IT & Comm Services

The NASA Augmented/Virtual Reality Lab

The State of the Art at KSC

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Background

KENNEDY SPACE CENTER

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Spaceport Innovators

- Begun in 2012
  - Created KSC Innovation Expo
    - Annual event designed to showcase innovative work being done at KSC
  - KSC Kickstart Competition
    - 90 second elevator speech to panel of judges
    - Winners receive up to $5000 to develop their ideas

Virtual Control Panel

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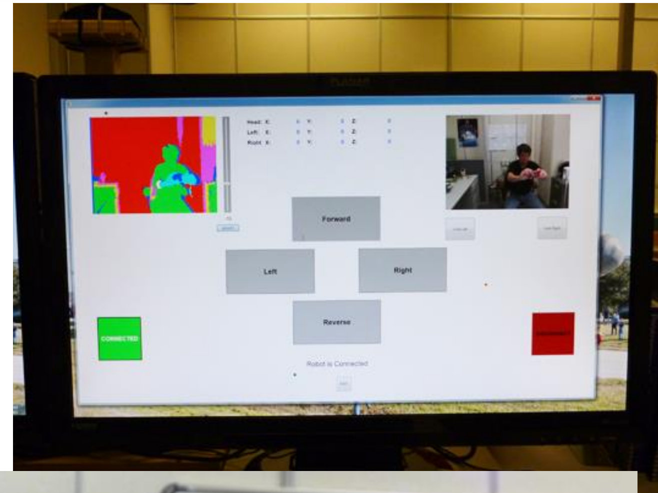
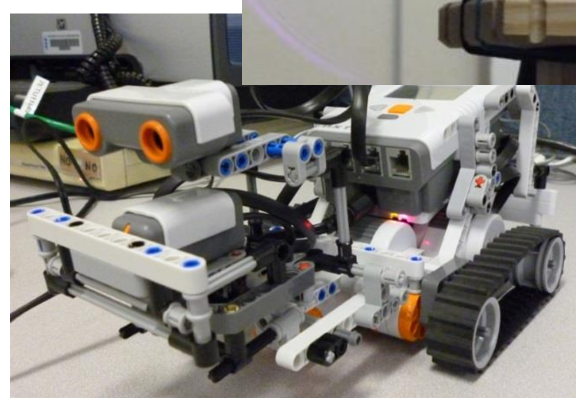
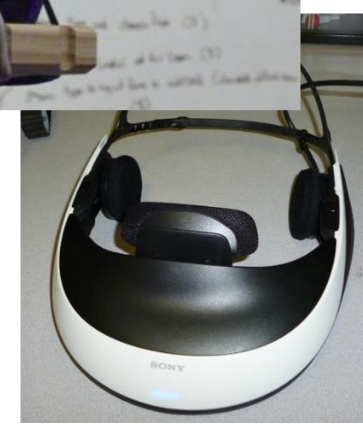
- Goals
  - Interact with a virtual environment
  - Use interactions to affect the state of physical objects in the “real” world
- Tools
  - Microsoft Kinect
  - Sony HMZ-T1
  - Lego Mindstorm
  - Custom desktop

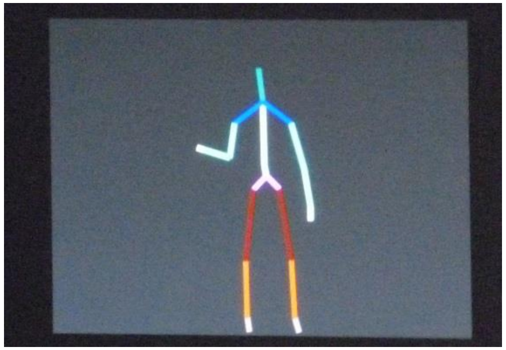


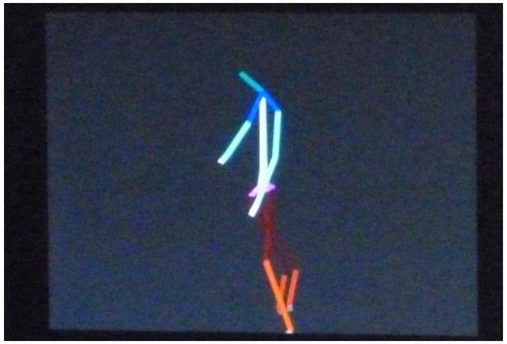




Virtual Control Panel

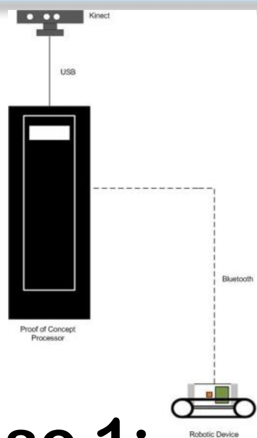
Results
- HMD issues
- Kinect
  - Weaknesses
    - Joint occlusion
    - Bone length
    - Jitter
  - Lack of fidelity (too few points)
- Mindstorm
  - Unreliable response to Bluetooth signals



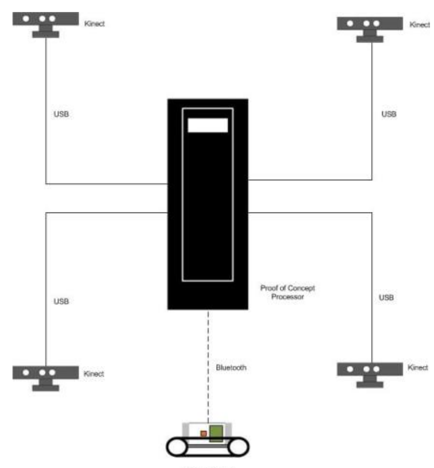


Fixes
- Replace HMZ-T1 with Oculus Rift DK2
- Introduce multiple Kinects, dedicated processors

Virtual Control Panel

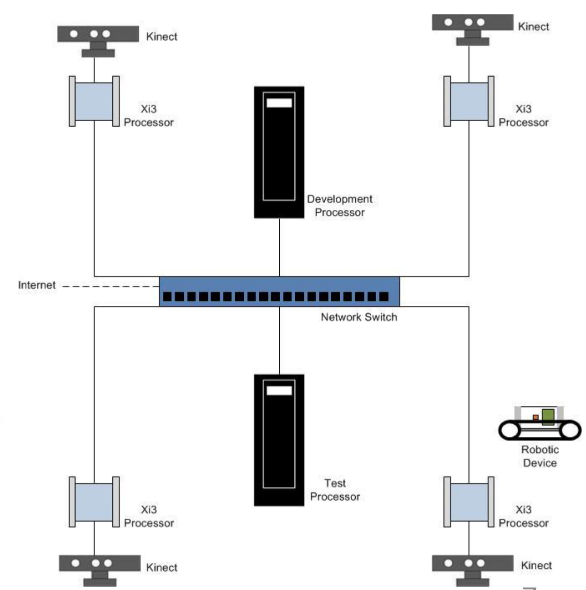


Phase 1: Single process or, single Kinect



Phase 2: Single processor, multiple Kinects

Phase 3: Multiple processors networked together, multiple Kinects



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Virtual Control Panel (cont'd.)

Problem:

- **Resolving multiple Kinect data streams of "skeleton" points into one reliable skeleton is mathematically, and therefore computationally, intensive, which adds latency.**
- **The requirement for a distributed system using multiple processors and networking increases the complexity of the system while reducing the latency problem.**

Note that, in the computation of each frame, the optimized joint-positions obtained in previous frames are used as the initial value of $\mathbf{X}$. Using the sequential linearly constrained programming, the second derivatives of the constraint are neglected. The equation $\nabla J^2(\mathbf{X})\mathbf{d} = -\nabla J(\mathbf{X})$ to be solved in each step is simplified to

$$\begin{pmatrix} H & \Lambda^T \\ \Lambda & 0 \end{pmatrix} \begin{pmatrix} \mathbf{d}_p \\ \lambda \end{pmatrix} = \begin{pmatrix} \mathbf{b}_p \\ b_\lambda \end{pmatrix} \tag{3}$$

with $\{\mathbf{p}_i^*\}_{new} = \{\mathbf{p}_i^*\} + \mathbf{d}_p$. Here, the vectors Λ and $\mathbf{b}_p$ are

$$\Lambda = \{\frac{\partial}{\partial \mathbf{p}_i^*} \sum_{\{i,j\} \in S_A} (\|\mathbf{p}_i^* - \mathbf{p}_j^*\| - l_{i,j})^2\} \tag{4}$$

$$\mathbf{b}_p = -\{\frac{\partial}{\partial \mathbf{p}_i^*} \sum_{i \in S_A} w_i^A \|\mathbf{p}_i^* - \mathbf{p}_i\|^2 + w_i^B \|\mathbf{p}_i^* - (\mathbf{R}\mathbf{q}_i + \mathbf{t})\|^2\} \tag{5}$$

and the value of b_λ is

$$b_\lambda = -\sum_{\{i,j\} \in S_A} (\|\mathbf{p}_i^* - \mathbf{p}_j^*\| - l_{i,j})^2. \tag{6}$$

H is a diagonal matrix $H = diag\{h_i\}$ that has

$$h_i = \frac{\partial^2}{\partial \mathbf{p}_i^{*2}} (w_i^A \|\mathbf{p}_i^* - \mathbf{p}_i\|^2 + w_i^B \|\mathbf{p}_i^* - (\mathbf{R}\mathbf{q}_i + \mathbf{t})\|^2). \tag{7}$$

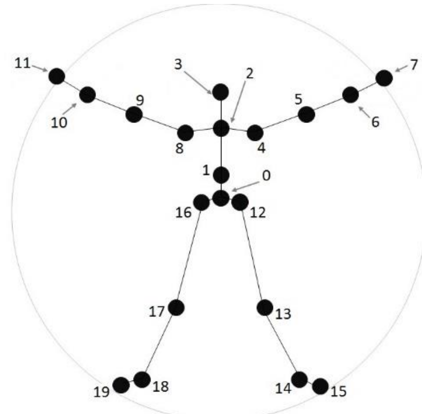
Efficient Numerical Scheme: By the above formulation, when applying the iterations to find optimal value of $\{\mathbf{p}_i^*\}$, we can actually determine the value of $\mathbf{d}_p$ in a more direct way (i.e., without applying the general numerical solver). Specifically, the value of λ can be computed by

$$\lambda = (\Lambda H^{-1} \mathbf{b}_p - b_\lambda)/(\Lambda H^{-1} \Lambda^T) \tag{8}$$

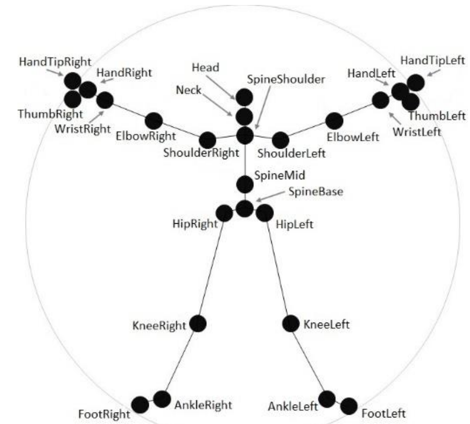
Virtual Control Panel (cont'd.)

Resolution

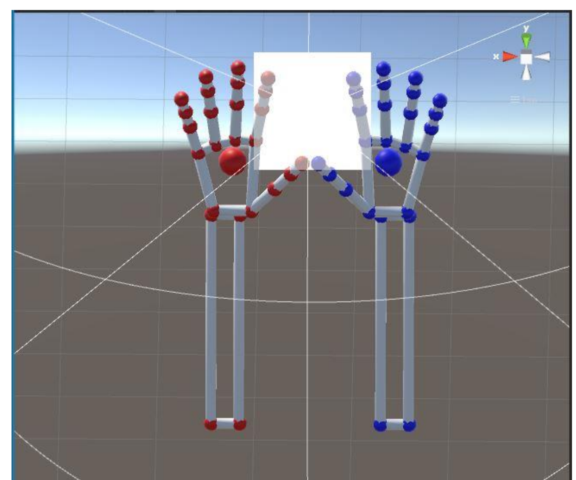
- Leap Motion
  - Same technology as the Kinect, but is specific to the hands and fingers
  - More interested in location, orientation of hands and fingers than with the whole body



Kinect V.1



Kinect V.2



Virtual Tablet

Goals

- Integrate VR and motion capture technologies
- Introduce haptic feedback to the virtual environment without using feedback devices

Tools

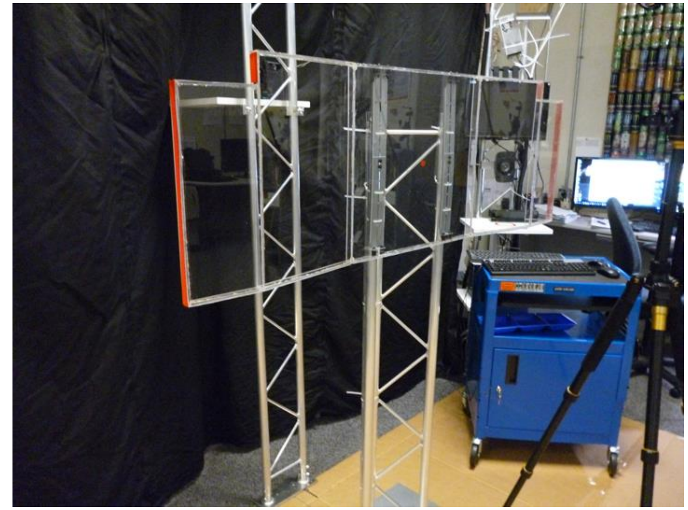
- Leap Motion
- Optitrack Motion Capture system
- Unity3D

Orion Virtual Cockpit

NASA's Space Launch System, under development now, is currently scheduled to launch once to twice per year.

Goals

- Trainer
  - Keep technical personnel skills up to speed
- Troubleshooting Platform
  - Evaluate problems, develop fixes without requiring a physical CM
- Testbed



Immersive Virtual Telepresence

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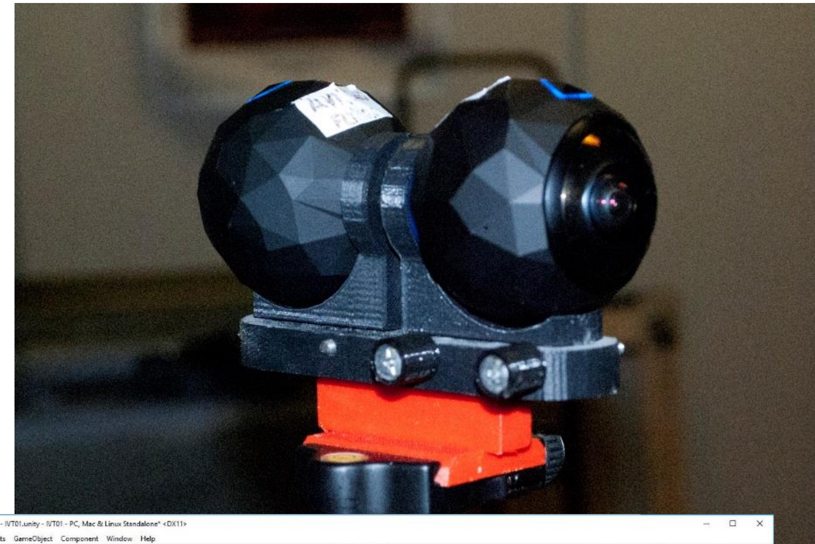
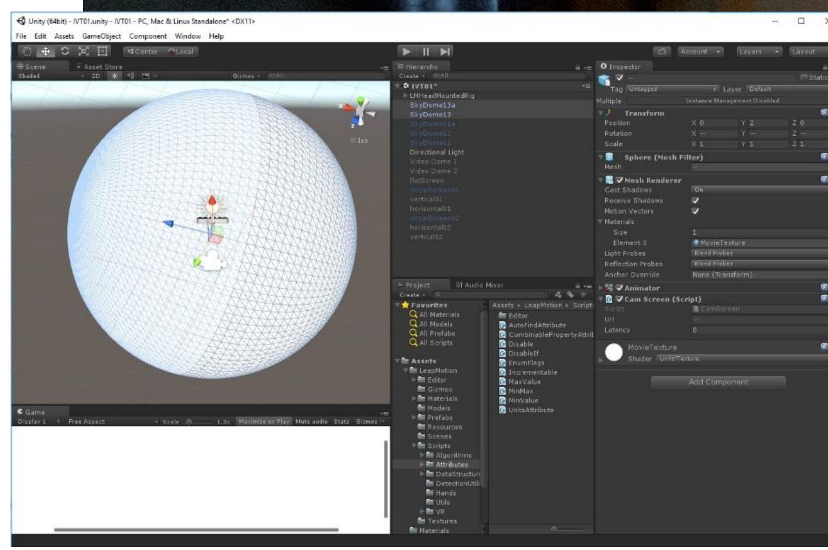
Goals

- Build a full 360^0 virtual environment using 360Fly cameras

Tools

- 360Fly cameras
- HTC Vive

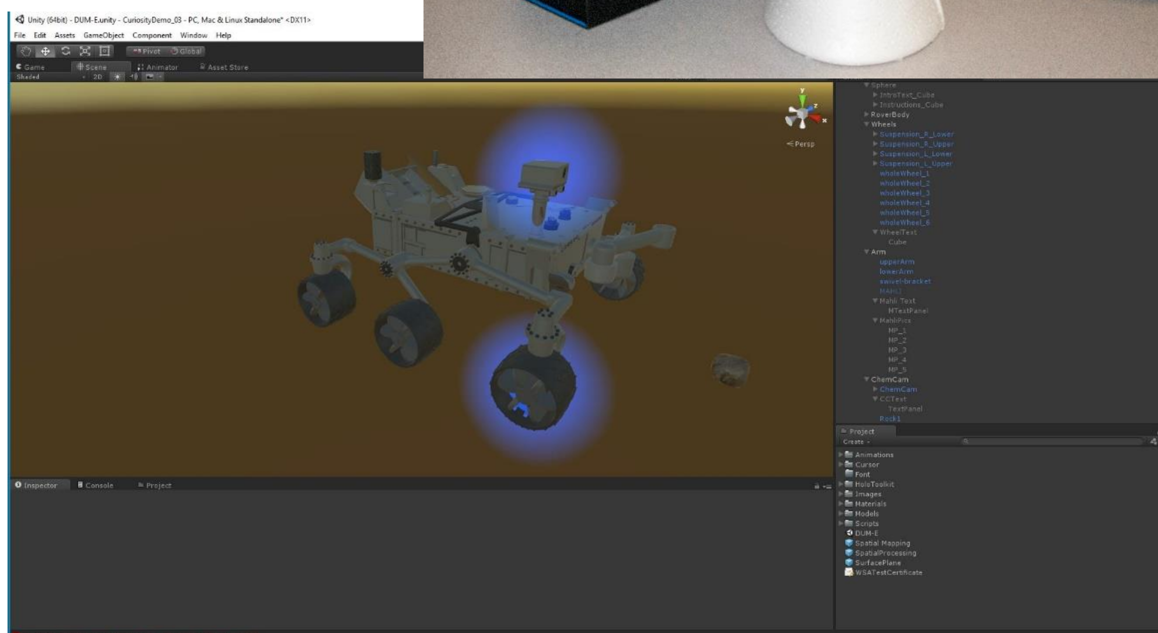




Holographic Rovers

Goals
- Evaluate the Microsoft Hololens as a potential tool for engineering, training, collaboration

Result
- Holographic Rovers
  - Intern project to work with device, learn its strengths, weaknesses



Next Steps

Natural User Interface

- Computer Vision
- Speech Recognition and Synthesis
- Artificial Intelligence

Conclusions

- AR/VR technology is the next wave of the computer revolution
  - Traditional forms of HCI are on their way out

HOWEVER

- The current maturity level of the tools in use is still too low to allow them to be used in operational scenarios as envisioned here
  - That will change rapidly