How Virtual Reality is Transforming Scientific Research, Education and Knowledge Transfer

Walt Scacchi
Institute for Virtual Environments and Computer Games
University of California, Irvine
Irvine, CA 92697-3445
USA
The Virtual Reality Legacy

- Dreams and lucid dreaming
- Hallucinations: brain injury or psychoactive drug induced
- Physical, everyday socio-cultural worlds
- Physical fantasy worlds (Disneyland, *Burning Man*)
- Cyclorama and panorama venues
- Cinema, theater, concert and dome venues
- CAVE room, wall-based, or table-top
- Head-Mounted Displays, (audio, haptics?), PCs, mobile devices
- Symbolic worlds: literary, cosmological, musical, gustatory, etc.
The Virtual Reality Legacy

• What is a virtual reality?
  – Computer-mediated immersive presentation that encapsulates one or more senses that renders a virtual world for play, work, or learning activities
  – VR is:
    • *Embodied* as technological mechanisms
    • *Engaged and rendered* as interactive content
    • *Recognized* as immersive and present experience (*being there*)
  – VR is *not* one technology, content, or experience
VR as Technology

• VR system elements are configured to support:
  – *Individuals*: HMDs/sensory “displays,” PCs, mobile
  – *Small groups*: CAVE, table-top, or wall-mounted displays
  – *Large groups*: cycloramic or cinematic venues, domes, virtual meeting halls
  – *Decentralized groups*: people distributed in space and time
VR as Experience

- We can go beyond the epistemology of *immersion* and *presence* to enable more effective VR experiences via:
  - Verisimilitude
  - Task/knowledge focused virtual world design
  - Method of loci and virtual “memory palaces”
  - Knowledge transfer
Verisimilitude – how much is enough?

$500 vs. $5000 vs. $50,000 vs. $500,000 vs. $5,000,000
R&D Challenges for VR

• Areas of interest
  – Scientific Research
  – Training, Education and Learning
  – Knowledge Transfer
VR Challenges: Scientific Research

- **Cyber-Physical Sciences**
  - Computational Astrophysics
  - Quantum Physics, Nanotechnology, Robotics

- **Life Sciences**
  - Biology (Molecular to Ecological to Exobiological)
  - Neurosciences (Human Brain EU, US BRAIN Initiative)

- **Informatics, Computer Science, Engineering**
  - MMO infrastructures, generative content tools, VR world repositories, domain engines, rapid dev. methods, etc.
  - Integrating Big Data and Internet of Things into VR
    - Across multiple levels of details (10X-10^{20}X)
Virtual Worlds for Scientific Research: 
Meta Institute for Computational Astrophysics

But there are non-scalar forces — electromagnetism! (Gauge fields more generally)
Big difference: both positive and negative charges, attraction and repulsion.
Could DM be charged under a new unbroken U(1)?

“Dark electromagnetism,” carried by a “dark photon.”

At the black hole boundary (the event horizon), the gravitational force is infinite, and the time stops.

The Schwarzschild radius of a black hole is $r_{bh} = 2GM/c^2$.
For our Sun, it would be 3 km.
For the Earth, it would be 9 mm.

Intel’s ScienceSim, an OpenSim-based VW dedicated to science and research

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VR in Biology/Life Sciences?
Large Group Virtual Research Conference
Current Barriers to VR in Scientific Research

- Limiting use to video conferencing alternative
- Client/server software configuration and media control
- User avatars
  - Non-intuitive gesture control (digital puppetry?)
  - How (best) to interact with visualized data sets?
- Unclear scientific VR modeling and simulation capabilities and guidelines
  - Scientists often model/sim things not visible or imperceivable
- Not readily integrated with research publications, demonstrations, or proposals
  - No support for “scientific storytelling” or simulated science visualization machinima
Training, Education and Learning

- **Training** – enterprise or device centered and performance assessment
  - “Observe then do” functional activities

- **Education** – academic curriculum and knowledge assessment by teachers to students
  - Show and tell *versus* interactive constructive engagement

- **Learning** – intrinsic motivation, complementary accretion, integration, and restructuring of new information by student/learner
  - Based on what you already know, want to know or experience, how you are engaging the new information, and discovery moments.
DinoQuest Online: Game-Based Virtual World for Informal Life Science Education

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**FabLab**: Semiconductor/nanotechnology fabrication operations and diagnostics training game world
DECENT: Virtual world for experimentation in decentralized command and control
VR advancing Education to accelerate 21\textsuperscript{st} Century learning

- Model, visualize, simulate, query structures, processes, and relationships (static or dynamic) within a \textit{domain} of study, work, or play
  - Domains are worlds that can be modeled, designed, animated/simulated, and adapted.
  - Domains enable their own “reality”
    - \textit{Configured universe} of actors, objects, attributes, relationships, rules, events, methods, constraints, etc.
    - A \textit{logic of action} (computational epistemology).
    - Actor perceptions, interactions, and interpretations produce local reality.
Planetary science data visualization and “spherecasting” support: NOAA Science on a Sphere installation in Opensim VW platform

Supporting virtual planetary exploration and near-earth objects (space debris, small satellites, near-earth asteroids)
• Interactive social multi-media ecology
  - Affordances
    • Facebook walls, Twitter tweets, geotagged pins, etc.
  - Socialization interactions
    • Interacting with friends, and others (via role playing avatars)
  - Mediated discourses (scaffolded writing/authoring)
    • Description (historic retelling; visual + aural storytelling)
      - Capturing images, sounds (sonifications), hyperlinks to render navigational stories
    • Proscription (potential actions to take)
      - Explaining what to do to someone else (“explanation-based learning”)
VR advancing Education to accelerate 21st Century learning

- VR classroom designs (not limited to classroom physics)
  - immersive learning worlds (activity laboratory labyrinth)
- Personal, self-representing, “protean” avatar
  - Taller, fitter, better dressed, culturally authentic voice
- Attention management and gaze engagement
  - Highlighted objects, links, animations, queries, puzzles
  - Students sits in the “golden seat” in virtual classroom
  - Teacher avatar eye gaze directed at student
- Role play and role reversal (student as anyone else)
Knowledge Transfer (KT)

- Building from Training, Education, and Learning
- KT modes
  - *Reaplication, repetition, and refinement*
    - practice, rehearsal, self-reflection, external feedback
  - *Reuse and adaptation* in new domain
    - generalization, analogizing and specialization
  - *Extension, composition, and (re)configuration* across domains
    - innovation, creativity
KT example: game-based production system for material transfer process

Put the soccer ball inside the box.
KT: create a game for decentralized virtual manufacturing system
KT for natural resource management:
Regional Water Quality Game Environment
Opportunity: develop reusable framework for developing interactive “science missions” for industry and public

Sample project: Capture Near-Earth Asteroid
KT R&D Challenges for VR

- **Science world engines** – worlds that can model and simulate current scientific phenomena
  - Electromagnetism (nano to macro)
  - Molecular chemistry and biochemistry
  - Dynamic human physiological systems
- **World development kits**
  - Prefabricated worlds open to user modification
  - Procedural world prototyping/generation framework
  - Executable narratives/scenarios and storytelling kits
Summary: VR Applications and Capabilities

- Group presentation, communication, and social interaction
- Training, education, rehearsal, learning
- Prototype and review of virtual objects, composite systems, etc.
- New commercial product or service demonstration
- Identity role-playing, team building, and other group processes
- Multi-media scenarios, storytelling and *machinima* production
- Avatar design, control and choreography
- Mirrored worlds and memorialization
- Envisioning future business processes
- Semi-automated discovery of in-world socio-technical processes
- Enabling human behavior transformation (health care)
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