3D Video and Graphics for Biomedical Applications

Sean S.Y. Kung
Principal
Modelsoft Inc.
There's millions and millions of unsolved problems. Biology is so digital, and incredibly complicated, but incredibly useful. Biology easily has 500 years of exciting problems to work on, it's at that level.

Donald E. Knuth, Professor Emeritus of The Art of Computer Programming at Stanford University
3D can

• make complex medical procedures and biological functions easier to understand.

• Medical visualization and 3D informatics provide surgeons and developmental biologists necessary spatial relationships for diagnosing and navigating a human condition.

One picture ~ 1000 words, one 3D ~ 1000 pictures
3D in Medical Applications

• Education/Entertainment
  Train physicians and technologists

• Research
  New cost effective diagnostic approaches
  New techniques for designing and planning of therapy

• Patient Care
  Provide valid, clinically relevant visualization and analysis of patient specific data
Interdisciplinary Collaboration

- James Clark Building - Multi-disciplinary Teaching
  The combination of art, science and technology
3D Computer Graphics

Martin Newell
- Postscript -> ADOBE
- Ashlar Vellum
- 3D MCAD - User Interface
- Geometric Inference Engine (Draft Assistant)

James Clark
- SGI – OpenGL, Netscape (Browser)
- CC Sub-surface Division Algorithm
- Pixar – Toy Story, ...

-- Polygonal Mesh Model
  (polygon reduction algorithm)
Game 3D Technologies

Spurs development of hyperfast medical imaging systems

- Games
  - 3D, Immersive

- Parallel technology

- Network, Multiple Players
Stereoscopy

• AVATAR

• “stereoscopy,” uses the characteristics of human binocular vision to create the illusion of depth

- Phenomena of Binocular Vision. By CHARLES WHEATSTONE, F.R.S., Professor of Experimental Philosophy in King’s College, London. June 21, 1838

- The first medical application to utilize stereo viewing was in teaching anatomy. Professors teaching anatomy at the University of Edinburgh in the 1880
3D TV

• Discovery Communications, Sony and IMAX Announce Plan to Launch First 24/7 Dedicated 3D Television Network in the U.S.

• ESPN successfully telecast of the Ohio State-USC football game on September 12, 2009. Beginning June 11 of this year, the network launches North America's first all S3D sports television network, ESPN 3D, with the broadcast of the 2010 FIFA World Cup match. At least 85 live sporting events.
S3D (Stereoscopic 3D)

• New Version of HDMI to Support Multiple Stereoscopic 3D Formats.
• HDMI 1.4 to Support “Additional” Stereo 3D Formats
• nintendo 3ds - a 3.53-inch 3D screen with a resolution of 800x240 pixels (400x240 pixels per eye, WQVGA)
• Microsoft's Applied Sciences Group have developed a new type of lens to make 3-D displays more practical and eyewear-free
3D Medical Applications

• Anatomy
  - Bassett Collection of Stereoscopic Images of Human Anatomy

• Surgery
  – DaVinci Si HD Surgical System -- MIS (Minimally Invasive Surgery)

• Biomedical Computation, Imaging, …
SUMMIT Research
Stanford University Medical Media Information Technology

- **Content**
  - Online modules for remote teaching and learning
  - Animations, videos, and other web-based media
  - Interdisciplinary Courses: Anatomy of Movement, International Health

- **Simulation**
  - Development Platform for Surgical Simulators
  - Virtual World environments
  - Assessment of surgical simulators & Virtual Patients

- **Visualization**
  - Display Walls
  - 3D Anatomy models
  - Media collections, portals, and viewers
Italian Anatomical Waxworks
mid-18th-century Bologna
Italian Waxworks
Timeless Preservation with Stereophotography
Dr. David L. Bassett and William B. Grub

Stereoscopic Atlas of Human Anatomy - dissections of every body region

1948 – 1962
1554 sets
Digital Stereo Projection
### Bassett Media Server

**Bassett Collection**

**Search By:**
- Region
- Bassett Number

1. **Select a Region**
   - Neck
   - Back
   - Thorax
   - Abdomen
   - Pelvis
   - Upper Extremity
   - Lower Extremity

2. **Optional: Add Keywords**

Start Search

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*See Stereo Requirement*
CT Scan of Mummy
60,000 2D CT Scans
Visible Human Project - National Library of Medicine

18000 digitized sections of human body

• Transverse Plane
Immersive Segmentation
Virtual World

- CPR (cardiopulmonary resuscitation)
- study was conducted with Woodside High School
Surgical Procedures

• Open Surgery
• Minimally Invasive Surgeries
  – Laparoscopic Surgery
    • 1987 – gallbladder removal by surgeons in France
      90% gallbladder surgeries are “laparoscopic”
  – Robotic Surgery
    • da Vinci Surgical System
Laparoscopic Surgeries

Laparoscopic Procedure

- Uterus
- Fallopian tube
- Ovary
- Gas filled area
- Laparoscope
Surgical Simulation
lack of human cadavers

Spring
(Open source)
Surgical Simulator
Robotic Surgery
da Vanci Si HD Surgical System

- Intuitive Surgical
- Sunnyvale
- 1999

www.davincisurgery.com

Immersive stereo viewer → Enhanced Dexterity, Precision & Control

3d telestration for improved proctoring and team communication
S3D Not for Everyone

- Samsung issued a warning about possible health effects.
- At least 12% of people have some type of problem with their binocular vision.
- Less than 5% of people have severe problems such as lazy eye, crossed eye (Strabismus).
Depth Cues - Monoscopic

- Perspective
- Shading and shadows
- Occlusions
- Atmospheric haze/Depth-of-field/Textural gradient
Depth Cues
The difference between real world stereopsis and artificial stereopsis

• Real world stereo
  The eyes converge and accommodate to the same position

• Artificial stereo
  The eyes converge on the perceived object position and accommodate to light from the screen’s distance
Problems

- Human eye has very little tolerance for discrepancies in color, geometry, and brightness between the left and right eye images.
- It is essential that they be identical in every way except for the horizontal parallax differences that create the 3D effect.
Side Effects

- Increased visual fatigue
- Loss of fusion between images
- Distortion of reality
- Undesired effect in the “look and feel” of the scene
Challenges

• Stereo grading is essential for achieving smooth transitions between shots and maintaining stereoscopic continuity, which reduces eye fatigue.

• Stereo grading with screen size also pose a challenge at the post-production stage.
3D Medical Informatics Pipeline
from Data to Knowledge

Medical informatics: knowledge management and data mining in biomedicine - By Hsinchun Chen

A word (knowledge) ~ 1000 3D
Display and Feedback

- Every process in a 3D medical informatics pipeline has the potential for interactive feedback and display of multidimensional data
- Inference engine for feedback generation

Geometric Inference
3D Reconstruction

- From CT/MRI/PET sectional data (Tomography)
- From point clouds from Laser, Photo, …

DICOM WG-02  Advances in X-Ray Angiography Projection Imaging and 3D
  - X-Ray 3D Informative Annex
  - N-Dimensional Presentation State

DICOM WG 11 + Web3D Medical WG

Visualize / Communicate more details (medical illustration)
Plan / Rehearse the Surgical Procedures
Reduce Surgery time & iterations
Design Custom Implants
Animation/Simulation – FEA, Physiology
User Interface
X3D Components and Profiles

- Components
  Families of related nodes

- Levels
  Of support (fields and functionality)

- Profiles
  Well-defined nodesets for vertical application functionality

Web-based 3D

- GPU hardware accelerated rendering supporting Shader Language such as HLSL, GLSL, CG
- Browser 3D support. WebGL (Firefox, Chrome)
3D Issues

• S3D Fatigue - Vergence/Accomodation
  – Exchange formats, No good feedback and interactivity
  – Not utilize the full potential of the data, ex. Google 3D warehouse, Full body scan data.

• 3D Contents - Costly, Time Consuming, 99%
  – 3D MAX, Maya, Sketchup, Blender3D, …
  – Need What You (Don’t) See Is What You (Don’t) Get
  – Modeling through simple CUT and Paste

• Interdisciplinary Communication

• Medical Regulations
Web Demo

• Neuro-Ophthalmology
Higher Resolution
High Resolution S3D?
3D/S3D

• Too big a topic to cover
• Powerful presentation tool for medical information objects
• Emergent market, but …
• Collaboration is the key
Thank You
Bigger Is Better?
UCI Display Wall

2560x1600
(WQXGA)

1920x1080
(HDTV-UWXGA)
Display Wall Prototype Project
Display Wall for Teaching
Immersive Learning
Immersive Learning in the Li Ka Shing Center (to open March, 2010)

Entire Basement is Immersive Learning Center
28,000 sq ft
lkc.stanford.edu

Medical School only
No nursing, pharm, dentistry
Biomedical Computation

- Simulation of biological structures, from atoms to organisms
- Prediction of protein folding from amino acid sequence
- Modeling how variation in human genes leads to variation in response to drugs
- Modeling and simulation of human movement
- Simulation-based treatment planning and device design
- Simulation of neural computation, from neurons to brains
Biomedical Imaging

- Imaging of protein complexes involved in synaptic communication in the brain
- Fluorescence tagging of molecules involved in intracellular signaling networks
- Non-invasive imaging of cancer
- Imaging of human movement using dynamic MR, motion capture systems, and ultrasonic imaging
- Molecular and biochemical imaging with PET, SPECT, and optical imaging
- Three-dimensional medical imaging of blood flow, blood vessels, and cardiovascular lesions
- Functional human brain mapping
- Strategies for fusing images across modalities (e.g., CT and MR)
- Ultrasonic diagnostic technology in medicine
- Computational analysis and reconstruction of complex imaging data
Hardware

- 100” HDTV (1920X1080)
- 40/100 gb/sec Internet,
- Quadro FX5600, 9800, AMD HD5970, …
- Eight core CPU
Stereoscopic Imaging

• Stereophotography – Live Action
  Loreo 3D lens
  3DX-3901 - Stereoscopic 3D video processor
  (3Gbps/HD) - live-action stereo projects

• Computers – Virtual Reality (CGI)
  – most S3D productions are simply stereo versions of computer graphics (CG) animated movies

• Lasers - Holography
X-Ray Angiography in DICOM

X-Ray Acquisition

2D Projection Images

X-Ray Acquisition

Supp 94: Radiation Dose Reporting

Supp 83: Enhanced XA/XRF

Supp 140: Presentation State

3D Reconstruction

Supp 116: X-Ray 3D Storage

Work in Progress

Follow-up of IHE REM Profile

CR-DX Dose Reporting

Supp 139-LB: Enhanced XA Informative Annex

X-Ray 3D Informative Annex

N-Dimensional Presentation State

DICOM WG-02 Advances in X-Ray Angiography Projection Imaging and 3D
X-Ray 3D Angiography – Rotational Acquisition

Frame #1: X-ray settings 1
Geometry settings 1

Frame #2: X-ray settings 2
Geometry settings 2

Frame #3: X-ray settings 3
Geometry settings 3

Frame #4: X-ray settings 4
Geometry settings 4

Frame #5: X-ray settings 5
Geometry settings 5

Optimized 3D Reconstruction

DICOM WG-02 Advances in X-Ray Angiography Projection Imaging and 3D
<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007: 3D surfaces (WG-17)</td>
<td></td>
<td>Indexed and Fan types compatible with existing ISO X3D</td>
</tr>
<tr>
<td>2007-2008: n-D Presentation States Work Item (WG-11)</td>
<td></td>
<td>Web3D Consortium leads the charge, Scoping</td>
</tr>
<tr>
<td>2009: Web3D &amp; WG -11 Darmstadt; WG-2, WG-12</td>
<td></td>
<td>Requirements processing: Masking, Segmentation, Cutting Planes, multi-planar reconstruction</td>
</tr>
<tr>
<td>2009: WG-6 Leipzig</td>
<td></td>
<td>The Hopscotch Strategy to ISO unification</td>
</tr>
<tr>
<td>2009: RSNA</td>
<td></td>
<td>Min max and average intensity projections added, volume blending pipeline support</td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td>SPIE Medical Imaging: new X3D 3.3 spec, IEEE VR: 3.3 implementations, Web3D Conference &amp; SIGGRAPH</td>
</tr>
</tbody>
</table>
Base X3D Concepts

• Include some set of components:
  – Grouping: Transformation, Switch, LOD
  – Viewpoints (Perspective and Ortho)
  – Lights (Directional, Point, Spot)
  – 3D, 2D surfaces, lines and point geometries
    • including Shape Appearance and Materials
    • Per-vertex data such as RGBA and ImageTexture maps
  – Annotation (Text, Layers)
  – Interactivity
    • Sensors
    • Event model, animation
    • Scripting?
MedX3D Nodes / Components

- 3D Texture Component
- Volume Component
- Annotation Component
  - Image plane projection & linking – YES
  - 3D equivalents of Extended (2D) Presentation State objects – YES probably
Specification Progress: Volumetric Presentation

• Volume Rendering
  – MedX3D styles have necessary and sufficient coverage

• Masks, subvolumes & segments
  – MedX3D voxel data structure and access per WG2 and WG12 requirements
    • Addressing voxels within volume
    • Volume time series

• UI
  • e.g. Clipping & MPR
    • Lines generate plane
    • Planes
    • 3D volume
DICOM WG 11 + Web3D Medical WG Specification Plan:

1. **Med X3D Functional Specification (abstract)**
   - Specify additional nodes and components for X3D abstract spec
   - Create MedX3D Profile for X3D abstract spec

1. **X3D (XML, Binary) encodings exist; DICOM encoding of MedX3D Profile?**
S3D Content Creation

• Live Action Production
• 3D Computer Generated Production (CGI)
• 2D to 3D Conversion
• Augmented Reality/3D Telestration
3D Data Acquisition
Cross Sectional Slices

- Ultrasound
- CT (Computed Tomograph) - ionizing radiation
- MRI (Magnetic Resonance Image) - harmless radio waves
  - ultra high field (UHF) MRI -- 7 tesla MRI brain images
- Nuclear Medicine - SPECT
Data Acquisition/Rapid Prototype

• 3D Digitizing

KONICA MINOLTA 3D Laserscanner -> point clouds

Orthodontics
Reconstructive surgery
Forensic medicine
Oral & Maxillofacial surgery
Cosmetics
Veterinary medicine
Orthopedics
Ear, nose and throat medicine
Tumor measurement