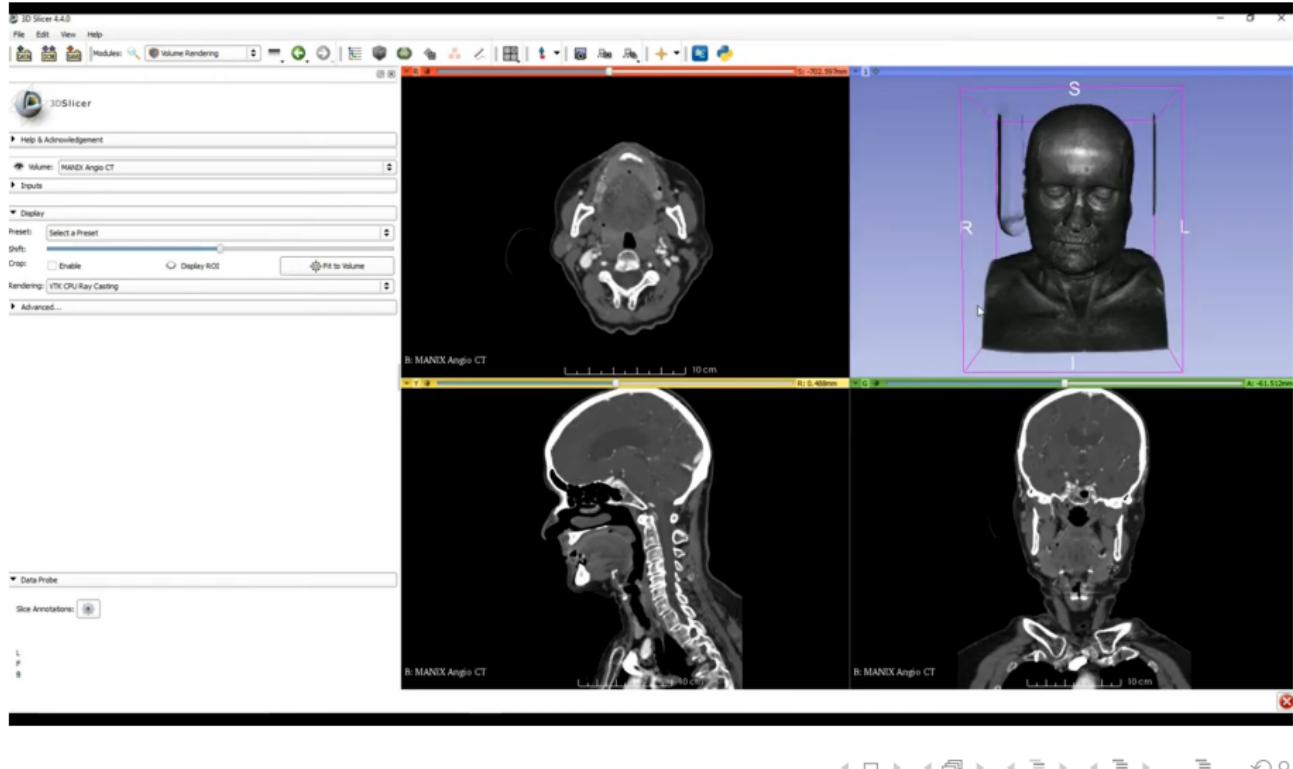
Source: 3D Slicer

# 3D Slicer

**VIETTEL  
SOLUTIONS**

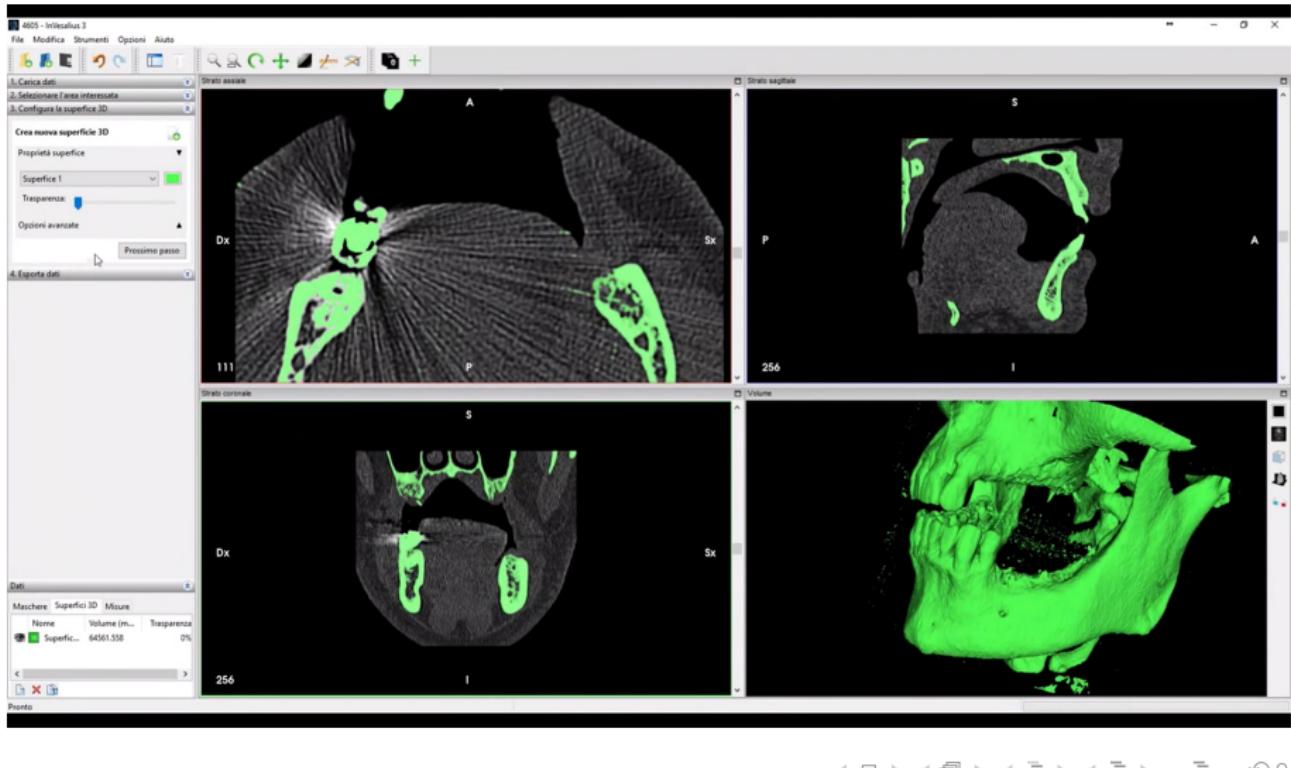
Development

Viettel Solutions Da Nang R&D Team



- A free software for reconstruction of computed tomography and magnetic resonance images.
- Mainly used for rapid prototyping, teaching, forensics, and in the medical field.
- Possible to use it on the Microsoft Windows, GNU/Linux and Apple Mac OS X platforms.





## Pros

- Capability of execution on different operating systems and act as a platform to encourage the use and development of medical images in Brazil.
- Minimal or null acquisition cost.
- Support printable 3D output.

# Application

# Working with clinicians

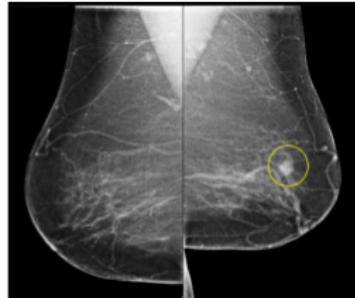


Doctors specify the problem



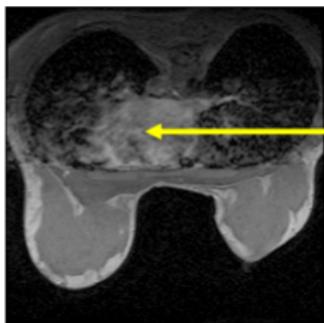
$$E^{\text{imp}}(\mathbf{x}) = \phi(V_t, \mathbf{x}) A_p t_s \\ \int_0^{E_{\max}} N_0^{\text{rel}}(V_t, \varepsilon) G(\varepsilon) D(\varepsilon) \\ \exp^{-\mu_{\text{nuc}}(\varepsilon)} h_{\text{plate}} \exp^{-h\mu(\varepsilon)} d\varepsilon$$

Doctors are unimpressed by mathematics, algorithm details, ....



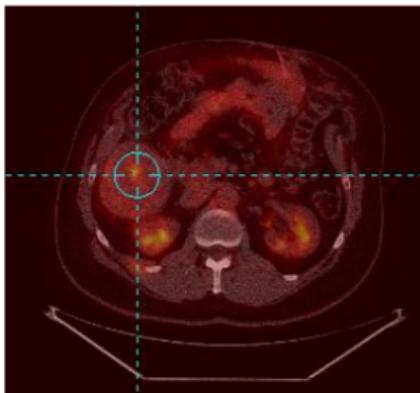
Doctors are impressed by results that enable them to work better

Confidence builds slowly, but can drop like a stone

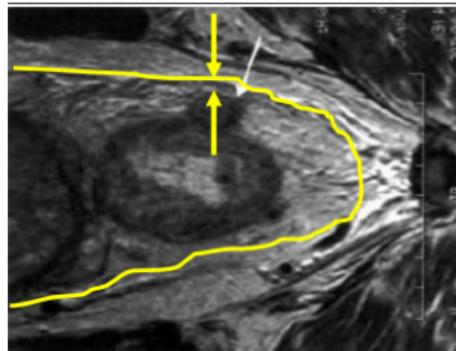
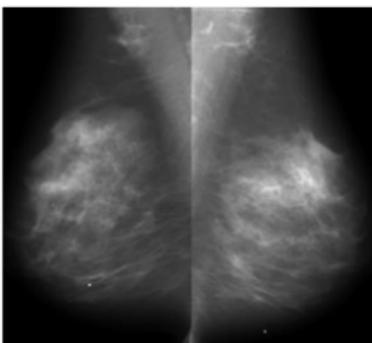


Algorithm: "this is a rapidly enhancing region, suggestive of cancer"

# What clinicians need



Focal enhancement of FDG in liver\*



It is recommended that the circumferential resection margin be at least 1mm if surgery is to be an option

	Right	Left
Volume of Fibroglandular Tissue (cm <sup>3</sup> )	129.5	123.3
Volume of Breast (cm <sup>3</sup> )	631.7	645.5
Volumetric Breast Density (%)	20.5	19.1
1.5 mGy	9.1 kPa	19.8%

Tools they can trust & provide the information they need

Numbers!!!

Accuracy

Response to therapy: If error in measurement  $m_i$  is  $\varepsilon_i$ , then error  $(m_1 - m_2) = \varepsilon_1 + \varepsilon_2$

# Applications have been developed

In medical imaging, many applications require visualization and analysis of 3D objects. The medical image visualization technology has been applied practically in clinical fields:

- Computer-aided diagnosis.
- E-learning in medicine.
- Virtual surgery.

There are variety of medical image viewing software: some paid, some targeted at medical students, others at seasoned experts, each with different specifications, systems requirements, ad-ons, and capabilities. Those are often developed with a focus on one or more of the following functions:

- Simple viewing of medical images
- Teaching
- Mini-PACS servers
- Research

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Source: Top 25 free dicom viewers

Blue Sky Plan: Plan Dental Surgery

The objective of the curricula of medical education is to offer the physicians with the best possible knowledge and clinical skills. Those are often developed with a focus on one or more of the following functions:

- Visualize internal organs.
- Simulate the processes inside the human body.
- Simulate the processes of surgery, treatment action.
- Learning management system.
- Track, manage, and report student's progress.
- Provide training courses and certification.
- Translation, search and look up definitions.
- Interacting through the internet with the specialists and blogging.

# Virtual surgery

Nowadays, 3D printing, realistic mannequins, and virtual reality are transforming how surgeons learn. Most surgery simulators fall into one of two categories:

- **Mannequins:** great because they offer haptic feedback.
- **Screen-based simulators:** cool because virtual mannequins can automatically, consistently, and objectively measure the surgeon's performance

Free screen-based surgery simulators: **Touch Surgery**, **Surgery Squad**, **Buckingham Virtual Tympanum**, **Operate Now**.

⇒ Lack of practical application in reality - Just Game

Current efficient AR/VR surgery application:

**XRHealth**[Page][Demo], **AccuVein**[Page][Demo],  
**Augmedics**[Page][Demo], **BlueSkyPlan**[Page][Demo],...

# Community

- NIPY is a community of practice devoted to the use of the Python programming language in the analysis of neuroimaging data.



- Embodi3D is the largest and fastest growing library of 3D printable anatomic models generated from real medical scans on the internet.



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Link: [Embodi3D Main Page](#)

These companies intend to be at the forefront of VR and AR healthcare.

- **FundamentalVR**[Page][Demo].
- **Karuna Labs**[Page][Demo].
- **OxfordVR**[Page][Demo].
- **Augmedics**[Page][Demo].
- **Surgical Theater**[Page][Demo].
- **EchoPixel  
Theater**[Page][Demo].
- **Medivis**[Page][Demo].
- **Health Scholars**[Page][Demo].
- **Vicarious  
Surgicals**[Page][Demo].
- **Touch Surgery**[Page][Demo].
- **Proprio Vision**[Page][Demo].
- **Immersive Touch**[Page][Demo].
- **OSSO VR**[Page][Demo].
- **SentiAR**[Page][Demo].
- **Medical Augmented  
Intelligence**[Page][Demo].
- **HoloAnatomy**[Page][Demo].
- **SyncThink**[Page][Demo].
- **XRHealth**[Page][Demo].

## The End

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