Multimedia Service Design (448430) Spring 2009 Midterm Exam – April 20th, 2009

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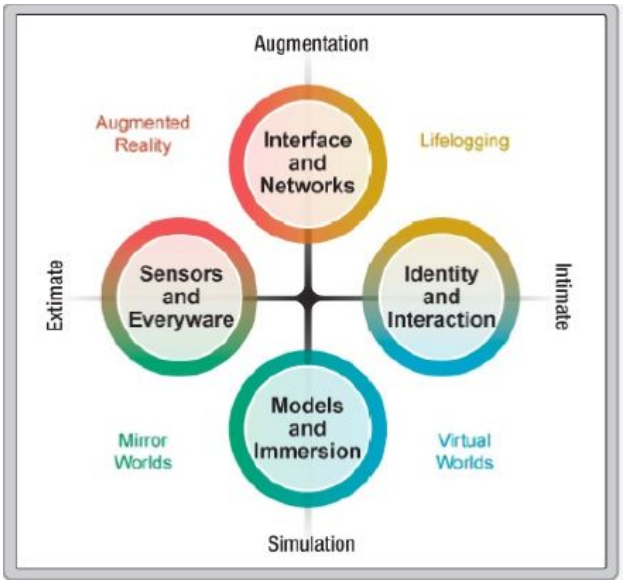
Major _____ Identification# _____ Name _____

1. What is the definition of Metaverse? Describes the characteristics of the following Metaverse scenarios: virtual worlds, mirror worlds, augmented reality, lifelogging. (extra 10 points)



Metaverse is is a virtual world, described in Neal Stephenson's 1992 science fiction novel *Snow Crash*, where humans, as avatars, interact with each other and software agents, in a three-dimensional space that uses the metaphor of the real world. The word *metaverse* is a portmanteau of the words "meta" and "universe". (wikipedia)

Augmentation – technologies that add new capabilities to existing real systems; in the Metaverse context, this means technologies that layer new control systems and information onto our perception of the physical environment

Simulation – technolgies that model reality, offering wholly new environments; in the Metaverse context, this means technologies that provide simulated worlds as the locus for interaction

Intimate – focused on the identity and actions of the individual or object; in the Metaverse context, this means technologies where the user (or semi-intelligent object) has agency in the environment, either through the use of an avatar or through direct appearance as an actor in the system

External – focused outwardly, towards the world at large; in the Metaverse context, this means technologies that provide information about and control of the world around the user

Virtual Worlds (intimate/simulation) – a key component of the virtual worlds scenario is one's avatar, the user's personification in the virtual worlds. E.g. second life

Mirror Worlds (external/simulation) – mirror worlds are informationally-enhanced virtual models or reflections of the physical world. E.g. Google Earth, Amazon's Block View, ArcGIS

Augmented Reality (external/augmentation) – enhance the external physical world for the individual, through the use of location-aware systems and interfaces that process and layer networked information on top of our everyday perception of the world. E.g. Location-tagging, location-based game, context-aware advertising

Lifelogging (intimate/augmentation) – In lifelogging, augmentation technologies record and report the intimate states and life histories of objects and users, in support of object- and self-memory. E.g. Object Lifelogs (spimes, blojects, etc), User Lifelogs (life-caching, documented lives, etc) E.g. Nike+ iPod (running statistics daily to the Nike Plus community)

2. A networked virtual environment (NVE) is defined as 'a software system in which multiple users interact with each other in real-time, even though those users may be physically located around the world.' Describe the following NVE features: a shared sense of space, presence, time, communication, and share. (10 points)

A shared sense of space:

Illusion of being located in the same place
Same characteristics for all participants
Time of day, weather, acoustics, haptics

A shared sense of presence:

A participant has a virtual persona, an avatar
Entering and leaving is visible for other participants

All participants do not have to be human-controlled

A shared sense of time:

See other participants' actions when they occur

Enables real-time interaction

A way to communicate:

By gesture, by typed text, by voice

A way to share:

Interact realistically not only with each other but also with the virtual environment itself

3. The core of the DIS network software architecture is the protocol data unit (PDU). Describes PDU (how they are used in distributed simulators) and some example of PDU. (10 points).

Protocol Data Unit (PDU):

-The core of the DIS network software architecture is the protocol data unit (PDU). Determining when each vehicle (node) of the simulation should issue a PDU is the key to this architecture.

-The DIS (IEEE 1278) standard defines 27 different PDUs, only four of which (Entity State, Fire, Detonation, and Collision) are used by nodes to interact with the virtual environment.

-In fact, most DIS-compliant simulations only implement those four PDUs, either throwing away the other 23 PDUs without comment or issuing a brief error message indicating a non-supported PDU was received.

-A demonstration at the 1993 Interservice/Industry Training and Education Conference (I/ITSEC) showed that Entity State PDUs comprised 96% of the total DIS traffic.

-Remaining 4% distributed mainly amongst Transmitter (50%), Emission (39%), Fire (4%), and Detonation (4%).

Issuing Protocol Data Unit (PDU):

-The vehicle's node is responsible of issuing PDUs

-entity state PDU

-when position, orientation, velocity changes sufficiently (i.e., others cannot accurately predict the position any more)

-as a heartbeat if the time threshold (5 seconds) is reached after the last entity state PDU

-fire PDU

-detonation PDU

-a fired projectile explodes

-node's vehicle has died (death self-determination)

-collision PDU

-vehicle has collided with something

-detection is left up to the individual node

Receiving Protocol Data Unit (PDU):

-The recipient is responsible for

-receiving the PDU

-changing the appropriate state tables

-updating the display

-entity state PDU

-update the other-vehicle state table

-fire PDU

-create a new vehicle

-detonation PDU

-compute the effects

-change the other-vehicle and own-vehicle state tables

-collision PDU

-process similarly

Loss Protocol Data Unit (PDU):

-Packets are sent via unreliable UDP broadcast

-State tables may differ among the hosts

-Lost detonation PDU

-Lost entity state PDU

-not a big problem

-larger jumps on the display

-Lost fire PDU

-receive entity state PDU for which no ghost entry exists

-Lost collision PDU

-continue to display a vehicle as live

-next heartbeat packet solves the situation

4. DIS used peer-to-peer heartbeat approach and dead reckoning algorithm. What is the “heartbeat”? (10 points)

-Each user periodically sends a message called a ‘heartbeat’ informing everyone of its status.
-Usually every 5 seconds, to keep other players informed that a particular object is alive and still in the system (and hence should be displayed).
-Entities must have a “heartbeat” otherwise cannot distinguish between live entities and ones that have left the system.
-Helps recovery from lost messages (to help network reliability)
-Helps users who just joined

5. Explain the concept of ‘dead reckoning’ algorithm that is widely used in networked virtual environments. What are the advantages and limitations of this algorithm? (10 points).

-Objects only place packets onto the network when their home node determines that the other nodes on the network are no longer able to predict their state within a certain threshold amount.
-Transmit state updates less frequently by using past updates to estimate the true shared state.
-Prediction:

-How the object’s current state is computed based on previously received packets.

-Each host estimates entity locations based on past data.

-Convergence: How the object’s estimated state is corrected when another update is received.
-No need for central server.
-Sacrifices accuracy of shared state for more participants.

-Advantages:

- Reduces bandwidth requirements because updates are sent less

frequently.

- Potentially larger number of players.
- Each host does independent calculations

-Disadvantages:

- Not all hosts share the identical state about each entity.
- Protocols are more complex to implement to develop, maintain and evaluate.
- Must customize for object behavior to achieve best results.
- Must have convergence to cover prediction errors.
- Collision detection difficult to implement.
- Poor convergence methods lead to jerky movements and distract from immersion.

6. Describe the three convergence methods (snap convergence, linear convergence, spline convergence) to correct inexact prediction in dead-reckoning algorithm. (10 points)

-Convergence methods tells us what to do to correct an inexact prediction:
-Trade-off between computational complexity and perceived smoothness of displayed entities

Zero order or snap convergence:

-Advantage: Simple

-Disadvantage: Poorly models real world & "Jumping" entities may distract users.

Linear Convergence:

-Advantage: Avoids jumping

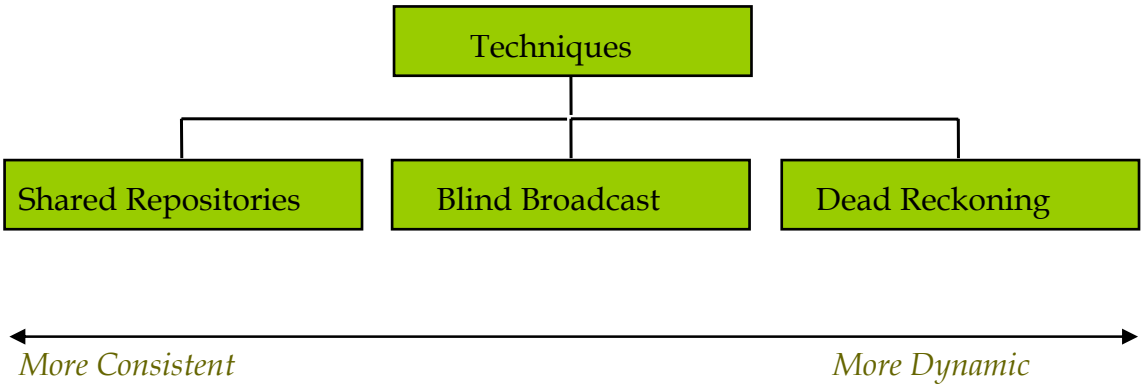
-Disadvantage: Does not prevent "sudden" or unrealistic changes in speed or direction.

Cubic Spline:

-Advantage: Smoothest looking convergence

-Disadvantage: Computationally expensive

7. Compare and Contrast the 'dead reckoning' with other dynamic shared state methods: shared repository and blind broadcasts. (10 points)



Centralized Shared Repositories:

- -Maintain shared state data in a centralized location.
- -Protect shared states via a lock manager to ensure ordered writes.
- -Advantage:
  - -Provides an easy programming model.
  - -Guarantees information consistency.
  - -No sense of data ownership is imposed; any host can update any piece of the shared state.
- -Disadvantage:
  - -Data access and update operations require an unpredictable amount of time to complete.
  - -Requires considerable communications overhead due to reliable data delivery.
  - -Vulnerable to single point failure.
  - -Push systems may send info where it is not needed.
  - -Limited number of users (else you overload the server or the network)
  - -One slow user can drag everyone down.

Blind Broadcast:

- -Owner of each state transmits the current value asynchronously and unreliably at regular intervals.
- -Clients cache the most recent update for each piece of the shared state.
- -Hopefully, frequent state update compensate for lost packets.

-No assumptions made on what information the other hosts have.
-Broadcast is sent “blind” to everyone.
-Usually the entire entity state is sent.
-No acknowledgements
-No assurances of delivery
-No ordering of updates.
-Advantage:
    -Simple to implement; requires no servers, consistency protocols or a lock manager (except for filter or shared items)
    -Can support a larger number of users at a higher frame rate and faster response time.
-Disadvantage:
    -Requires large amount of bandwidth.
    -Network latency impedes timely reception of updates and leads to incorrect decisions by remote hosts.
    -Network jitter impedes steady reception of updates leading to ‘jerky’ visual behavior.
    -Assumes everyone broadcasting as the same rate which may be noticeable to users if it is not the case (this may be very noticeable between local users and distant destinations).

Dead Reckoning:
-Advantage:
    -Reduces bandwidth requirements because updates are sent less frequently.
    -Potentially larger number of players.
    -Each host does independent calculations
-Disadvantage:
    -Not all hosts share the identical state about each entity.
    -Protocols are more complex to implement to develop, maintain and evaluate.
    -Must customize for object behavior to achieve best results.
    -Must have convergence to cover prediction errors.
    -Collision detection difficult to implement.
    -Poor convergence methods lead to jerky movements and distract from immersion.

8. Describe the benefits and limitations of centralized, distributed, and hybrid network model used in networked virtual environments. (10 points)

Centralized:

-Client-server model

-Each player sends packets to other players via a server

-One computer (server) collects all data and sends updates to the users (clients)

-Simple structure, easy to maintain database (useful for compression & admin tasks)

-Not scalable, the central server is the bottleneck

Distributed:

-Peer-to-peer model

-Each user maintains its own copy of the database

-Updates are send to other users

-Difficult to manage the number of connections

-Not scalable, the network is the bottleneck

Hybrid:

-Multi-players client-server model with multiple servers

-Players can locate in the same place in the NVE, but reside on different servers

-Server-to-server connections transmit the world state information

-Each server serves a number of client players

-Scalability

9. Shortly explain the characteristics of TCP, UDP, IP Multicasting, and IP Broadcasting network protocol. Describes which network protocol should be used for NVE? (10 points)

Transmission Control Protocol (TCP)

-Most common protocol in use today

-Layered on top of IP referred to as TCP/IP

-Provides illusion of point to point connection to an application running on

another machine

-Each endpoint can regard a TCP/IP connection as a bi-directional stream of bytes between two endpoints

-Application can detect when other end of connection has gone away/disconnected

The User Datagram Protocol (UDP)

-A lightweight communication protocol

-Differs from TCP in three respects: connection-less transmission, best-efforts delivery, packet-based data semantics

-Does not establish peer-to-peer connections

-Many operating systems impose limits on how many simultaneous TCP/IP connections they can support.

-Operating system does not need to keep UDP connection information for every peer host, UDP/IP is more appropriate for large-scale distributed systems where each host communicates with many destinations simultaneously

-When a socket is receiving data on a UDP port, it will receive packets sent to it by any host, whether it is participating in the application or not

-This possibility can represent a security problem for some applications that do not robustly distinguish between expected and unexpected packets

-For this reason, many network firewall administrators block UDP data from being sent to a protected host from outside the security perimeter

IP Broadcasting

-With UDP/IP, an application can direct a packet to be sent to one other application endpoint

-This approach has two disadvantages:

Excessive network bandwidth is required because the same packet is sent over the network multiple times

Each host must maintain an up-to-date list of all other application endpoints who are interested in its data

-UDP broadcasting provides a partial solution to these issues

-Allows a single transmission to be delivered to all applications on a network who are receiving on a particular port

-Useful for small NVE's

-Expensive because every host on network must receive and process every

broadcast packet

-Not used for large or internet based VE's (use IP Multicast)

IP Multicasting

-UDP broadcasting can only be used in a LAN environment

-Even if no application on that host is actually interested in receiving the packet each host on the LAN must: receive packet & process the packet

-Multicasting is the solution to both of these concerns

-Appropriate for Internet use, as well as LAN use

-Does not impose burdens on hosts that are not interested in receiving the multicast data

-239.255.255.255 are designated as multicast addresses

-The sender transmits data to a multicast IP address, and a subscriber receives the packet if it has explicitly joined that address

-Rapidly emerging as the recommended way to build large-scale NVEs over the Internet

-Provides desirable network efficiency

-Allows the NVE to partition different types of data by using multiple multicast addresses

-Using a well-known multicast address, NVE participants can announce their presence and learn about the presence of other participants

-Also an appropriate technique for discovering the availability of other NVE resources such as terrain servers

-However, although an increasing number of routers are multicast-capable, many older routers are still not capable of handling multicast subscriptions

10. What is scene graph? Explains some benefits of putting NVE world into a scene graph. (10 points)

-Scene graph tree is head by a top-level root node

-Right under the root node, group nodes organize geometry and the rendering state that controls their appearance

-Root and group nodes can have zero or more children

-Leaf nodes contain the actual geometry

Benefits of putting world into a scene graph:

-Grouping of related objects

-Co-movement of connected objects

-Better pruning of unseen objects (via bounding volumes): Leaf has a bounding volume & Grouping node has a bounding volume that encompasses all sub nodes

-Bounding volumes also serve to help with faster determination of intersections

-Features can be inherited: Color, Texturing, Lighting, Position

11. Suppose that you are designing a networked virtual environment to be placed in the 6th grade science classroom focused on geology and life on Mars. The students in the classroom can navigate Mars surface, collect Martian (and asteroids) rock properties, and visualize the collected data. Describe your system design with the consideration of NVE design challenges: distributed, real-time graphics, user interactivity. Highlight your important points. Justify your choices. (10 points)