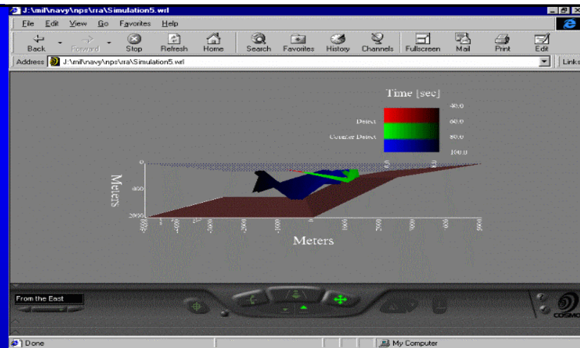
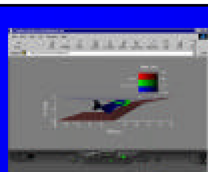


Shallow Water Sonar Propagation & Visualization

LT Tim Holliday

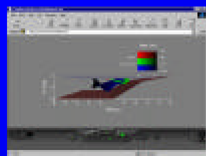
Thesis Advisor - Dr. Don Brutzman

Co-advisor - Dr. Kevin Smith



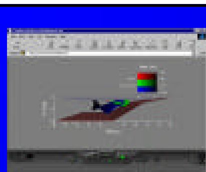
Outline

- Introduction
- Ray Acoustics
- Visualization
- Java and VRML
- Power of the Web
- Simulation Results
- Cool VRML Stuff
- Conclusions/Future Work



Introduction

- Phoenix AUV
- Artificial Intelligence
- Manta UUV
- Real Time Sonar Training
  - Personnel
  - Machine

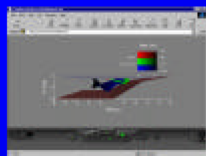


Ray Acoustics

- Derivation
  - Helmholtz Equation $\nabla^2 j(\mathbf{r}) + k_0^2 n^2(\mathbf{r}) j(\mathbf{r}) = 0$
  - Assumed Solution $j(\mathbf{r}) = a(\mathbf{r}) e^{-jk_0 W(\mathbf{r})}$
  - High Frequency approximation (>500Hz)
  - Differential Solution $\frac{¶}{¶ s} W(\mathbf{r}) = n(\mathbf{r})$
  - Difference Solution

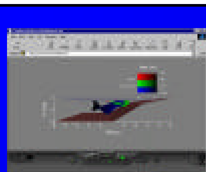
$$\hat{n}(\mathbf{r_f}) = \hat{n}(\mathbf{r}) \frac{c(\mathbf{r_f})}{c(\mathbf{r_o})} - (\mathbf{r_f} - \mathbf{r_o}) c(\mathbf{r_f}) \frac{1}{c^2(\mathbf{r}^*)} \nabla c(\mathbf{r}^*)$$

  - Transport Solution $I_o A_o = I_f A_f$



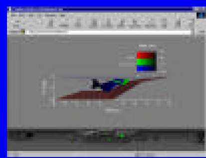
Visualization

- Static Visualization
  - See how sonar covers an area
  - Several different aspects in the same scene
- Dynamic Visualization
  - See the time dependence in action
- Interactive Visualization
  - Simulate searching an area in a virtual world



Java and VRML

- Why Java
  - Network oriented
  - Tight integration to VRML
  - As fast as compiled C++ code.
- Why VRML
  - Free
  - 3D capable
  - Easy to learn



Power of the Web

- Power of parallel computing
  - Loki Cluster
    - 1.4 GigaFlops for < $25,000
    - 2100 rays in real time
  - Even less if network already there
- Massive simulation capability
  - Many people interacting over the MBONE
  - Each one contributes a "Vehicle" to the scene

Simulation Results

Sound Speed Profile 5

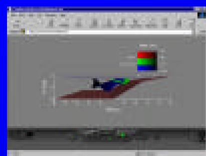
Method	y_0 (m)	β_0 (deg)	r (km)	y (m)	τ (s)	s (km)
FORTRAN	50	45	10.0	1760.21	9.604047	14.2771
Java	50	45	10.0	1758.87	9.604941	14.2781
FORTRAN	50	85	10.0	1595.33	6.806873	10.1264
Java	50	85	10.0	1596.28	6.807168	10.1266
FORTRAN	50	125	10.0	840.08	8.295966	12.3284
Java	50	125	10.0	839.14	8.296582	12.3290

Sound Speed Profile 5: Classic SSP

$c(y) = 1500\ m/s + (0.016/s)y$ $\quad 0 \le y < 100$ n

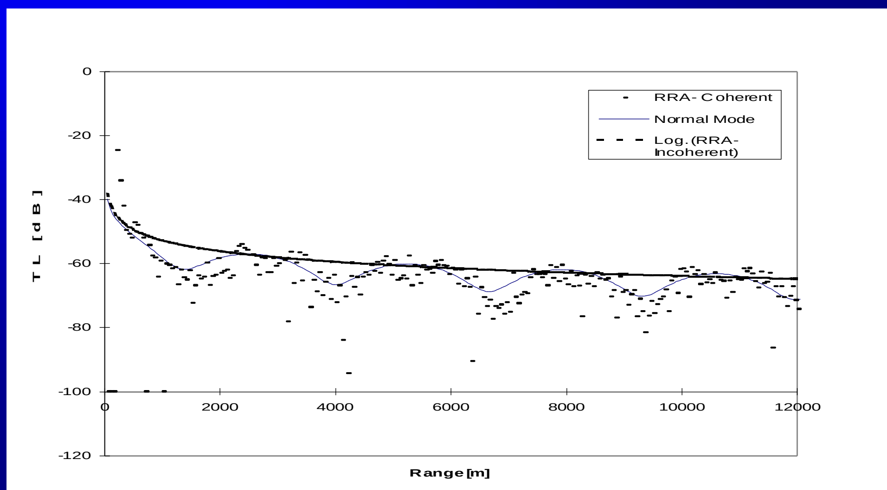
$c(y) = 1501.6m/s + (-0.02956/s)(y-100m)$ $\quad 100 \le y < 10$

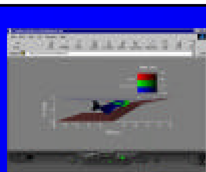
$c(y) = 1475m/s + (0.017/s)(y-1000m)$ $\quad y > 1000$ m



Simulation Results

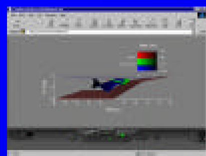
Ray Theory





Cool VRML Stuff

- Sonar Ray Trace
- Sonar Beam Trace
  - Static
  - Dynamic
  - Experimental
- Sonar Lobe Trace
  - Static
  - Dynamic



Conclusions/Future Work

- Conclusions
  - 3D can enhance perception of information
  - 3D will likely be an important tool
  - Real-time sonar simulation is possible
  - Ray tracing is not the only possible algorithm
- Future Work
  - Enhancements to ray and visualization models
  - 3D target localization
  - Take the fleet out of flatland