Welcome. My name is Jason Jerald, Co-Founder & Principal Consultant at Next Gen Interactions

I'm here today to talk about the human side of VR Interactions. For the technology is only part of the equation- with no human there is no VR!

What makes me qualified to speak at this awesome conference?

- 20 years of VR experience on over 60 projects with over 30 organizations ranging from academics to startups to Fortune 500 Companies.
- What I've learned is that every VR project is different. There are few absolute truths when it comes to VR. But theory, processes, and guidelines can be useful.

The VR Book: Human-Centered Dessign for Virtual Reality

- 600 pages of VR goodness. Lots of theory & application, hundreds of guidelines, references, and definitions.

This talk is based on the interactive design parts of this book.

Outline

1. Some basic theory
2. Input devices
3. Interaction patterns and techniques
4. Iteration

Reality Tradeoffs

- Representational fidelity
- Experiential fidelity
- Interaction fidelity
  - Realistic vs Nonrealistic
    - Buttons
    - Speech recognition
    - Lasers
  - Magic

One way to think about VR design is in terms of fidelity continua

These questions help to think about what you trying to create.

Representational fidelity – the degree to which the VR experience conveys a place that is, or could be, on Earth.

- Not necessarily the goal—abstract relaxing worlds of color blobs has low representational fidelity

Experiential fidelity- the degree to which the user's personal experience matches the creators intent. Free-roaming social virtual worlds have low experiential fidelity.

Interaction fidelity – the degree to which physical reality for a virtual task matches the equivalent real world task.

- Magical techniques (e.g., superhuman powers) lie somewhere between realistic and nonrealistic interactions

The point of here is that your VR design heavily depends on what you are trying to do.

Norman's Principles of Interaction Design

- Affordances
- Signifiers
- Constraints
- Feedback
- Mappings

From Norman [2013]

Norman's Principles of Interaction Design from the book the Design of Everyday Things

- Turns out these concepts are extremely important for VR design
- Affordances are misunderstood by most everyone
- Because of that confusion, I'm going to focus on affordances and signifiers.

Affordances are **NOT** Signifiers

Affordances are not signifiers!

- I've heard several people talking about affordances without defining what affordance are resulting in misuse of the term.
- To be fair, everybody gets this wrong.
- I highly encourage you to revisit how Norman clearly distinguishes between affordances and signifiers in his 2013 version of The Design of Everyday Things.

Affordances

- Define what actions are possible and how something can be interacted with by a type of user.
- Not a property but a relationship between the capabilities of the user and the properties of a thing.
- Interface elements afford interaction.
- A virtual hand affords selection
- Different users might have different affordances.

Signifiers

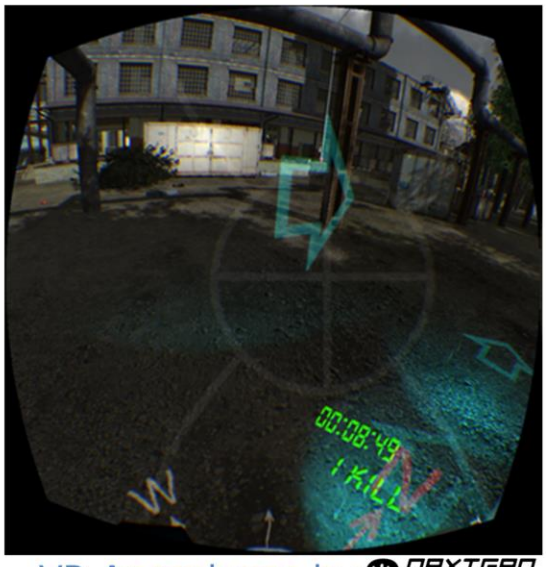
- A signifier is a cue or clue to how an object is expected to

behave.

- Affordances are the relationship between an object and the user
- Any perceivable indicator that communicates appropriate purpose., structure, operation, and behavior of an object to a user.
- Some affordances are perceivable and some are not
    - Create good signifiers to make affordances obvious before interaction occurs.
- Signs, labels, arrows, handle on a door, feel of a button on a controller.

Reference Frames

- Head
- Eyes
- Hands
- Torso
- Real World
- Virtual World



VR Apocalypse by NextGen Interactions

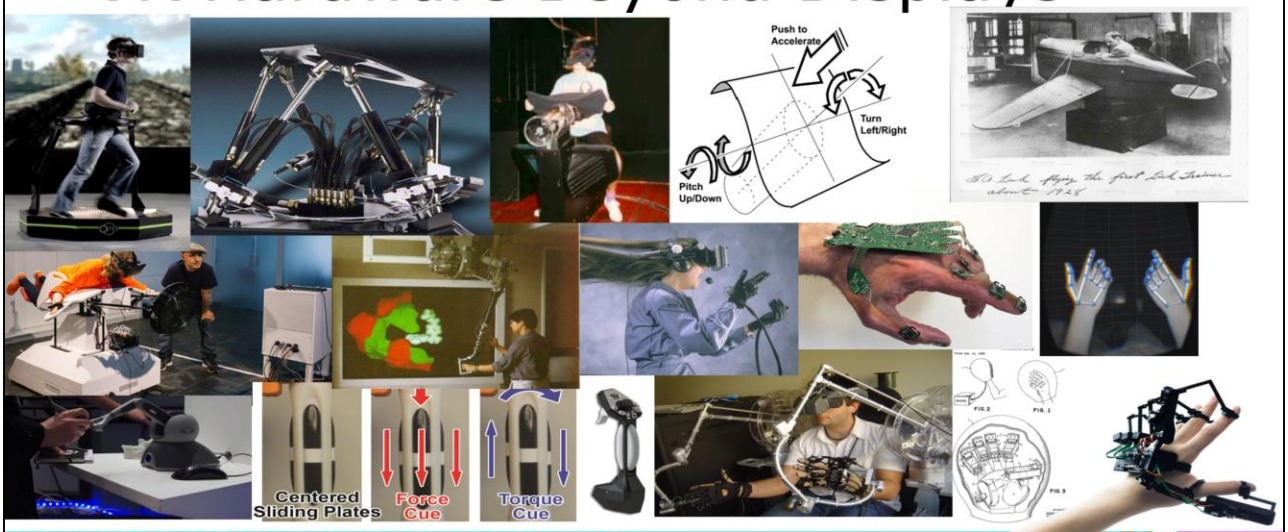
Reference frames-- important for designing human-centered interafaces

- Ref frames define the axiis that determine translation along x, y, & z and also rotation along yaw, pitch, and roll.
- Many of you that do traditional game development are familiar with ref frames. Screen space, object space, world space.
- Put interfaces in appropriate reference frames. Important for usability and comfort
- The image here looks complex in 2D but becomes intuitively obvious when immersed
    - Head reference frame—similar to screen coordinates in 2D development. Transparent Crosshairs in head reference frame useful for systems without hand controllers. Be careful! Such HUDs as done with traditional video games usually do not work well unless you are extremely careful and modify them for VR.
    - Virtual World reference frame. Compass in virtual world reference frame around the feet. Its easy to

become lost in virtual worlds with virtual turns so a compass can be important. If I get disoriented but know I should be traveling north then easy to know which way to go.

- Torso Reference Frame. Put information displays and tools here as if a utility belt that always travels with you—simply look down to see info or grab a tool. Takes advantage of proprioception, e.g., we know a virtual bag is always on the left side of our body.
- Real World Reference Frame. Cues stabilized relative to the real world to reduce sickness are called “rest frames”. Reduces sensory conflict between what you are seeing and what you are feeling.

VR Hardware Beyond Displays



There is much more to VR beyond HMDs

- Hardware is varied and depends upon project goals
- E.g., location based entertainment can be very different than games in the home

Input Device Classes

	Proprioception	Consistent	Useable in lap or the side	Haptics capable	Unencumbered	Physical buttons	Hands free to interact with real world	General Purpose
Hand								
World-Grounded Devices	✓	✓		✓	✓	✓	✓	
Non-Tracked Hand-Held Controllers		✓	✓	✓		✓		
Bare Hands	✓				✓		✓	✓
Tracked Hand-Held Controllers	✓	✓	✓	✓		✓		✓
Hand Worn	✓	✓	✓	✓		✓	✓	✓
Non Hand								
Head Tracking	✓	✓					✓	✓
Eye Tracking							✓	
Microphone			✓		✓		✓	✓
Full-Body Tracking	✓	✓	✓	✓			✓	✓
Treadmills	✓	✓			✓		✓	

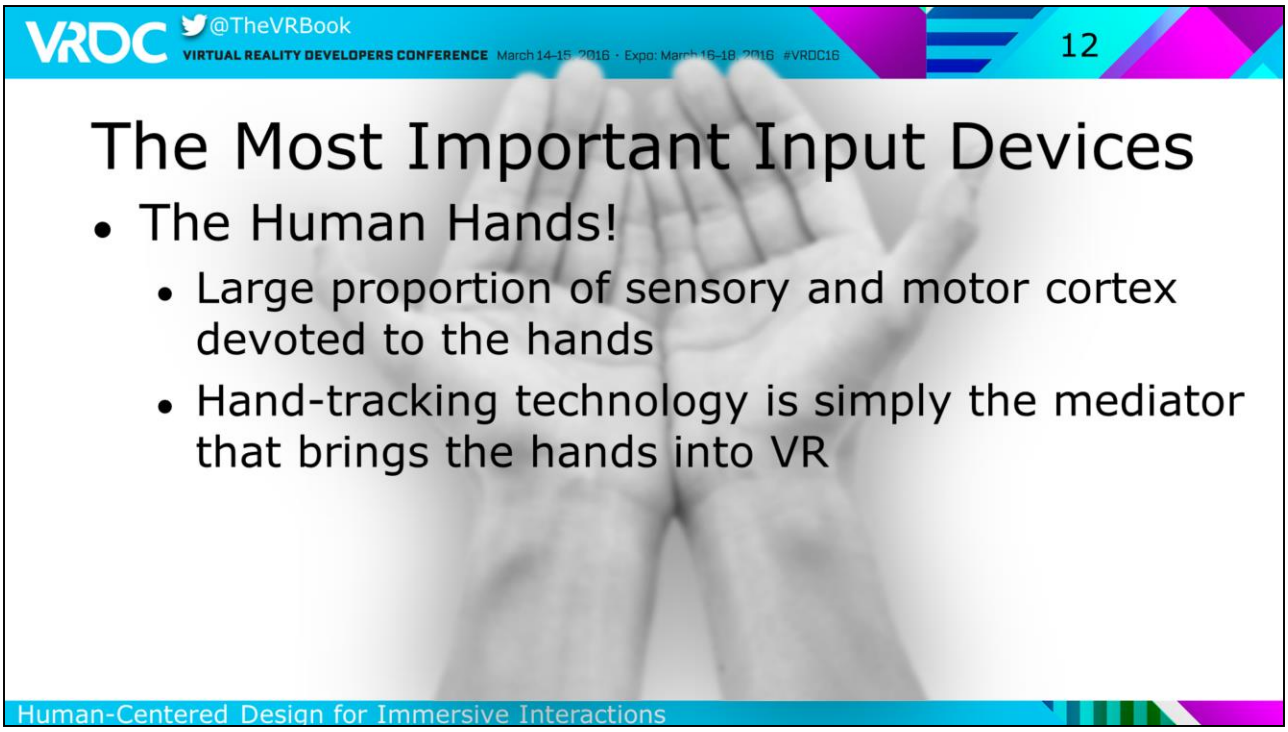
No single input device class has all qualities or is the ideal solution for all applications.

- The most appropriate device depends on goals of the application/experience.
- Hybrid and multimodal interaction can be ideal (if designed and integrated well), but more expensive and difficult to implement.

The Most Important Input Devices

I've seen some crazy input devices

- However, there is one type of input that is especially important for VR
- Clue: Shown on previous slides. Multiple times
- Turns out these input device is important for the real world as well.



- A relatively large part of the human brain is dedicated to input/output of the hands
- Hardware simply enables us to bring the hands into and interact with the experience
- Many ways to bring the hands into VR

The Evolution of Tracked Controllers

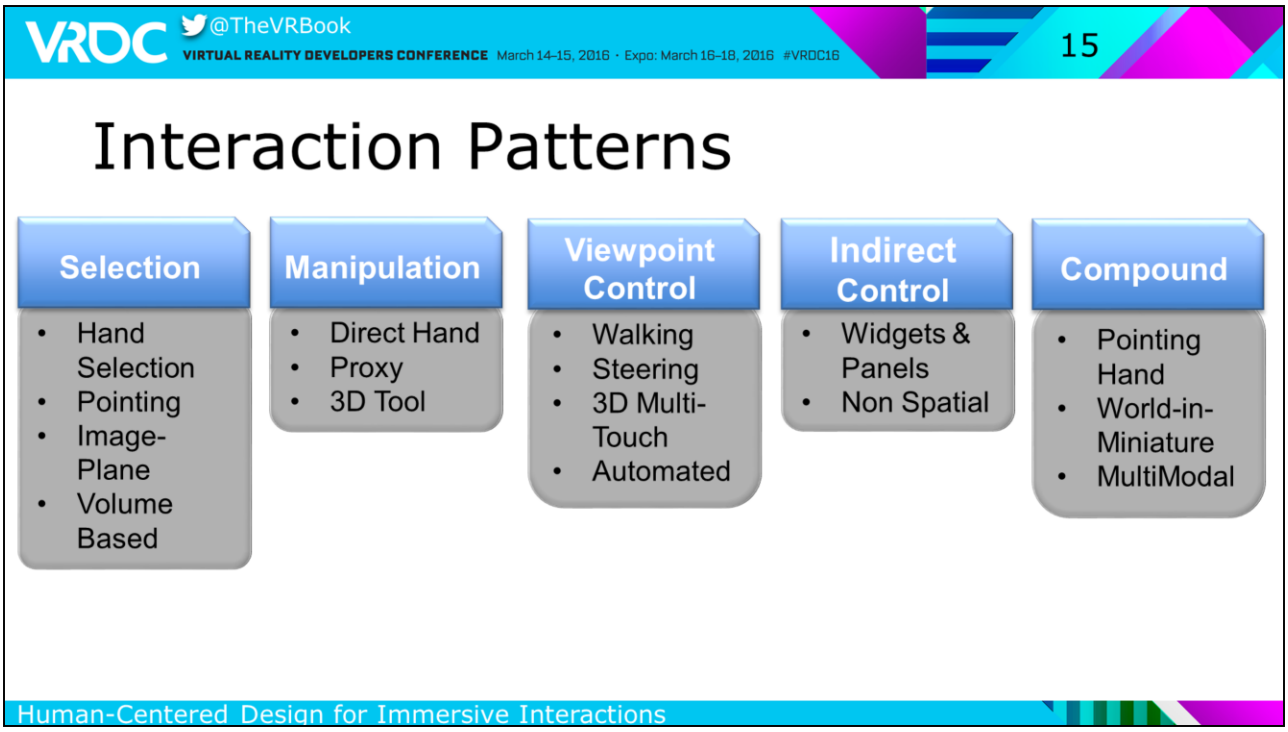
So what can we do with the tracked hand-held controllers?

Bimanual Classifications

- Hand symmetric
  - Synchronous
    - Pushing on a large object with both hands
  - Asynchronous
    - Climbing a ladder
- Hand asymmetric
  - Dominant hand
    - Precise control
  - Non-dominant hand
    - Subconsciously provides a comfortable reference frame
    - Gross movements
    - Positioning a piece of paper or peeling a potato

Two handed interfaces can be worse than no hands if not designed well.

- The hands do not necessarily work in parallel.
- Symmetric means each hand performs identical actions
  - Symmetric interactions might consist of the hands working simultaneously together or one hand at a time
- Asymmetric means each hand performs different actions
  - The non-dominant hand provides a comfortable reference frame for the dominant hand to comfortably work in
- A well designed interface enables users to work with their hands in a fluid manner, often switching between symmetric and asymmetric modes as appropriate.

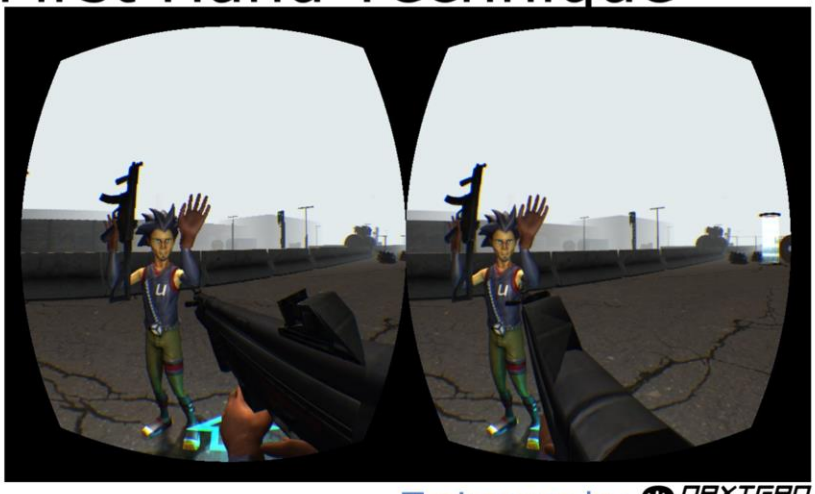


Now lets move on to some common interaction themes that occur across VR applications.

I looked at ~100 interaction techniques and categorized them into interaction patterns.

- Very different from software design patterns. These patterns are from the user point of view.
- I organize the patterns into 5 overarching groups of patterns.
- These 16 patterns can be further broken down into more specific interaction techniques.
- For example the Walking Pattern, a form of viewpoint control, consists of real-world walking, redirected walking, walking in place, treadmill walking, etc.
- Now I'll show some specific examples of some of these patterns.

The First Hand Technique

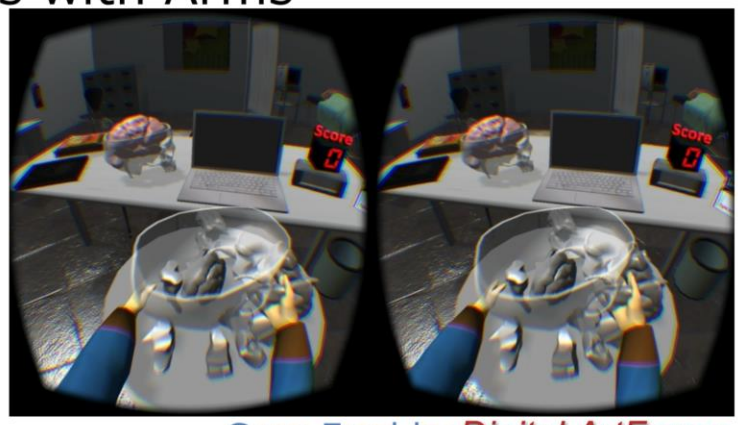


The first thing people do when hand tracking becomes available is direct selection and manipulation.

- Here is what I built back in 2013 just after the Oculus Kickstarter DK1 shipment
- Quite a bit can be done just by tracking three points—the head and the two hands.
- Here, I'm threatening Paul Mlyniec, the President of Digital ArtForms. Since his hands are tracked he doesn't have to think of where the surrender button is. He just naturally raises his hands to non-verbally say "don't shoot!"
- Simply pick up the object like you do with the real world
- Other parts of the body can be moved with inverse kinematics and animations. For example the feet move with a walking animation when pressing forward with joystick on a hand-held controller.
- Inverse kinematics can be extremely compelling if done well and where appropriate.

The Hand Selection Pattern

- Hands with Arms



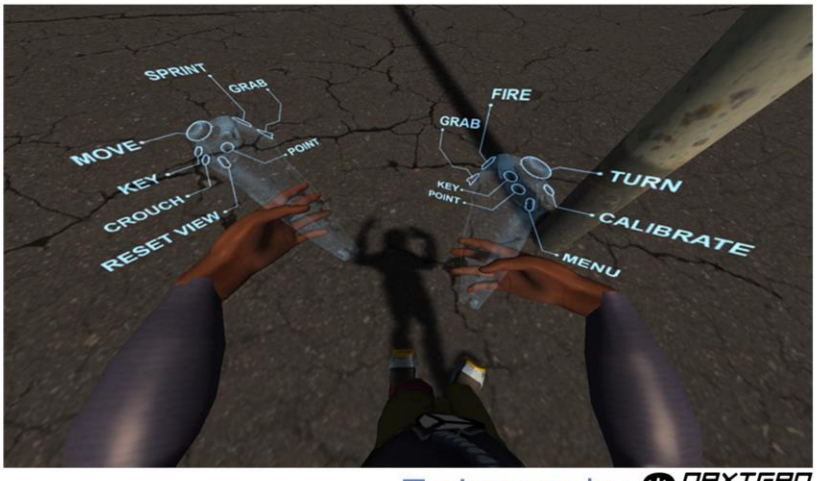
Cure Fred by Digital ArtForms

Example of some work we did with Digital ArtForms, Sixense, and the Wake Forest School of Medicine to teach kids about how their brains work.

- Learn by doing
- Simply reach out to grab the brain parts-intersect the hand with the object and then push a button
- Can do so much more than you can with a real-world puzzle. E.g., integrating with digital media, smarter interactions, special effects.

Play movie

Interface in the Hands



Trainexus by nextgen Interactions

Why do VR developers think user interface elements should go in the head reference frame?

- A simple solution:
  - Put UI signifers/labels in the hands.
  - Simply look at your hands when performing an action until you get good at the task—similar to real reality.
  - These signifiers are simple transparent textures with labels attached to a Razer Hydra.
    - A 3d model matching what the user physically feels would be better.
  - No finger tracking, but close enough for users to intuitively know what button does what by touch.
  - Enable users to turn on/off the visuals. Important for both novice and expert users.

The Pointing Pattern

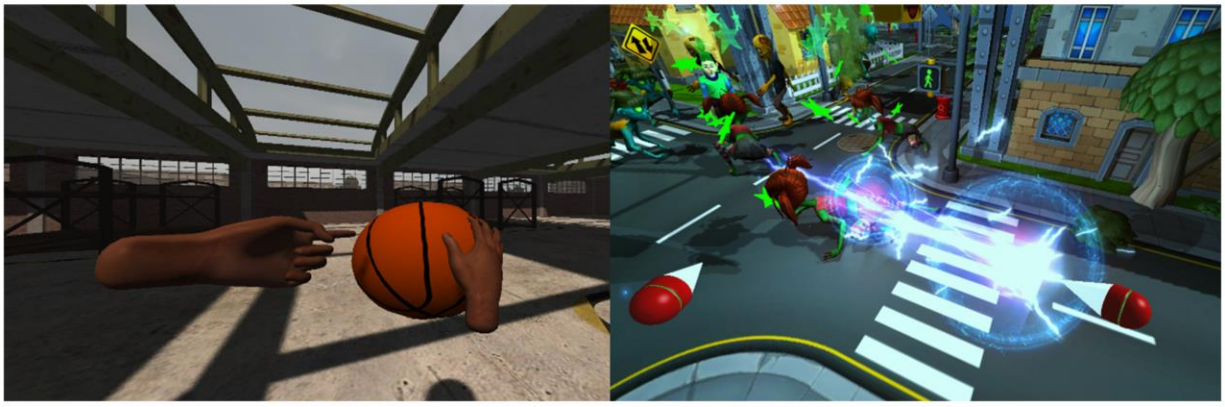
Zombie Apocalypse by Digital ArtForms

Pointing is normally considered to be non realistic (unless simulating a laser pointer)

- Enables selection at a distance
- Here we have an exocentric view of the world from an egocentric perspective.
- Here, pointing enables the user to shoot electricity from his hands to protect a friend in a smaller world (Work with Digital ArtForms)

Non-Realistic Hands

- Hands without Arms



VR experts argue if arms or realistic looking hands are better.

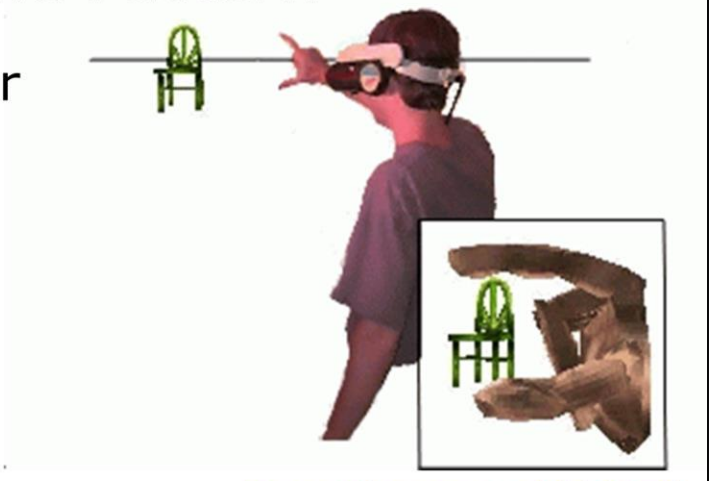
- Like many other great VR debates, the answer is it depends!
- Arms are most appropriate when:
    - Realism is important
    - It can be assumed the user will always be facing in one direction or the torso is tracked.
- Arms are not appropriate when:
    - Reaching further than the physical length of your arms is important
        - For example:
            - Reaching to pick up items off the floor from a seated position
            - You want to reach out further into the distance than you could if you were physically constrained with how far your arms can reach.
                - The Go-Go Techniques is a hand selection technique that has 1to1

mapping within personal space at 2/3 of your physical arm length. Beyond 2/3 of your arm length, your arm reach expands exponentially enabling selection at a distance.

- Hand selection/manipulation can be quite compelling even when the hands don't look like hands (i.e., 3d cursors).
    - With appropriate spatial and temporal compliance, 3D cursors feel like they are your hands—even though they don't look at all like your hands.

The Image-Plane Pattern

- The Head-Crusher Technique



From Pierce et al [1997]

- Rarely used interaction pattern but can work quite well for selecting objects at a distance.
- Shown here is the Head-Crusher Technique
  - Think of the world as a 2D plane in front of the user
  - Hold the hand up and place the two fingers of the dominant hand around the object of interest
  - Push a button on the non-dominant hand or verbally say “select”.
- Requires closing one eye and can result in gorilla arm if used often.

Widgets & Panels Pattern

- 2D Desktop Integration

From Taylor et al [2010]

Widgets and panels often take desktop applications or metaphors and bring them into the virtual world

- Often not ideal, but easy to do.
- Hand pointing via ray selection is most common and most usable.
- Here I'm bringing in arbitrary desktop applications into a CAVE VR system.
- If you want to do a quick mathematical calculation, you don't want to have to exit the virtual world to bring up a calculator app and its not worth writing an immersive 3D calculator app. Instead of exiting the virtual world, bring the existing application into VR.
- Many other forms of immersive widgets and panels. For example hand-held panels, panels above the head, finger menus, marking menus, etc.

Hand-Held Panels

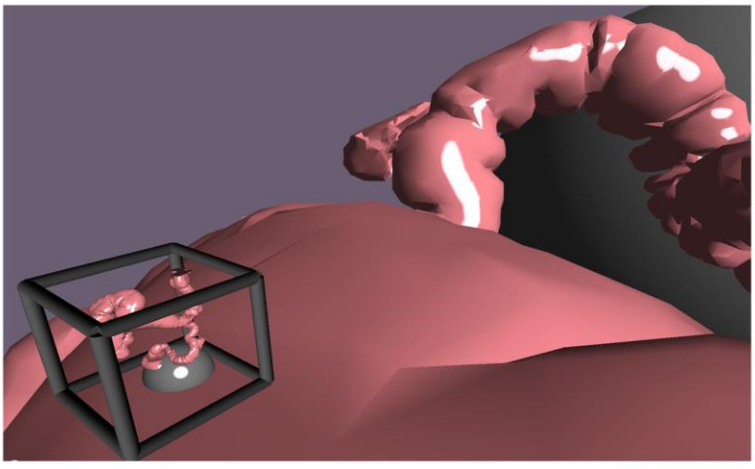
- Buttons
- Sliders
- Dials
- Color Cubes

Hand-held panels by Digital ArtForms

Putting a virtual panel on the hand works surprisingly well

- Provides double dexterity where the nondominant hand provides a reference frame to work in.
- Interface always available
- Turn on/off with the click of a physical button
- Examples here include traditional GUI elements (buttons, sliders, drop down menus) as well as more interesting GUI elements (dials, marking menus, color cube)

World-In-Miniature



iMedic by Digital ArtForms

A WIM is basically a real-time map of the world a user is in.

- Can hold in the hand or have it attached in the world or to your body (torso reference frame)
- Can reach into the map and move things that then moves the corresponding object in the larger world

3D Multitouch Pattern

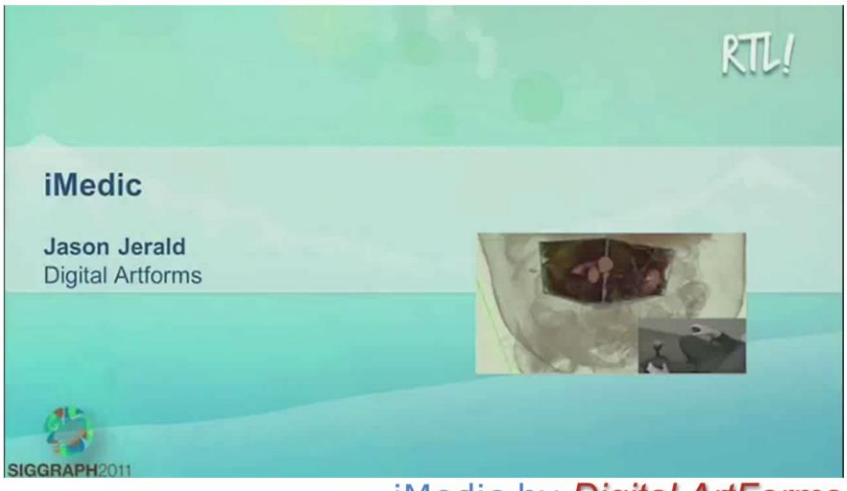
- Appropriate for abstract Non-realistic interactions
- Written Specifically for Immersive Interaction
- Content/Data Independent
  - Emergency preparedness
  - Medical Visualization
  - MakeVR
- Solves Gorilla Arm
- Reduces Sim Sickness

- Similar to 2D multitouch.
  - Think of manipulating the world as an object—grab with both hands to translate, orient, and scale the world
  - Thinking about manipulating the world as an object results in the user thinking of the world moving instead of moving through the world, resulting in reduced motion sickness.
- Appropriate for abstract non-realistic interactions
- Data independent. We've used this across a variety of applications including volumetric data—no polygons required because no intersection computations are required.
- Solves gorilla arm. A focus study found users could go 4 hours with no report of arm fatigue.
  - To translate, simply grab the world with one or both hands
  - To scale/zoom, "pinch" with two hands instead of two fingers
  - To rotate, grab the world with both hands and orbit about the midpoint between the hands as if it were a

globe

- Can do translation, scale, and rotation simultaneously with a single gesture
- interaction is direct & immediate—starts as soon as you push the button—no need to wait for the system to recognize the motion
- Results in the feeling that you are are crawling through and stretching space

Digital ArtForms 3D Multitouch



iMedic by Digital ArtForms

- An example of 3D Multitouch shown at SIGGRAPH 2011. Non-HMD here but the 3D multitouch actually works better with HMDs as that is what it was originally designed for.
- Play movie

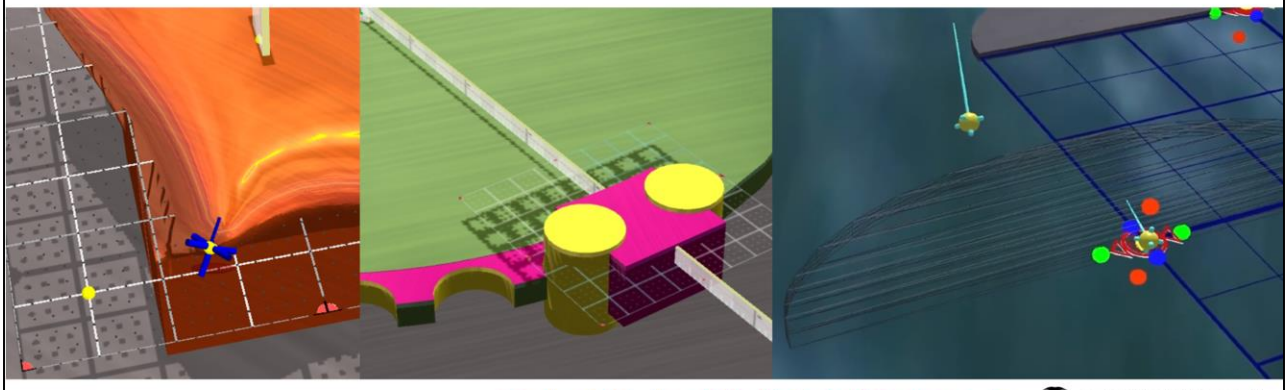
3D Multitouch

MakeVR by Digital ArtForms & SIXENSE

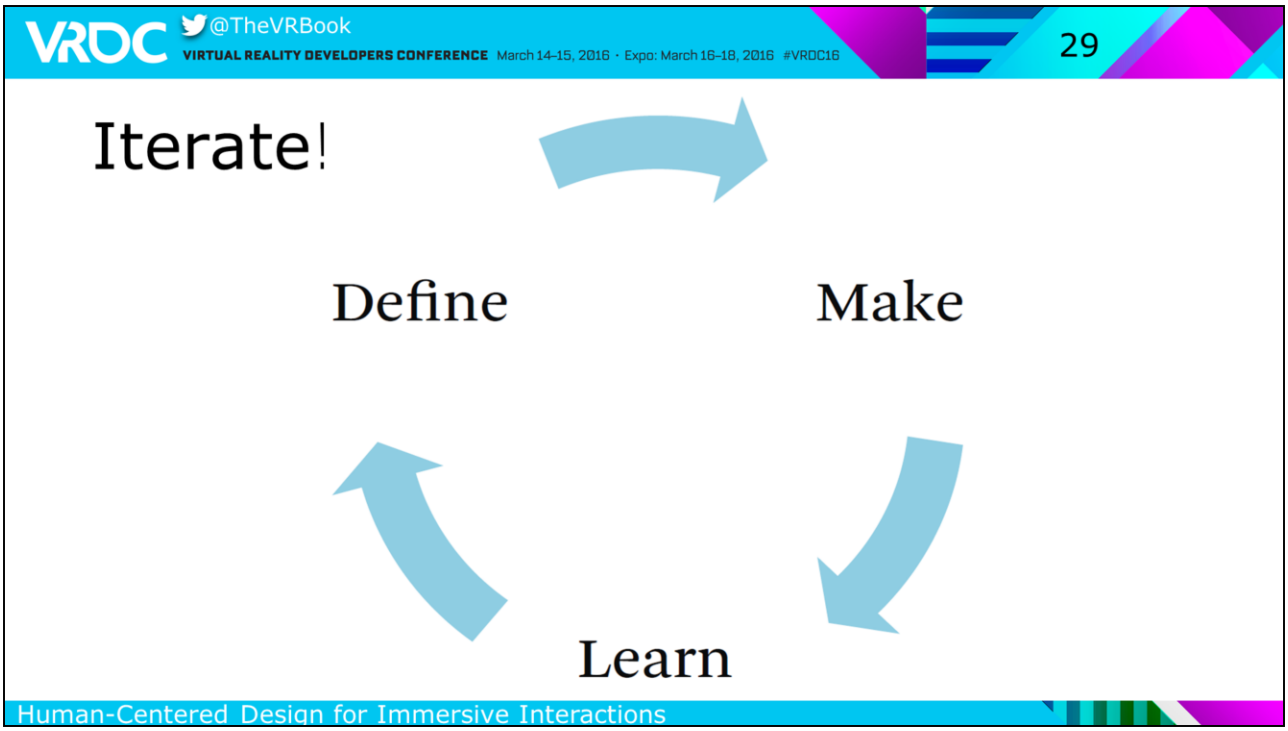
- The same interface is used with MakeVR (new company should be formed by VRDC 2016). An immersive CAD modeling program.
- 3D content creation and world building intuitive and accessible by anyone.
- Currently works with Sixense STEM, Razer Hydras, and SpaceGrips.
    - Support coming for Oculus Touch controllers and HTC Vive controllers

3D Tools Pattern

- The Jigs Technique



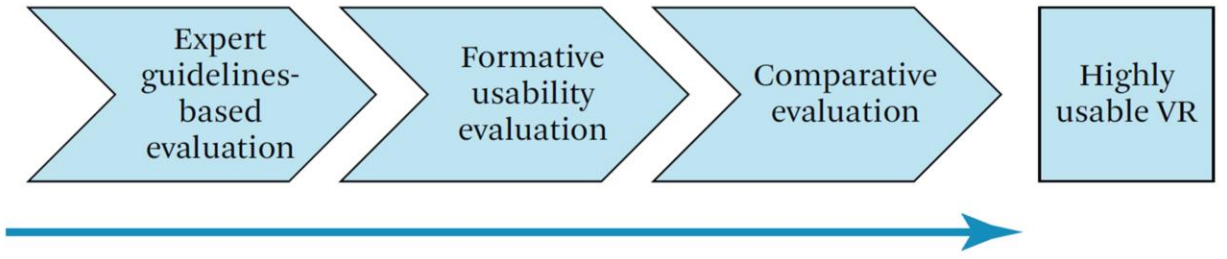
- Precision is normally difficult in VR.
  - No physical constraints as there is with a mouse on a desk.
  - So instead add artificial constraints—what we call jigs. Shown here as used with MakeVR. Think of carpenter tools to provide the user more precise interaction.
  - E.g., grids can be attached to polygon faces and then the grid spacing can adjusted.
- Jigs are constraint tools, similar to tools that real world carpenters use to build things.
  - They can constrain objects to a plane or a models surface.
  - Or snap objects to grid points that can be spaced as needed.
  - Or snapping an object to another object.



There are very few absolute rules with VR.

- Iteration is more important for VR than for any other medium. Especially for viewpoint control, due to risk of sickness and injury.
- Human-Centered Design requires lots of feedback from your target audience and continual iteration.
- For anything beyond the basics, you (and I) will fail the first time. And the second time. And the third time. Get used to it if you want to be successful.
- Such iteration goes by many names. I call it the Define-Make-Learn Cycle.
    - Can be broken into many more iterative components that we don't have time to get into today. Even these processes require iteration that depends upon your goals.

Expert Evaluations



Based on Gabbard [2014]

A big part of what we are working at NextGen Interactions is to creating processes for providing better feedback to VR creators for their specific projects.

- That starts with task analysis to really understand what is trying to be accomplished
- That leads to expert guidelines-based evaluations that are the first steps to making sure the most important items are being done well. That leads to formative usability analysis which is using techniques such as speak-out-loud protocols where the user explains out loud what he is doing and thinking, to observational analysis of breaks in presence.
- Then those that want to get more formalized results can conduct formal scientific studies to compare different techniques or conditions.

Summary

- Widespread access to tracked hand-held controllers will take VR to the next level
  - But only for applications that are designed well
- There are no universal answers
  - Selecting devices and interaction patterns are project dependent
  - Understand tradeoffs and where what is appropriate
- Iterative. Iterate. Iterate.
- Have fun!

- Widespread access to tracked hand-held controllers not only provides a large user base but provides developers with quality input devices that will lead to innovative interfaces that nobody has yet considered.
- Just because anything is possible doesn't mean everything will work. Viewpoint control especially requires caution due to risk of sickness and injury.
- Iteration is absolutely essential for VR.
- Most importantly have fun! Otherwise what is the point of reality, whether virtual reality or real reality?

- If you want to learn more about human-centered design for VR then check out my book at TheVRBook.net.
- This book is available in the GDC bookstore above us in the the South Hall Lobby.
- In fact we have a book signing starting at 5:45pm.

Questions?

Take questions offstage and at book signing.

References

- Gabbard J. (2014). Usability Engineering of Virtual Environments. In K. S. Hale and K.M. Stanney (Eds), Handbook of Virtual Environments (2nd ed., pp. 721-747). CRC Press.
- Jerald, J. [2015] The VR Book: Human-Centered Design for Virtual Reality. Morgan & Claypool Publishers and ACM Books.
- Norman D. [2013] The Design of Everyday Things, Expanded and Revised Edition. Basic Books.
- Pierce, J., Forsberg, A., Conway, M., Hong, S., Zeleznik, R., and Mine, M. R. (1997). Image Plane Interaction Techniques in 3D Immersive Environments. In ACM Symposium on Interactive 3D Graphics (pp. 39–44). ACM Press.
- Taylor, R., Jerald, J., VanderKnyff, C., Wendt, J., Borland, D., Marshburn, D., Sherman, W., and Whitton, M. (2010). Lessons about Virtual Environment Software Systems from 20 Years of VE Building. Presence: Teleoperators and Virtual Environments, 19(2), 162–178.