From MMO to Virtual World Networking

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Virtual World

Partitioning and Consistency

Large, Immersive Environment

Real-time Interaction
PARTITIONING AND CONSISTENCY

A Typical Networked Game Model
Cell-based World Partition
E. Cheslack-Postava et. al., *A Scalable Server for 3D Metaverses*, ATC ‘12

LARGE, IMMERSIVE ENVIRONMENT
The Case of Second Life

• Partition the world into 256m x 256m regions
  – Static region-to-server mapping
• Distance-based discovery
  – Visible range < 100m
  – Object detection range < 15m
• Broadcast communications
  – Within 10, 20, or 100m
Sirikata

Sirikata: an open-source platform for scalable virtual worlds.

http://www.sirikata.com/blog/
World Partitioning in Sirikata

- Use split-axis kd-tree
- Upper tree is very stable

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

<table>
<thead>
<tr>
<th>Depth:</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<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>
</tr>
<tr>
<td>Zipf</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>1240.4</td>
<td>290,000.0</td>
</tr>
</tbody>
</table>

http://www.csie.ntnu.edu.tw/~u91029/PointInterval.html
Object Discoveries in Sirikata

- Identify large, distant objects as well as groups of small objects
- Visual perspective

(a) Planar angle
(b) Solid angle
Object Discoveries in Sirikata (cont.)

• Object aggregation (LBVH)
(c) Ideal (10,000 objects)
(a) Distance (3,000 objects)
(b) Sirikata (3,000 objects)
REAL-TIME INTERACTION

A. Bharambe et. al., Donnybrook: Enabling Large-Scale, High-Speed, Peer-to-Peer Games, SIGCOMM ‘08
First-Person Shooter (FPS)

http://www.gratisjuegos.org/descargar/quake-3-team-arena-full-ingles-ul/

Quake 3 gameplay (1:13) http://www.youtube.com/watch?v=vaVhcnBiob0
FPS Facts

• Usually more than 20 frames per second
  – Less than 10 => unacceptable

• 196 bytes packet in Quake 3
  – 32 bytes if using delta coding
  – 36 bytes if using 2-frame delta coding
Interest Set

• “A human can only focus on a constant number of objects at once.”
  – “Send updates only to those who are interested in him,” once per frame

\[
A_{ij} = \sum_{k=1}^{3} w_k I_{ij}^{(k)}
\]

\[
I_{ij}^{(1)} = \max\{(1 - \text{dist}(i, j)/D_{\text{max}})^{1.5}, 0\}
\]

\[
I_{ij}^{(2)} = \max\{(1 - \hat{a}_{ij}/45^\circ)^{1.5}\cdot\log(\text{dist}(i,j)), 0\}
\]

\[
I_{ij}^{(3)} = \begin{cases} 
  e^{-t_{ij}/1 \text{ sec}} & \text{if } t_{ij} \leq 3 \text{ sec} \\
  0 & \text{otherwise}
\end{cases}
\]
Doppelgangers

• For those who aren’t interested in him, the player can be rendered at a lower fidelity
• Replace a player by a doppelganger (a guided bot) to maintain smooth, reasonable appearance
• Each player sends guidance packet once per second
Disseminating Updates/Guidance

• Two issues
  – Not every player has enough bandwidth
  – Some players may draw particular attentions

• Each client reserves 200 kbps for sending updates

• Seek help from a forwarding pool (source creates a probabilistic forwarding tree)
Forwarding Pool

• Membership
  – Average latency
  – Rate limit (minus 200 kbps)

• Advertisement
  – Include a byte in each guidance packet
  – Only advertise half of its available bandwidth
    • Source may choose multiple forwarders
    • Reduce queuing delay
Implementation and Evaluation

• ~4,000 lines of code for interest sets, guidance, and doppelgangers
• ~6,000 lines to change Quake 3 from a client-server to a p2p game
• Invite pairs of volunteers to play Quake 3; blind test on pairs of network settings:
  – LoBW: rate limit = 108 kbps
  – LoBW-IS: same as above, and include interest set
  – HiBW: no rate limits
Figure 3: Total time players spend on each version. Error bars show 95% confidence intervals.
Figure 4: Average response to question, “How fun was this game on a scale of 1 (not fun) to 10 (extremely fun)?” Error bars show 95% confidence intervals.
Figure 8: Maximum scale achievable by Donnybrook with various capacity distributions, compared to idealized models: Standard (no interest sets) and NoGF (no guidance forwarding)
Results (cont.)

Figure 16: Performance as a function of interest set size for various capacity distributions and player counts. Error bars show 95% confidence intervals.
Recap

• Three Aspects of Virtual World
  – Partitioning and consistency
  – Large, immersive environment
  – Real-time interaction
State-of-the-Art MMOFPS

(1:09) https://www.youtube.com/watch?feature=player_embedded&v=Fb90FBlfPBA#!
References

  http://www.inf.ufpr.br/aldri/disc/TSD/2012/2012_TSD_Apre_Artigos/Gustavo_01_SRDS11_Transaction.pdf
• [3] A. Bharambe et. al., Donnybrook: Enabling Large-Scale, High-Speed, Peer-to-Peer Games, SIGCOMM ‘08
• [7] OMF (Open Metaverse Foundation) http://openmetaverse.org/
• [8] Quake 3 gameplay http://www.youtube.com/watch?v=vaVhcnBiob0