Chao Wang

Building Scalable Networked Virtual Worlds
Outline

- Definition
- Applications
- History
- Challenge
- Results
Definition

“A synchronous, persistent network of people, represented as avatars, facilitated by networked computers.”

– Mark W. Bell, Indiana University

Applications

- Entertainment
- Education
- Organizational Presence
- Planning
- Rehearsal

A Brief History of Virtual Worlds

Maze War (1974)

http://www.digibarn.com/collections/games/xerox-maze-war/maze-war.jpg
A Brief History of Virtual Worlds

Avatar Conf (1998)

http://www.digibarn.com/collections/games/xerox-maze-war/maze-war.jpg


A Brief History of Virtual Worlds


http://www.edutopia.org/blog/second-life-professional-development-alina-padilla-miller
Consistency - Everyone should perceive the same world

... hard to achieve consistency as the world scales up (limited link bandwidth)

Partitioning a Virtual World

- Location-based partitioning \[^1\][^2]\n- Population-based partitioning \[^3]\n
Population-Based Partitioning

- Managed by a set of partitioning servers
- Each server caches the upper tree
  - Leaf stores the domain name of the server that maintains a lower tree

<table>
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<tr>
<th>Depth:</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>20</th>
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</thead>
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<td>World Pop</td>
<td>6.0</td>
<td>40.0</td>
<td>238.0</td>
<td>966.0</td>
<td>4642.0</td>
<td>22,140.0</td>
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<td>Zipf</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>1240.4</td>
<td>290,000.0</td>
</tr>
</tbody>
</table>

Table 1: Number of changes in the partitioning service’s upper tree with different choices of cut depth.

Coordinate / Object Segmentation Services

- Coordinate service
- Arbitrary space server
- Space server K
- Object service
- CDN
- Avatar
- Other space servers

Determining Visible Objects

- Distance-based
- Visual perspective [1]

Object Classification

- **Mutable objects**
  - Accounts for most of objects in a virtual world
  - Infrequent update (e.g., query-based)

- **Dynamic objects**
  - Accounts for avatars
  - Frequent update (e.g., object sends updates)
Updating Dynamic Objects

- Frequent updates from avatars of interest
  - Proximity
  - Aim
  - Recent Interaction

- Less updates from other avatars
  - May be replaced with computer-controlled bots

Message Forwarding

- **Server-based** [1]
  - The allocated capacity for each object pair is proportional to the geometric size and decays with distance

- **Peer-managed** [2]
  - Pre-allocate bandwidth
  - Use forwarding pool

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Peer-Managed Forwarding

- Membership of a forwarding pool
  - Latency threshold (Tl)
  - Rate limit threshold (Tr)

- Capacity Advertisement
  - Only advertise half of capacity

- Dynamic adjustment of Tr

Networked virtual worlds have abundant applications

Hard to achieve consistency in large-scale settings

May be achieved by exploiting geometric information and human cognition limit