Interactive 3D Visualization in the Wide Web of Health

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Virginia Tech

Keynote: Hl7 PLenary Meeting Baltimore, MD
Oct 1, 2018

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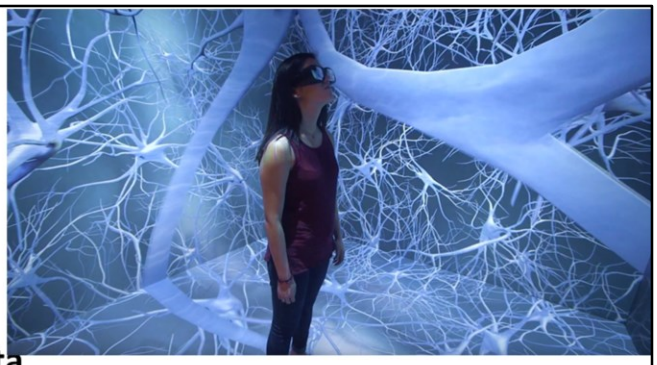
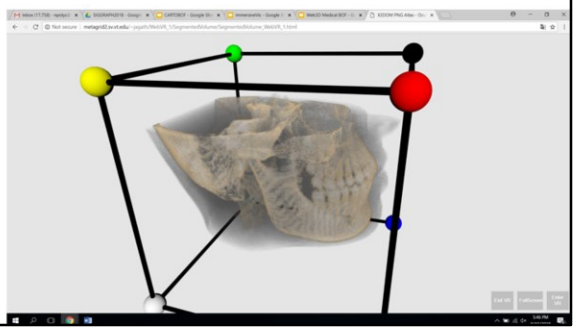
Outline

- **Web3D & Me**
- **Born 3D**
- **Things Change - a Lifetime of 3D**
- **Standards**
- **The Many Faces of 3D Health Data**
  - **Metadata**
  - **Health & Medicine**
  - **Access: WWW, Virtual & Augmented Reality, 3D printing**
  - **Data-driven 3D visualization**
- **Convergence & Interoperability**
- **The Path Forward**



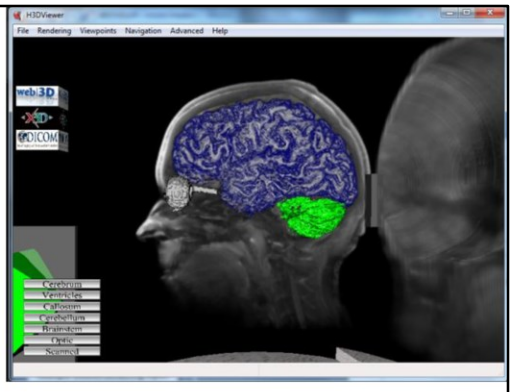


Goal:

Global Interoperability!

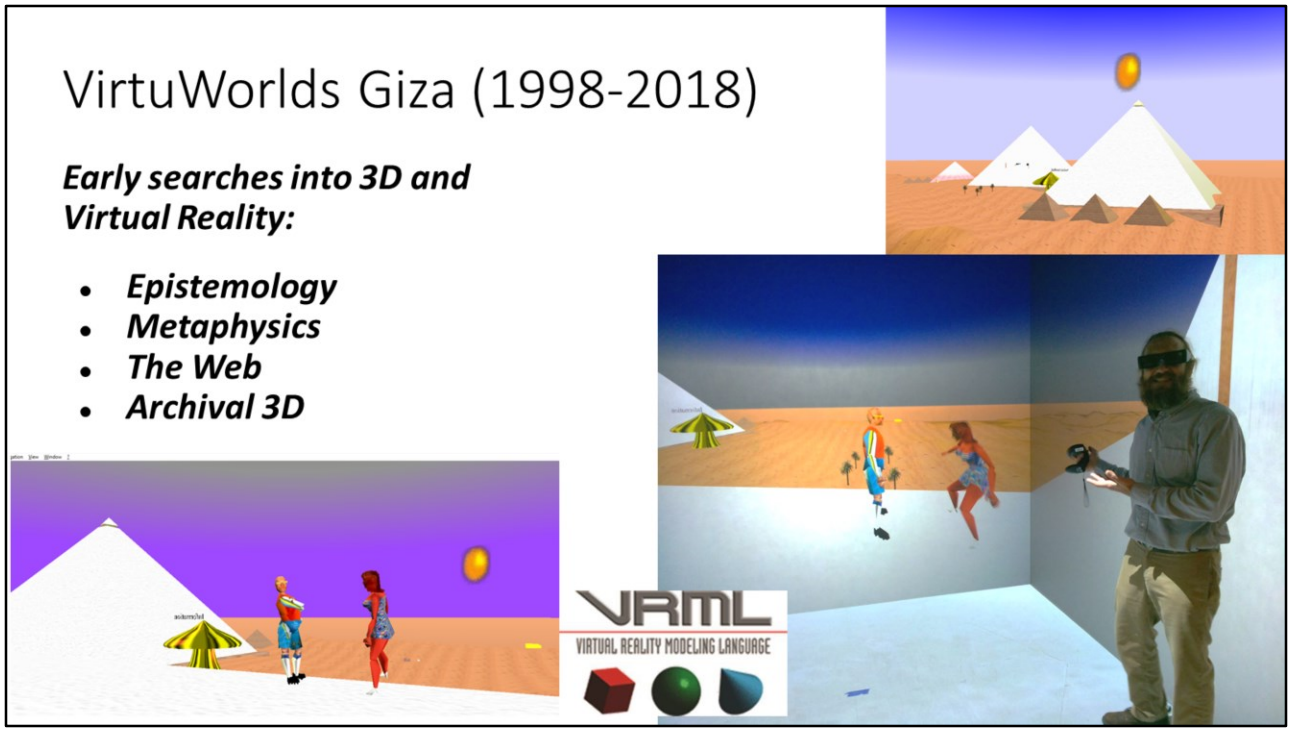
To achieve this, we need to:

1. **Cross-fertilize informatics communities, knowledge, and practice**
2. **Adopt standards to improve exchange and reproducibility today**
3. **Extend standards and practice for better outcomes tomorrow**



Introduction

1996: BA in Cognitive Science
1998: built first VRML world of the Giza Plateau
1999: attended first ACM Web3D Conference & joined Web3D Consortium
2006: received PhD in Computer Science from Virginia Tech, U appointments
2007: took over the Visionarium Lab, aligned with Central IT: HPC
2008: Medical WG and Volume Component
2010-present: leadership with DICOM, MMVR, IEEE VR, Web3D, SIGGRAPH, ...
2017: HL7 Collaboration



Picture of me in the Hypercube last week… with my first VRML world
… the same world … runs a lot faster now even though we wrote it for transmission over a 14.4 k modem (and it was before Linux and GPUs)!

ISO-IEC Web3D Standards Evolution

Durability of 3D information across industry epochs:

- **1994: VRML 1.0**
- **1997: VRML 2.0**
- **2002: VRML 2.1**
- **2005: X3D 3.0**
- **2006: X3D 3.1 ; H-Anim 1.0**
- **2008: X3D 3.2**
- **2013: X3D 3.3**
- **2018: H-Anim 2.0**

Encodings:

- ***XML,***
- ***utf8,***
- ***binary,***
- ***JSON***

Bindings:

- ***Javascript,***
- ***Java,***
- ***C#,***
- ***C++, C,***
- ***Python***

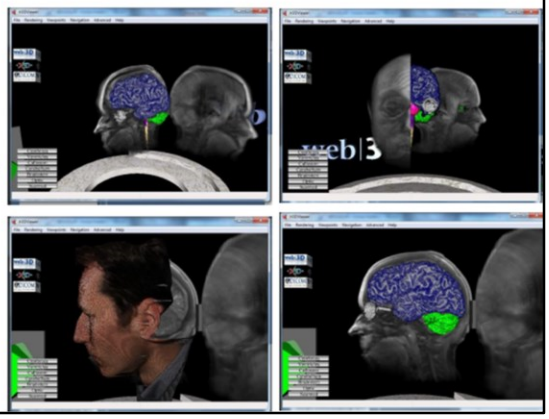
http://www.web3d.org/standards/all

http://www.web3d.org/x3d/content/Basic/Web3dOutreach/Web3dTimelineIndex.html

Web3D.org & WG introductions

Enterprise 3D (X3D): ISO-IEC formats and API:

- Royalty-free, open X3D holds:
  - Volumes, meshes, appearances, text, metadata
  - Lights, cameras
  - Animation, interaction
  - XML, Binary, JSON encodings
- Web3D Medical Working Group
- DICOM Liaison & reciprocal membership
- HL7 Liaison & reciprocal membership



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Games and diversions are fun, but what about real 3D??? Health… safety …. Utilities… These are not silicon valley cycles ...

Born 3D

… but highly dimensional !:-)

The last centuries' hopes for health through medical science has been driven by Reductionism

… while still essential, the situation is now flipped!…

The integration of disparate (Big) data and scientific disciplines provide us new insights into the whole person, their environment, and their health!

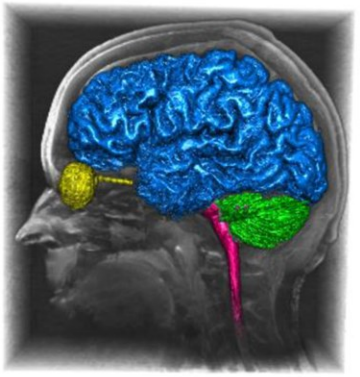
Things Change

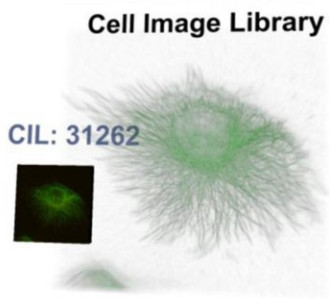
A lifetime of 3D … ‘Mission-critical data’

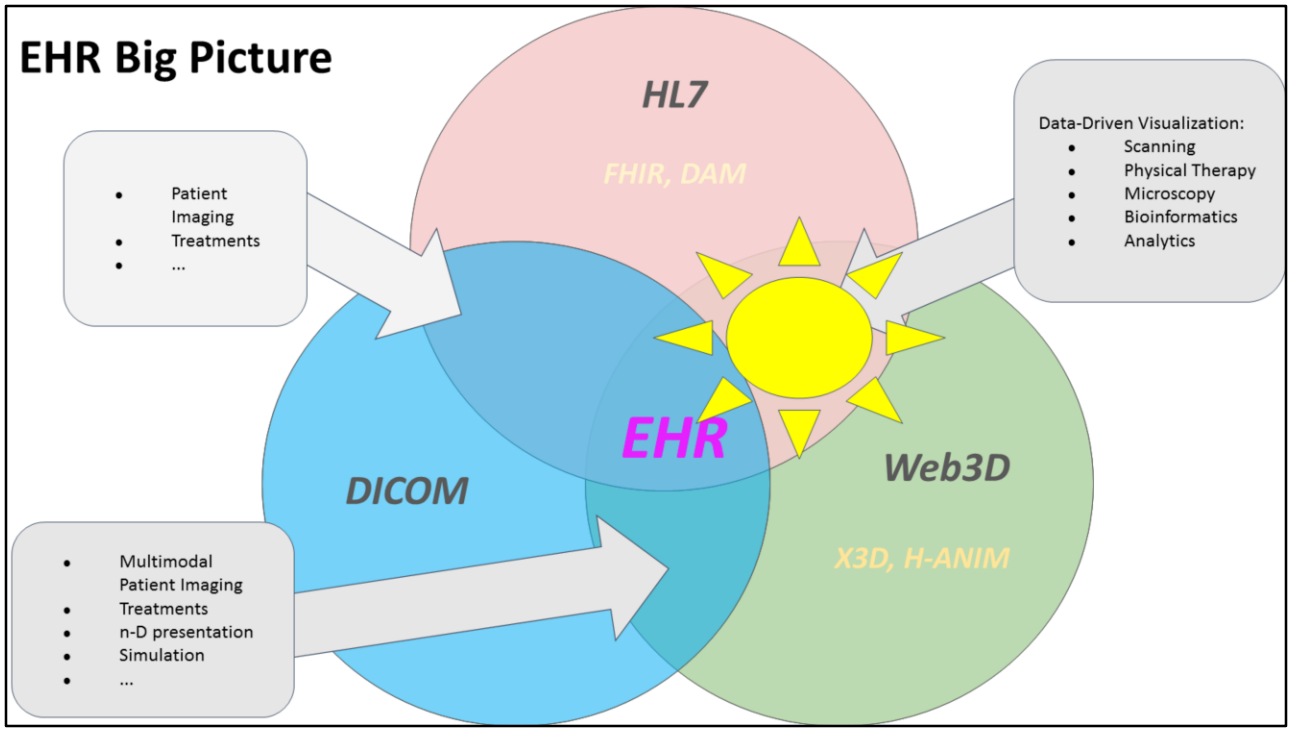
- Requires durability longer than Silicon Valley cycles and market hype
- Requires Patient Rights to digital twin and conformant EHR
- Emerging technologies and Access

Web3D & HL7 Opportunities

- Interactive 3D on the:
  - Desktop (any OS)
  - VR systems
  - mobile device
  - … or any web browser
- DAM X3D payloads!
- Healthy X3D on the WWW (L7)!






EHR Big Picture
HL7
FHIR, DAM
Patient
Imaging
Treatments
...
Data-Driven Visualization:
Scanning
Physical Therapy
Microscopy
Bioinformatics
Analytics
EHR
DICOM
Web3D
X3D, H-ANIM
Multimodal
Patient Imaging
Treatments
n-D presentation
Simulation
...

Web3D & DICOM History

Official Liaison began in 2008 and manifested in several WGs toward the interoperability of 3D semantics and data structures:

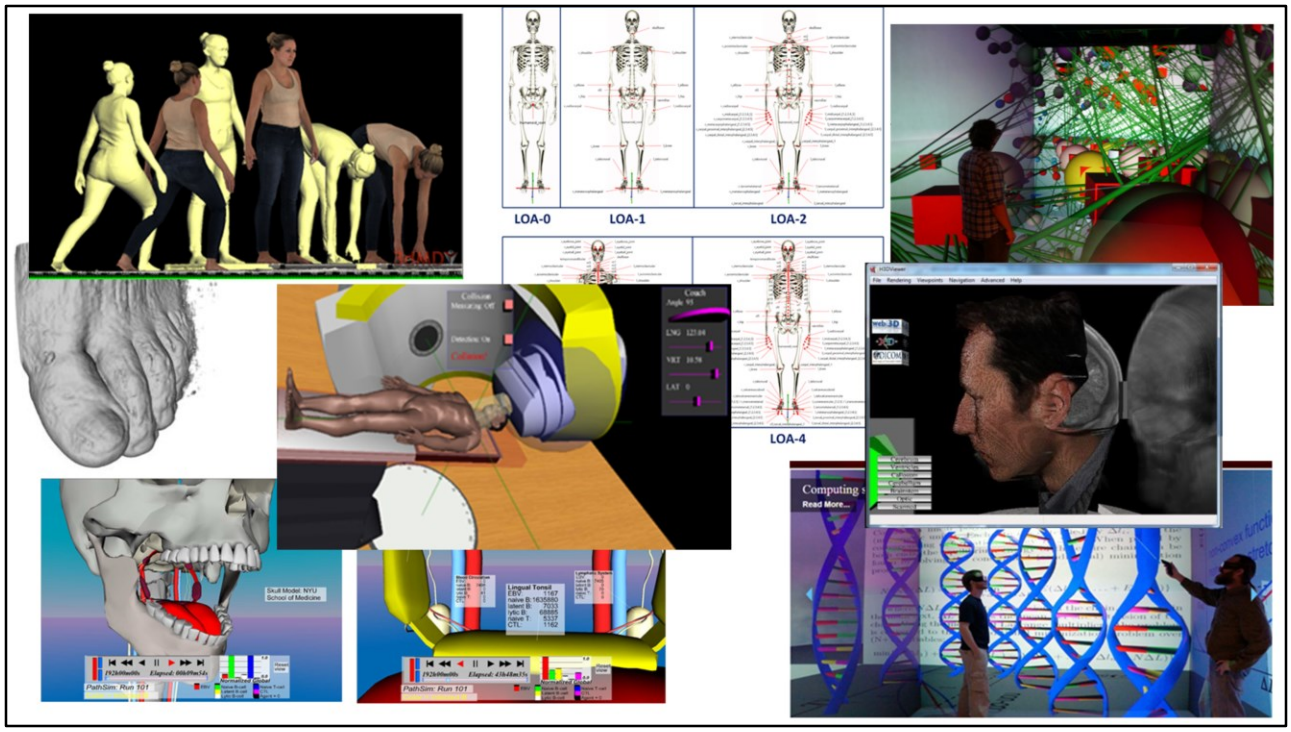
- X3D 3.3 Volume Component
- DICOM SUP 132 3D Surfaces
- DICOM SUP 111 Volumes & Segmentations
- DICOM SUP n-D Presentation states (rendering)
- 3D Printing DICOM SUP 205 (eg STL payload)
- 3D Printing DICOM SUP 208 (e.g VRML, X3D payload: TBD)

CURA, LULZBOT etc

The Many Faces of 3D Health Data

Q: Which one is not like the others?

Let’s play a game:



Trick question!
They are are relevant information in determining your health outcome!!!

Kinds of data, kinds of stakeholders

Health and Medicine

- Exercise
- Therapy
- Simulation
- Surgery
- Genomics
- Analytics
- Networks
- …

H|anim
HUMANOID
ANIMATION
WORKING GROUP

Scope and Requirements

ISO-IEC provides international ratification and recognition.

The X3D and H-Anim specifications provide platform-independent 3D graphics relevant to health.

… How about the values for interoperability?

… How does X3D play across the Health Enterprise?

- Metadata
- Kinds of Health data
- Access (WWW, VR/MR/AR)
- Data-driven Visualization

- THE VALUE ADD OF X3D

X3D Metadata

Travels with the 3D information and can be granular at any node when embedded in the scene graph. Scenes can be composed through the Inline node.

- UNITS & measures defined per scene
- ***Metadata can be on any node in the scene***
  - Provenance and source of data
  - Document processing tool chains for derived data
  - Community vocabularies and annotations (FMA, SNOMED, CT, ...)
  - W3C encryption and authentication by element

Exercise

H-Anim 2.0 (ISO-IEC 19774 - 2) specifies the 3D graphics mappings for combining anatomy and Motion Data Animation (e.g. .bvh). These standards data structures are especially important in physical therapy and ergonomics.

Virginia Tech VR exercise mirror for stroke victims: we demonstrated real-time visual feedback for patients as avatars achieving progressive goals of muscular extension.

- *EHR: "What happened there?"*

High spatial and temporal resolution body scans

www.3dmd.com

3dMD

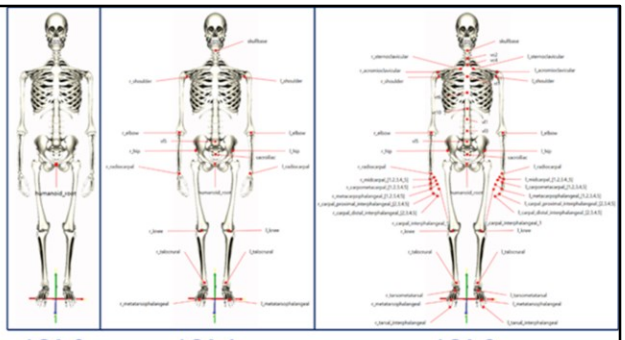
Humanoid Animation v2

ISO-IEC 19774 - 1 : H-Anim (2018)

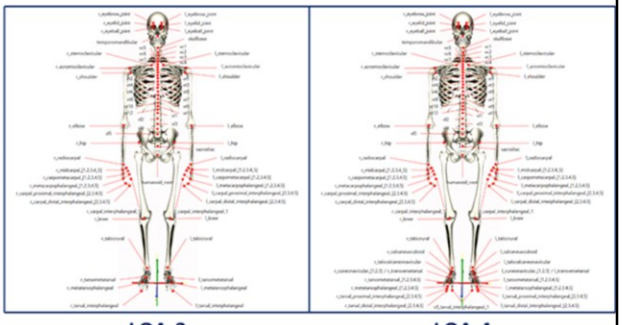
Level of articulation (LOA) represents the complexity and detail of joints for a humanoid skeletal hierarchy, and can be used for generating various motions based on the joints.

There are five levels of articulation:

- **LOA-0** represents only the humanoid_root Joint object without hierarchy.
- **LOA-1** represents the simplest organization and hierarchy of joints for a humanoid. 18 joints and 18 segments. Each segment has a joint in the hierarchy.
- **LOA-2** consists of 71 joints and 71 segments.
- **LOA-3** consists of 94 joints and 94 segments.
- **LOA-4** builds on LOA-3 by adding anatomical details of hands and feet, consisting of 148 joints and 148 segments.



LOA-0 LOA-1 LOA-2



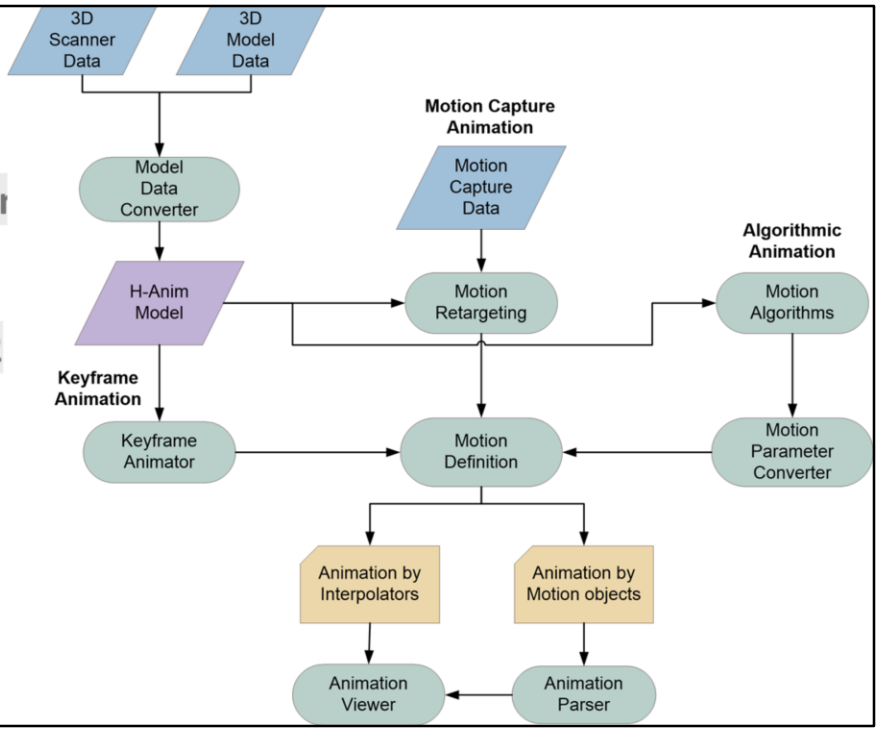
LOA-3 LOA-4

H-Anim v2

Anatomies & Motion

ISO/IEC DIS 19774-2

(e.g. .BVH)

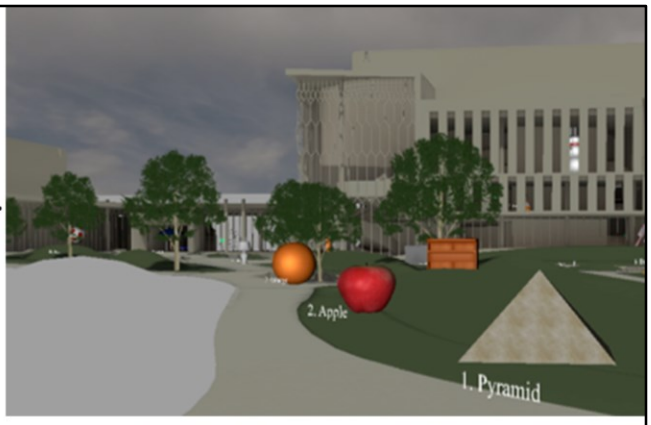


Memory Exercise

Method of Loci - Palaces of the mind…

spaces and things we remember

3D worlds Significantly improve performance!



User study compared 4 study conditions

For word recall

IEEE VR Poster (cite Jesse Mann et al, 2017)

J. Mann, N. Polys, R. Diana, M. Ananth, B. Herald and S. Platel, "Virginia tech's study hall: A virtual method of loci mnemotechnic study using a neurologically-based, mechanism-driven, approach to immersive learning research," *2017 IEEE Virtual Reality (VR)*, Los Angeles, CA, USA, 2017, pp. 383-384. doi:10.1109/VR.2017.7892337

Immersive VR

Clinically effective:

- VR experiences reduce subjective pain experience
- Faster out of bed - saves money and reduces risk of secondary issues (e.g. infection)
- Proven treatments for PTSD with VR exposure therapies

https://www.nature.com/articles/s41746-018-0026-4.pdf -

Economic analysis of implementing virtual reality therapy for pain among hospitalized patients

http://www.mobihealthnews.com/content/depth-therapeutic-vr-2018-no-longer-just-distraction-therapy?

http://www.mobihealthnews.com/content/15-health-and-wellness-use-cases-virtual-reality

https://scholar.google.com/scholar?hl=en&as_sdt=0%2C47&q=ptsd+and+Vr&btnG=

"What happened there?"

Access: VT Visionarium

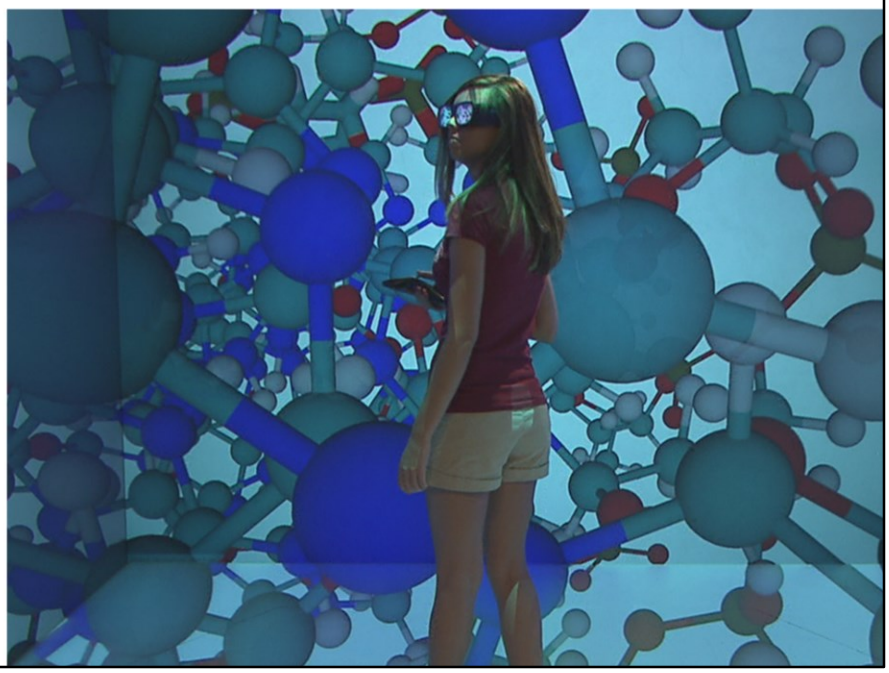
Immersive

Visualization

27 mil

stereo

pixels !



Access: WebVR

- X3D and HTML5 files
- Uses the browser as the platform
- Many headsets

Access: WWW and VR

- X3D: desktop, mobile, immersive VR/MR/AR
- Imaging
  - X3D Volume Rendering
  - TIFF stacks, DICOM, NRRD, PNG
  - Scripted automated conversions
- Molecular Visualization
- Immune Simulation
- Genomic alignment
- Polygons and volumes living together
- VR and 3D printing !!!

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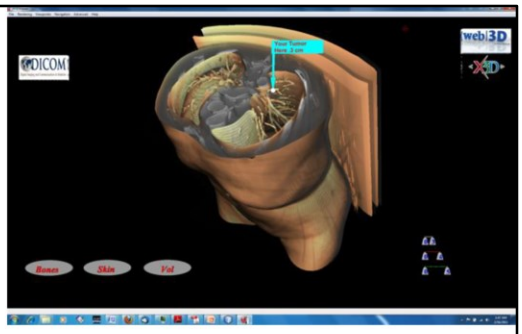

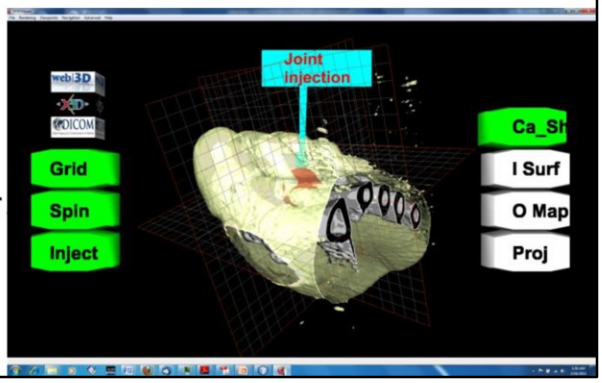

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N.W. John, M. Aratow, J. Couch, D. Evestedt, A.D. Hudson, **N. Polys**, R.F. Puk, A. Ray, K. Victor, Q. Wang. (2008). "MedX3D: Standards Enabled Desktop Medical 3D." *Medicine Meets VR (MMVR)*.

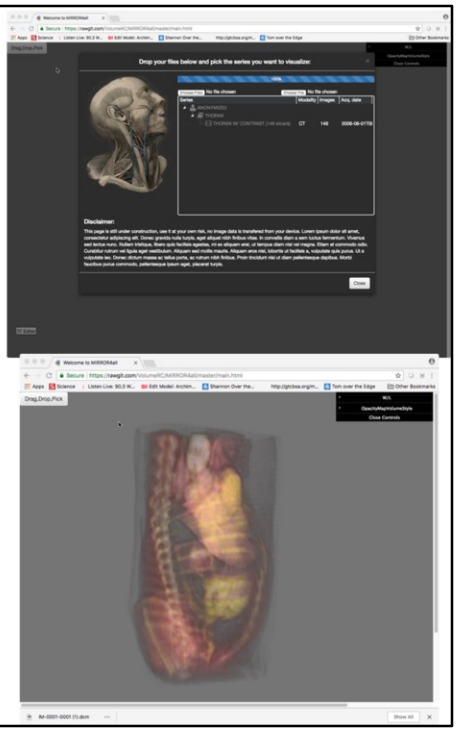
Access: X3D Volume Rendering

- DICOM, NRRD, TIFF:
  - https://www.youtube.com/watch?v=mI7zfrH6A9U&t=37s
- Segmentations and Interaction Mashup:
  - https://www.youtube.com/watch?v=ZO3jWjW9soE
- Cell images with corresponding surfaces:
  - https://www.youtube.com/watch?v=srpiEBvbG-Q&list=UUoQklIQuVbdKEBqgefLbhzw
- Many publications (cite)

Access: Web Volume Rendering

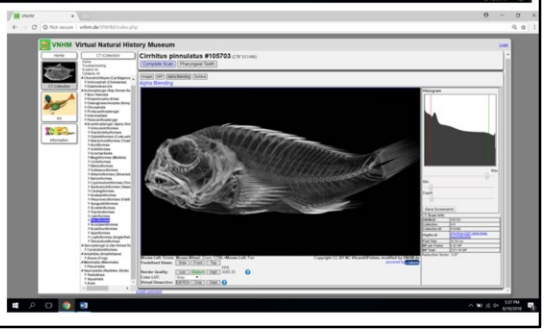
HTML5 + WebGL + X3D

- VICOMTech: Volumerc.org
- Online drag-and-drop service for DICOM:
  - To HTML5/WebGL/X3DOM Mirror4All by VICOMTECH and KShell

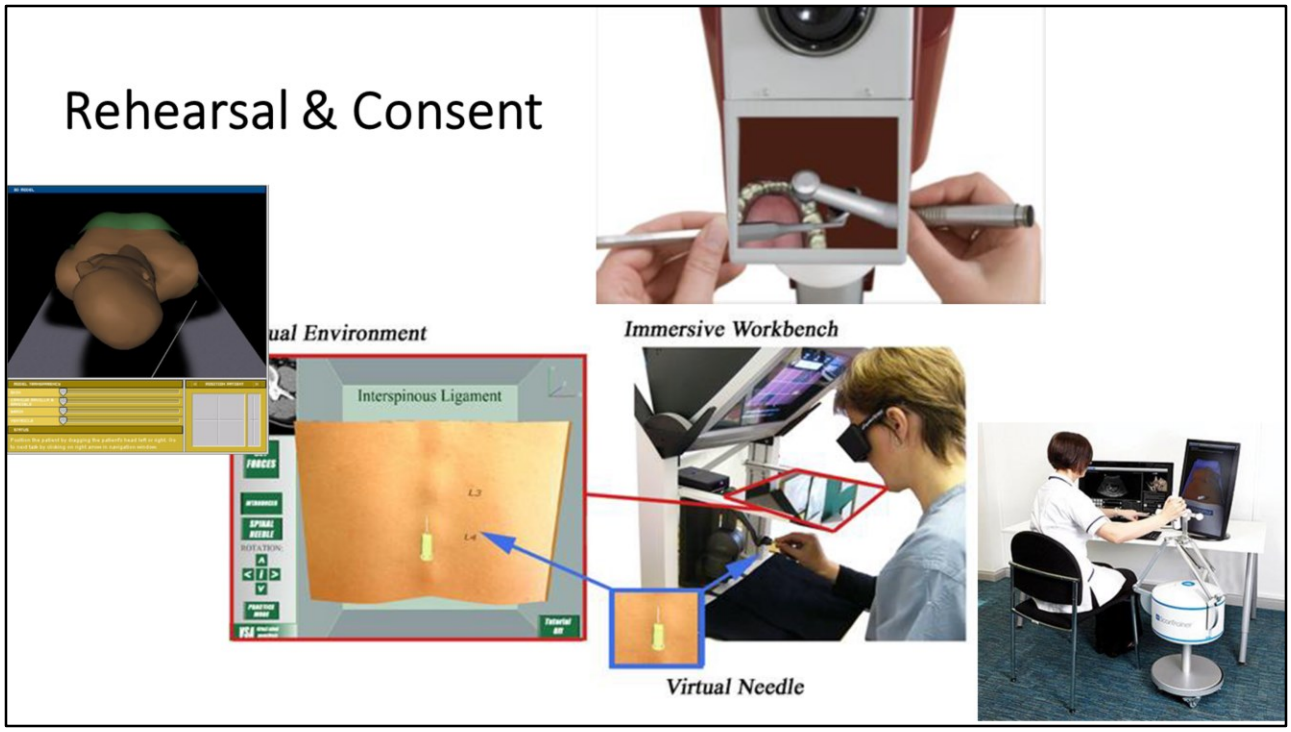


Access: WWW and VR

- **HTML5 + X3D Portals**
  - ***Zebrafish genetic and neuro atlas***: zbbrowser.com
  - ***Virtual Natural History Museum***: http://vnhm.de
  - CNS-PF neuron viewer
  - Cell image library
  - NIH 3D Print Exchange



Marquart, G. D., Tabor, K. M., Horstick, E. J., Brown, M., Geoca, A. K., **Polys, N. F.**, ... & Burgess, H. A. (2017). “High precision registration between zebrafish brain atlases using symmetric diffeomorphic normalization”. *GigaScience 6 (8)*.



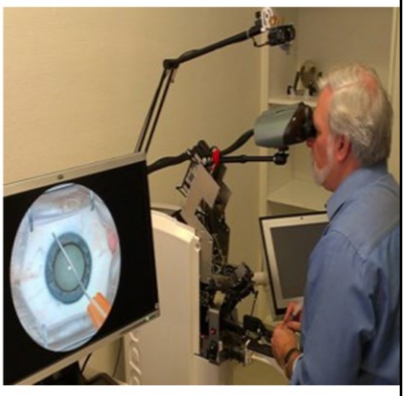
Hamza-Lup, F. G., Bogdan, C. M., Popovici, D. M., & Costea, O. D. (2011). A survey of visuo-haptic simulation in surgical training. *Proc. eLmL*, 57-62.

Hamza-Lup, F. G., & Stanescu, I. A. (2010). The haptic paradigm in education: Challenges and case studies. *The Internet and Higher Education*, *13*(1-2), 78-81.

Surgical Simulation

X3D as a platform for Haptic simulation and Medical training

- H3D.org
- Nigel John's trainers:
  - Eye surgery simulator
  - Ventricular catheterization training
- MMVR 2014 workshop (cite?)
- "Quantizing the Void" paper (cite)



S. Ullrich and T. Kuhlen, "Haptic Palpation for Medical Simulation in Virtual Environments," in *IEEE Transactions on Visualization & Computer Graphics*, vol. 18, no. , pp. 617-625, 2012. doi:10.1109/TVCG.2012.46

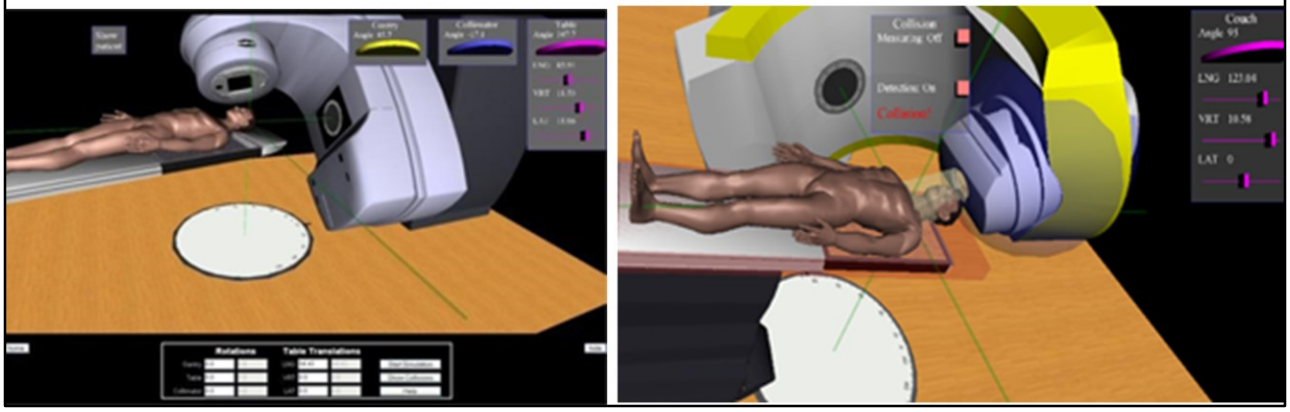
Ullrich, S., T. Kuhlen, N. F. Polys, D. Evestedt, M. Aratow, and N. W. John, "Quantizing the Void: Extending Web3D for Space-Filling Haptic Meshes", Medicine Meets Virtual Reality (MMVR), vol. 163, Newport Beach CA, USA, IOS Press, pp. 670-676, February, 2011.

N.W. John, "Design and Implementation of Medical Training Simulators", Virtual Real. 12, 4 (Dec. 2008), 269-279.

F.P. Vidal, N.W. John, A.E.Healey, D.A. Gould, "Simulation of Ultrasound Guided Needle Puncture using Patient Specific Data with 3D Textures and Volume Haptics", Computer Animation and Virtual Worlds. Vol. 19, Issue 2, pp111-127, May 2008, Online ISSN: 1546-427X , Print ISSN: 1546-4261,

Safety and Radiation Therapy

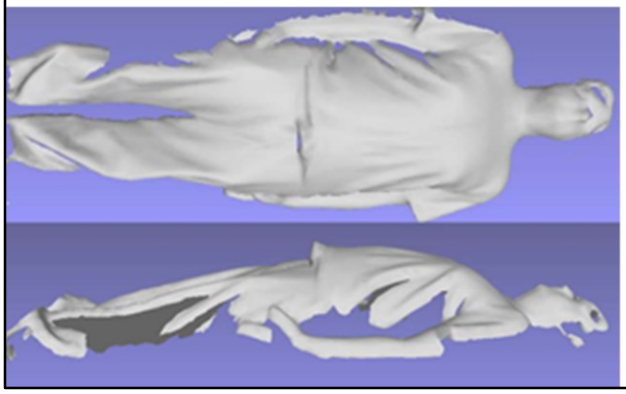
X3D simulation of X-Ray therapy: Felix Hamza-Lup

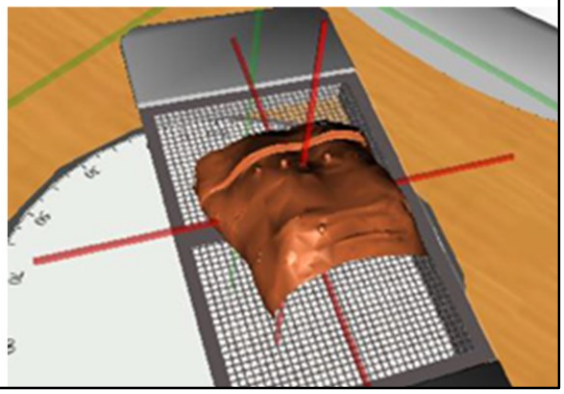


Hamza-Lup, F. G., Farrar, S., & Leon, E. (2015). Interactive X-ray and proton therapy training and simulation. *International journal of computer assisted radiology and surgery*, *10*(10), 1675-1683.

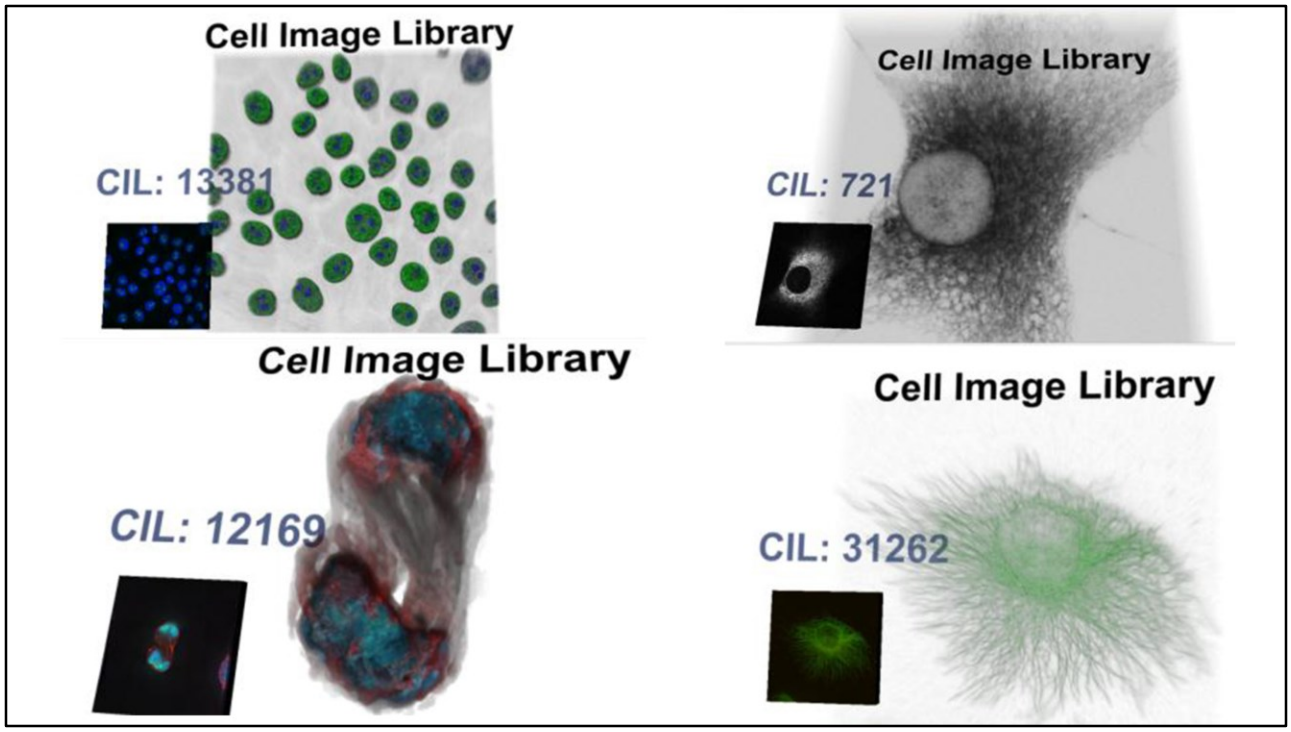
Safety and Radiation Therapy

Patient CT data and real-time boundary representation for the 3DRTT simulator *(3DRTT.org)*





Felix G. Hamza-Lup, Shane Farrar, and Erik Leon. 2015. Patient specific 3D surfaces for interactive medical planning and training. In Proceedings of the 20th International Conference on 3D Web Technology (Web3D '15). ACM, New York, NY, USA, 107-113. DOI: https://doi.org/10.1145/2775292.2775294



Ander Arbelaiz, Aitor Moreno, Luis Kabongo, **Nicholas Polys** and Alejandro Garcìa-Alonso (2017). *"Community-driven Extensions to the X3D Volume Rendering Component".* In *Proceedings of the 22nd International Conference on 3D Web Technology* (Web3D '17). ACM, New York, NY, USA.

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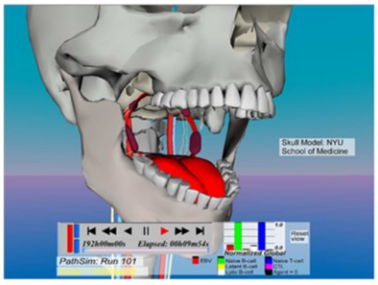
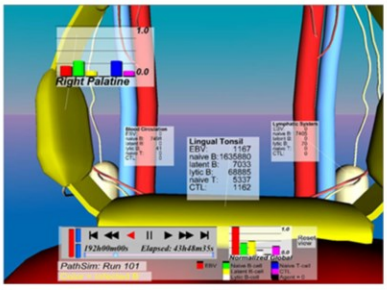
Computing stretched DNA
Read More...

Bioinformatics & Analytics

- Physics of DNA (cite)
- Agent-based immune system (cite)
- MPI_Blast results
- Network visualization





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Compute the Cure (MPI-Blast)

Genomic

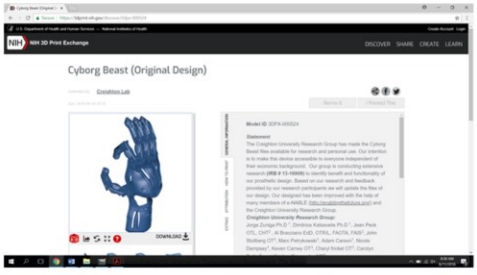
Alignments

(i.e. for treatment compatibility studies)

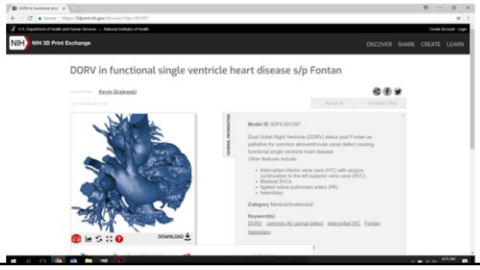
With Wu Feng et al

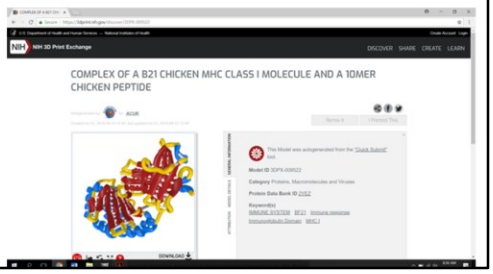
Balaji, P., Feng, W. C., Archuleta, J., Lin, H., Kettimuthu, R., Thakur, R., & Ma, X. (2008, February). Semantics-based Distributed I/O for mpiBLAST. In *Proceedings of the 13th ACM SIGPLAN Symposium on Principles and practice of parallel programming* (pp. 293-294). ACM.

Access: NIH X3D Printing 3dprint.nih.gov



NIH 3D PRINT EXCHANGE

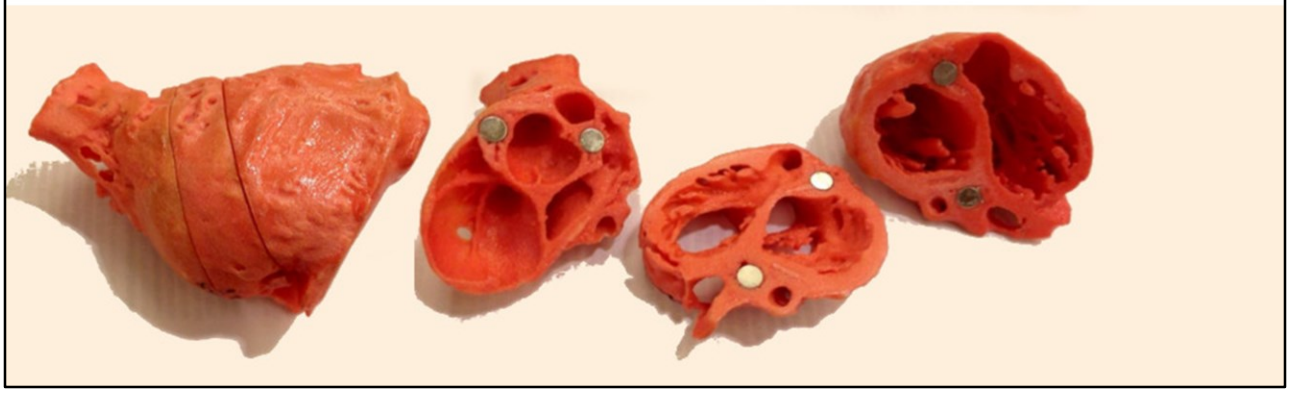




web 3D CONSORTIUM

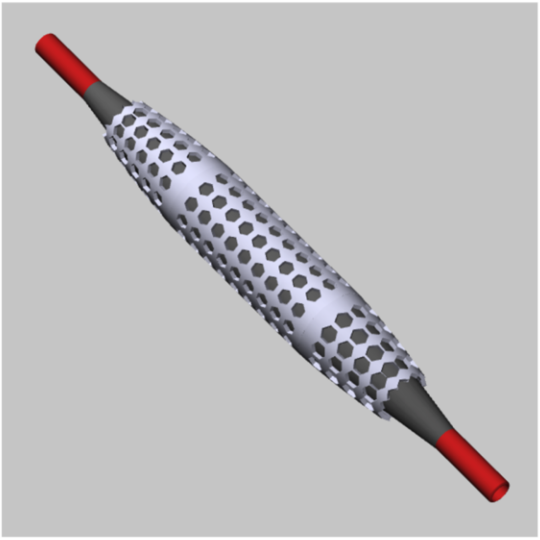
3D printed heart : Case Study

From the patient's MRI, a model was 3D printed and fitted with magnets



Prosthetics and Implants

Detailed 3D visualizations of mechanical structures generated with Computer-Aided Design processes and interoperable ISO CAD standards.



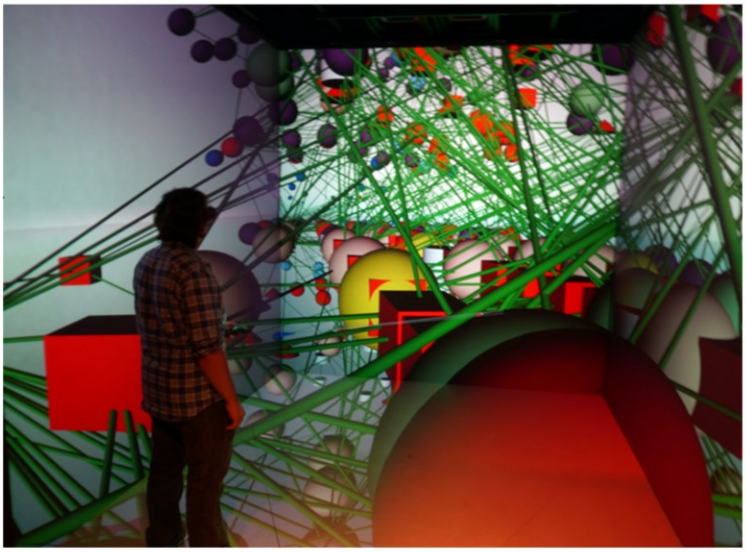
http://www.kshell.com/pages/stent_with_balloon/index.html

Network Visualization

Semantics:

FMA, CT

Ontologies



Narratives in the Network

- Novel graph mining techniques
- Applied to Cell Signalling

Peter J. Radics, **Nicholas F. Polys**, Shawn P. Neuman, and William H. Lund. (2015). "OSNAP! Introducing the open semantic network analysis platform", Proc. SPIE 9397, Visualization and Data Analysis 2015, 939707 (February 8, 2015); doi:10.1117/12.2077834;

Hossain, S., Akbar, M., and **Polys, N**. (2012). "Narratives in the Network: Interactive Methods for Mining Cell Signaling Networks." Journal of Computational Biology **19**(9): 1043-1059.

Hossain, S., Akbar, M., **Polys, N.** (2009) "Storytelling and Clustering for Cellular Signaling Pathways". *Proceedings of International Conference on Information and Knowledge Engineering (IKE),* Las Vegas, NV. 2 Volumes. CSREA Press 2009, ISBN 1-60132-116-3

F. Bacim, E. Ragan, S. Serbo, M. Setareh, B. D. Jones, **N. Polys**. (2013). "The Effects of Display Fidelity, Visual Complexity, and Task Scope on Spatial Understanding of 3D Graphs." *Proceedings of Graphics Interface*, Regina, 2013. ISBN: 9781482216806.

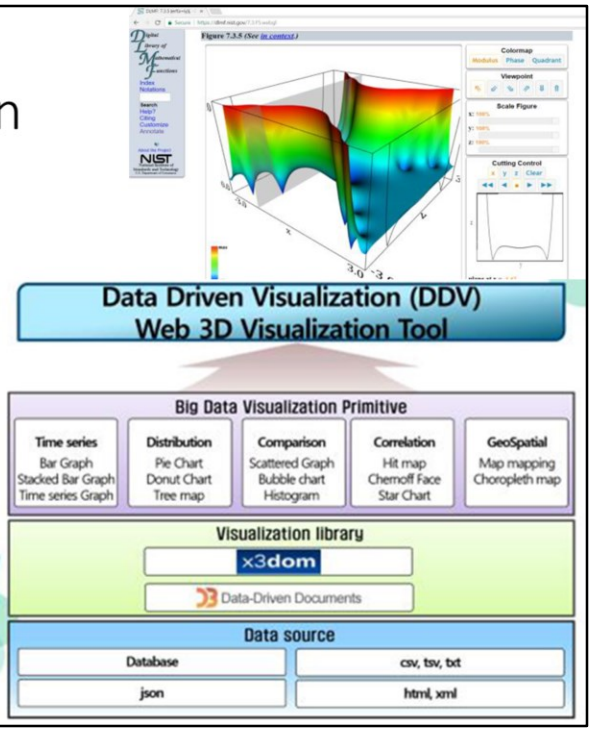
Henry, James A.G. and **Polys, Nicholas**. (2010). "The Effects of Immersion and Navigation on the Acquisition of Spatial Knowledge of Abstract Data Networks".

Proceedings of the International Conference on Computational Science. Proceedia Computer Science, Volume 1, Issue 1, pp. *1737-1746*, Elsevier.

Data-driven 3D Visualization

Analyzing high-dimensional data with X3D graphics (i.e. HL7 records)

- 3D Web plotting (Matlab, D3, X3DOM, X_ITE)
- NIST's Digital Library of Mathematical Functions (DLMF) graphics
- Virginia Tech's Discovery Analytics: Semantic Interaction

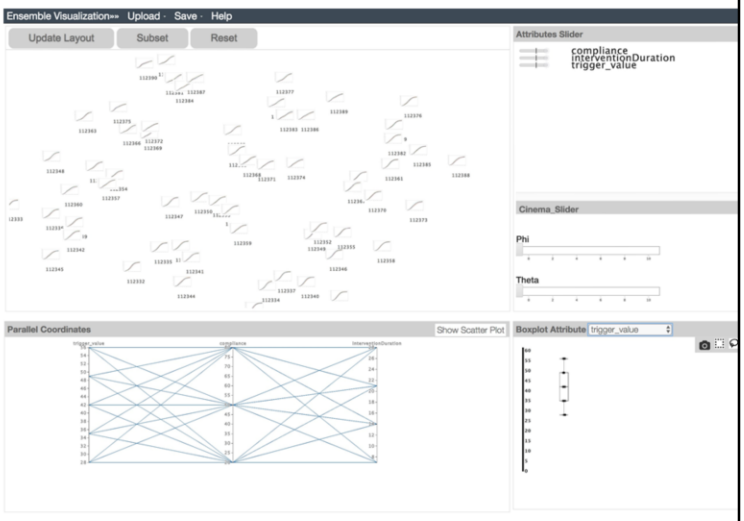


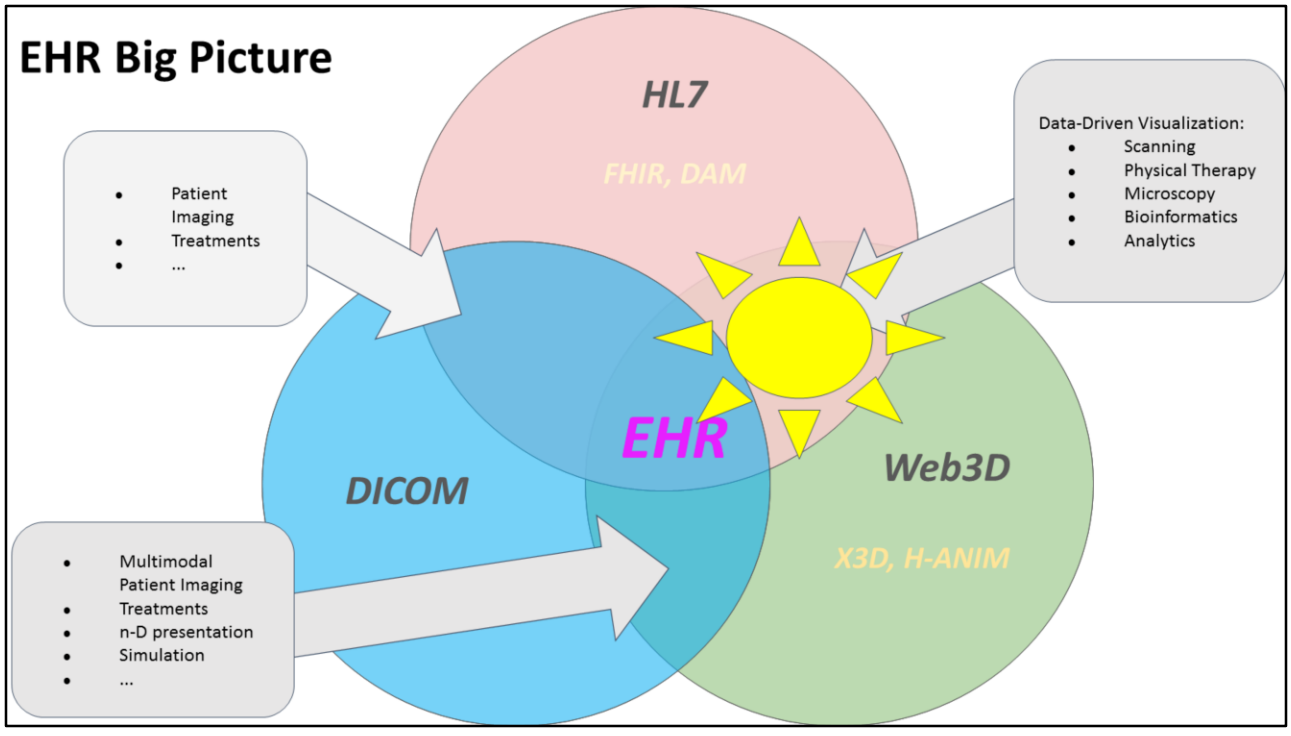
Semantic 3D Interaction

Exploration and Discovery

Where *the human is the loop*:

- Users group records based on visual features, knowledge, and intuition
- Machine learns relevant parameter weights and re-projects records
- Linked panels and plots allow selection and statistical inquiry




EHR Big Picture
HL7
FHIR, DAM
Patient
Imaging
Treatments
...
Data-Driven Visualization:
Scanning
Physical Therapy
Microscopy
Bioinformatics
Analytics
EHR
DICOM
Web3D
X3D, H-ANIM
Multimodal
Patient Imaging
Treatments
n-D presentation
Simulation
...

Path Forward

X3D in HL7:

- XML & JSON payloads of X3D content in FHIR
- DAM-specific integrations

HL7 in X3D:

- Metadata vocabularies & reference practice
- Using 3D Semantic Interaction to explore high-dimensional HL7 information

Web3D & HL7 Opportunities

- **Reciprocal Liaison membership, Working Group communications, and joint strategies**
- **Project -based implementations that can solve health problems with the informatics of 3D**
- **Cross fertilize communities:**
  - **Medical/HL7 track at the Web3D VR Hackathon**
  - **Web3D track at the HL7 Connectathon**
  - **Web3D Annual Conference, AMIA, RSNA, ...**

Human Opportunities

- Synergy is real and makes a difference…
- Common languages, practice, and translations are required
- Each new turn of the ratchet takes us further
- Join the efforts!

It's easier than building Giza or

living under the Tower of Babylon!

Thank You! and Join us!

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Director of Visual Computing

Virginia Tech Research Computing

Affiliate Professor

Virginia Tech Department of Computer Science

web 3D CONSORTIUM

www.Web3D.org - esp Medical Workin
Group and public wiki

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