

Case Study

Teaching 3D Modeling and Simulation: Virtual Kelp Forest

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Don Brutzman
MOVES and Undersea Warfare Academic Groups
Naval Postgraduate School
brutzman@nps.navy.mil



Topics


Project Description and Motivation

Participants, Site Selection, Goals, Audience

Physics and Models

3D and VRML

Demonstration, Teaching Considerations




Background: Naval Postgraduate School

"Navy's University" Monterey California

- USN, USMC, USA, USAF, allied officers, civil service
- Two-year masters' degrees with theses
- Awesome students!

MOVES Institute


- Modeling, Virtual Environments & Simulation
- Mix of computer science & operations research simulation
- Multiple specialized degree programs
- Curriculum includes both 3D and modeling & simulation courses



Project Description

Goals


- Fifteen graduate students used the **Virtual Reality Modeling Language (VRML)**, physically based modeling and analytic simulation techniques to model the three-dimensional (3D) shape and motion of plants and animals in the **kelp forest exhibit** at the **Monterey Bay Aquarium**.
- Educational objective: model all aspects of exhibit!



Project Description

Motivation

- Produce high-resolution 3D virtual environment
- Provide challenging projects for NPS students
 - *Who all must write a masters thesis*
- Prototype for visualizing scalable worlds
 - *Reality more important than virtual*
 - *Composing geometry, behaviors, physics, network*
- Serve as learning tool for studying lessons learned



Participants, sources

Modelers

- MOVES students: 3D models
- Undersea warfare students: physics

Data Sources

- Website
- Site: photos, movies, plans, observation, experience

Site selection


One grove stands apart from the others. The Kelp Forest exhibit, an aquarium centerpiece, looks so natural many visitors believe they're looking through a window to the bay. It's an illusion designed for both visitors and kelp. The exhibit opens to the sky, and the sunlight streaming majestically through the amber fronds helps the kelp grow.

[\[link\]](#) Monterey Bay Aquarium (MBA 99)

Compelling location



Compelling location



Audience

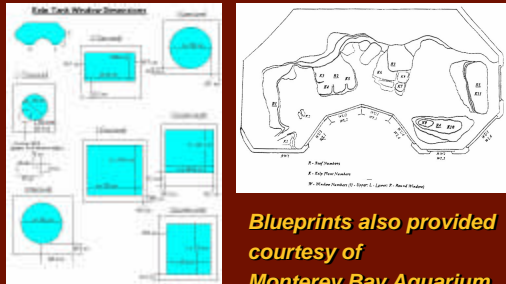
Students, scientists and general public

- First demonstrated to about 1000 participants at the Oceans Fair in Monterey, held on Friday June 12 1998 as part of the National Ocean Conference
- University of California Berkeley as part of a seminar entitled *The Educational Uses of VRML: From PreSchool to Higher Education*
- Monterey Bay Aquarium Student Oceanography Club
- Monterey Bay National Marine Sanctuary Symposium

Modeling

Physical tank structures
Coordinate systems
Hydrodynamic flow
Lights, pumps, access, etc.
Animals and plants

Proper prior planning prevents poor performance



Blueprints also provided courtesy of Monterey Bay Aquarium

Naming and coordinate systems already available

Lots and lots of data

Collecting data is valuable

- Figuring out what is important
- Getting an intuitive feel for quantitative values
- Figuring out what isn't important

Escape common attitudes

- "somebody else" knows that
- Experts versus generalists

Coordinate systems are key

Tank Coordinate System

Animating fish motion

Animation axiom: "cheating" is OK when done well

```

t = 0:1:2*pi-1;
y = sin(t) * .3 * pi;
plot (t * 2 / pi, y);
axes ('XAxisLocation','top');
xlabel ('time period per wiggle (seconds)', 'FontWeight', 'bold', 'FontSize', 12);
ylabel ('rotation about entity Y axis (radians)', 'FontWeight', 'bold', 'FontSize', 12);
    
```

Hydrodynamics: physics of water flow

Tantalizing challenge!

- The answers were right in front of us
- Driving force: positive-displacement circulation pump
- Good mix of student capabilities helped
- Eight weeks of mathematically intense effort

We didn't know precise answer in advance

- ... but we did know that reality "worked"

Mathematically speaking

Measure:

Fluid dynamics is hard

$$\psi(x,y,z) = \sum_{n=1}^{\infty} \sum_{m=1}^{\infty} A_{nm} J_n(\alpha_n x) + B_{nm} e^{-\alpha_n y} + C_{nm} e^{-\alpha_n z}$$

where $A_{nm} = \frac{4}{\pi} \int_0^{\pi/2} f(x,y) \cos(n\pi x) \cos(m\pi y) dx dy$
 $B_{nm} = \frac{4}{\pi} \int_0^{\pi/2} f(x,y) \sin(n\pi x) \cos(m\pi y) dx dy$
 and $C_{nm} = \frac{4}{\pi} \int_0^{\pi/2} f(x,y) \sin(n\pi x) \sin(m\pi y) dx dy$

An innovative but still-intractable approach

- Spreadsheet curve fitting: 8th-order polynomial

Final answers relatively "simple"

- Decomposition of vertical, horizontal
- Linear equations for sinusoid coefficients

$$Y \text{ displacement} = \frac{-8.5m - y_coord}{12m} \times \frac{|x_coord|}{12m} \times 30.5m$$

$$X \text{ displacement} = \frac{12m - |x_coordinate|}{12m} \times 30.5m$$

A place to put things helps the world grow

Incremental integration

Virtual tour guides: Lefty and Lucy Shark

Sharks are the coolest!

Only student model built using a professional tool

- Advanced student
- Once geometry and motion was captured, then model converted down to VRML

Direct observation and video helped

- An obvious result. Or not?

Web pages and mail lists

Website is also a place to "put things"

- Build as we go
- Students like contributing
- Webmaster necessary (e.g. instructor)

Mailing list essential

- Semi-private supportive dialog
- Serendipity
- Students start stepping up

Entry view welcomes newcomers to 3D graphics

Familiar entry view for many visitors

- Must always answer question "What do I do?"

Navigation was the toughest issue

- A real hazard: "Lost in Cyberspace"
- Goal complexity: single click
 - Not possible using mice due to inconsistent user interfaces
- **PageUp PageDown** for viewpoints worked fine
- 3D accessibility remains an undiscovered country
 - Is everyone access impaired in 3D worlds?

A view from above



Many viewpoints essential for sense of presence

- Keep things moving and the mind can integrate the action
 - "If it ain't moving, it ain't 3D." Andy van Dam
- Good choices help tell the story


No animals were harmed...



New technology: X3D

Extensible 3D (X3D) Graphics Specification

- 3rd generation Virtual Reality Modeling Language
- ISO international standard, non-proprietary
- 3D graphics interchange for World Wide Web
- Suitable for scaling up to very large networked worlds
- Open source, commercial implementations available
- <http://www.web3D.org/x3d.html>
- Analogies to Hypermedia and HTML



Primary benefits of XML

Simpler parsing, with lots! of software tools

- More tools every day, it seems

Validation of content

- Nodes can only go together in legal ways
- Validate values (e.g. color-triplet arrays)
- Broken content can't escape
- Fixes the "garbage in, garbage out" problem!

XML finally enables structured data

- hmmm, structured programming was important...

Compelling content, conversions


Bidirectional command-line autotranslation

Cool examples lots already here

- Geospatial, H-Anim, DIS, Lattice all work
- KeySensor, StringSensor, NURBS need code
- Autogeneration of web-page examples works
- Compelling content (interactive-profile ⇒ full profile) needed

Combined XML languages challenge ☺

- XHTML +X3D + SVG+SMIL+MathML+...



X3D-Edit authoring tool

Simple and free

- Use IBM Java-based Xena editor builder, licensed to Web3D

Error-free editing, authoring, validation

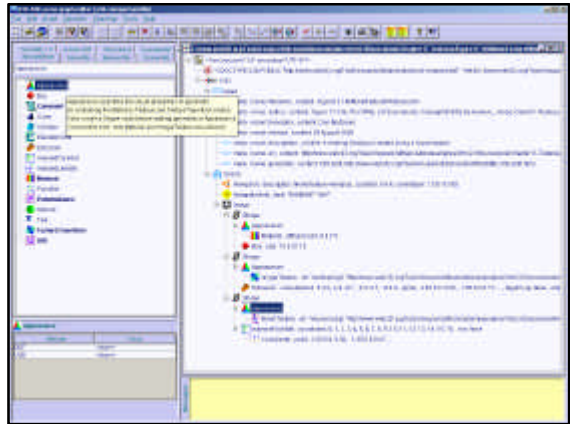
- X3D scene-graph files, converts to VRML 97


Tooltips for nodes and attributes

- Context-sensitive hints for every node, field
- Multilingual versions available, growing

~ 1700 example scenes available

- Non-CS students able to learn authoring without programming






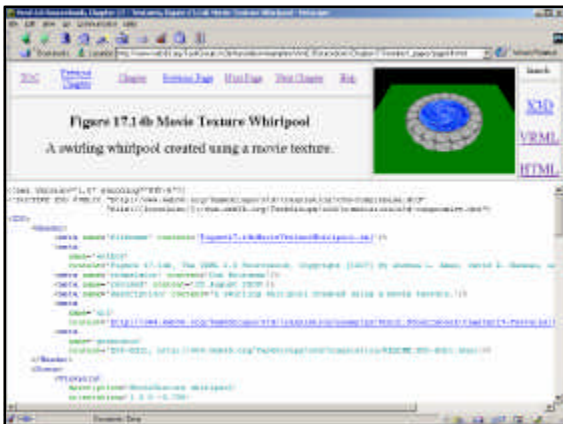
Reference: VRML

Ames, Andrea L., Nadeau, David R. and Moreland, John L., VRML 2.0 Sourcebook, second edition, John Wiley and Sons Inc., New York, 1997.

- Essential reference for using VRML
- includes CD-ROM
- SIGGRAPH course notes

<http://www.wiley.com/compbooks/vrml2sbk/cover/cover.htm>









X3D upgrade in progress, with help from Jeff Weekley





Pedagogical lessons learned

- VRML/X3D is an excellent language for teaching beginning and intermediate 3D graphics concepts
- Frequent project demos benefit students, visitors and sponsors
- Modeling the real world makes abstract geometric and rendering concepts more intuitive
- Documented examples by prior students provide a rapid boost to new students
- Learning goes way up when students are directly involved producing an exciting project
- Web publication attracts new students from other fields interested in applying 3D as a tool



Two gating factors for ubiquitous 3D graphics

Hardware acceleration

- Solved ☺

Content interchange

- Authoring is hard, "content is king"
- Provide greatest common factor for any, all 3D

Solution set: X3D and the Web



Contact

Don Brutzman

brutzman@nps.navy.mil
http://web.nps.navy.mil/~brutzman

Code UW/Br, Naval Postgraduate School
Monterey California 93943-5000 USA
1.831.656.2149 voice
1.831.656.3679 fax