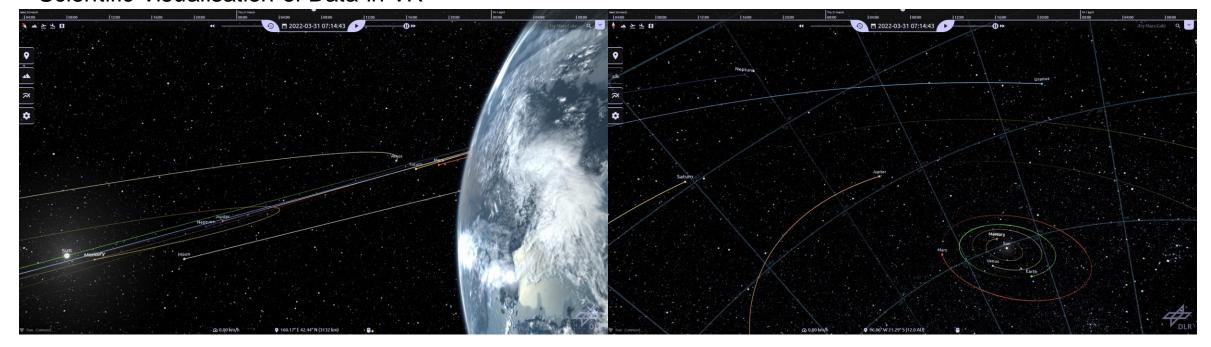
Motion Sickness Reduction for 6-DoF-Navigation in a Virtual Solar System





What is CosmoScout VR?

- Virtual Reality Simulation of our solar system
- High resolution elevation models and satellite imagery
- Real-time exploration of entire planets and space missions
- Scientific Visualisation of Data in VR





What Problems Do I Want To Fix?

- 6 DoF Navigation Controls with remote lead to complex rotations in free movement
 - Disorientation increases likelihood of motion sickness
- Automatic Navigation uses simultaneous translation and rotation during travel path
 - Quick rotation at peak speed may induce sickness symptoms
 - Occurs during bookmark navigation and landing/ascending animation





What Causes Motion Sickness?

Sensory Conflict Theory

- Information from user's senses conflict with each other or with the expectation in given context
- Sensory conflict due to vection though as one of the prime causes of cybersickness

Postural Instability Theory

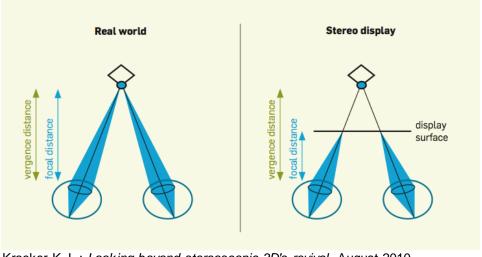
- State in which uncontrolled movements of the perception and action system happen
- Postural instability i.e., lateral-medial body sway often precedes experiences of motion sickness
- People who are naturally unstable seem to be more likely to become motion sick during VR



What Causes Motion Sickness?

Vergence-Accomodation Conflict Theory

- Vergence refers to lateral eye movement to adjust to objects moving towards or away from the user together with the proces of focusing on the object (Accomodation)
- Process does not occur in stereoscopic displays, where accomodation occurs at fixed sceen depth

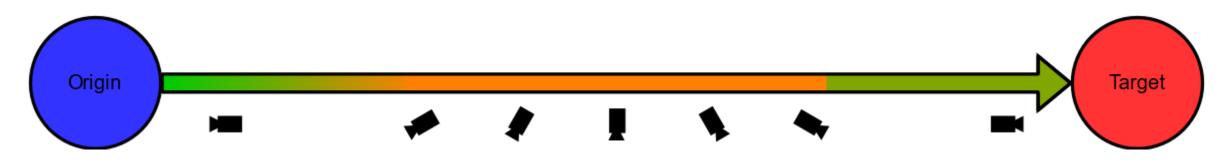


Kroeker K. L.: Looking beyond stereoscopic 3D's revival. August 2010. https://doi.org/10.1145/1787234.1787241

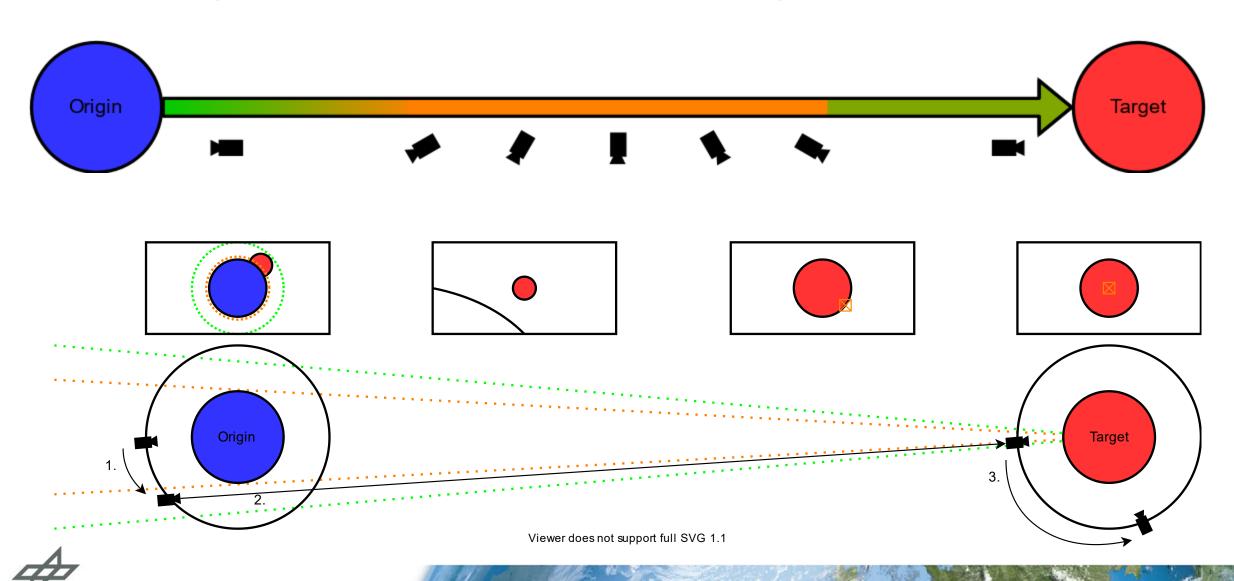
Saredakis D., Szpak A., Birckhead B., Keage H. A. D., Rizzo A., Loetscher T.: Factors Associated With Virtual Reality Sickness in Head-Mounted Displays: A Systematic review and Meta-Analysis. March 2020. https://doi.org/10.3389/fnhum.2020.00096



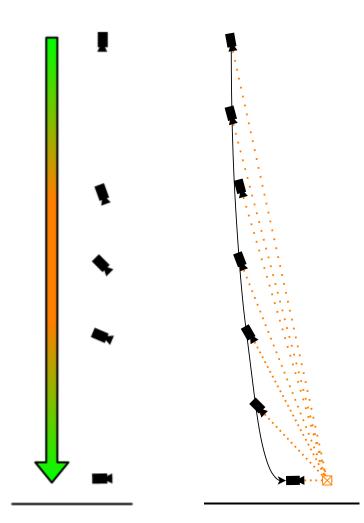
- Orbit-to-Orbit Navigation
 - Travel between objects in interplanetary space
 - Travel in the orbit of an object
- Orbit-to-Surface Navigation
 - Travel to and from the surface to the standard orbit distance
- Surface-to-Surface Navigation
 - Travel between different location on the same body





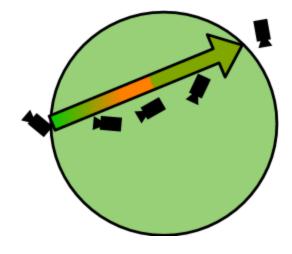


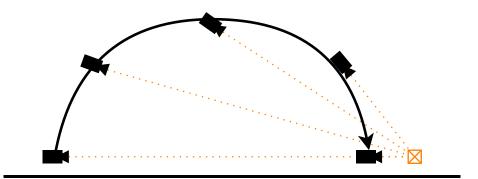
- Travel paths moving the user forwards
 - Move in orbit over and rotate towards target
 - Lock view direction onto traget's orientation and move along parabola curve down to target
- Simple, predictable movements to mitigate sensory conflicts
- Parabola movement instead of linear to "move into" target orientation





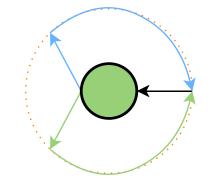
- Old method ignores collisions or target location
- Surface travel also via curves, lifting user to new location (short distances)
- Long distance travel via orbit

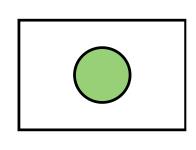




move forward into orbit

move backwards into orbit

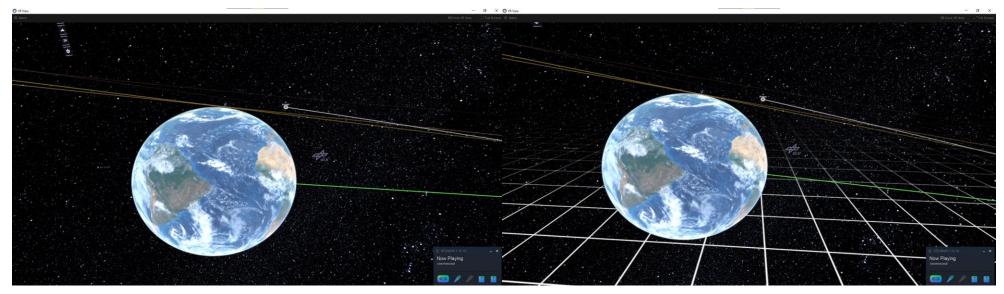






How To Mitigate The Problems? - Floor Grid

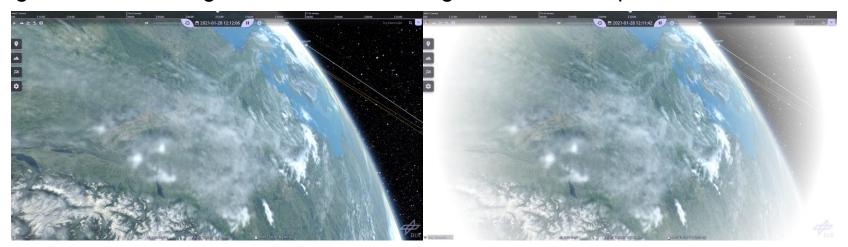
- Provides a stable simulated frame of reference during interplanetary free and automatic navigation
 - Assist with postural stability and sensory conflicts
- Change interaction context from Observer moving through the simulation to solar system being simulated and manipulated around the fixed user
 - Mitigates sensory conflict problems as the user is not moving, and VR orientation mirrors real-world situation





How To Mitigate The Problems? - FoV Vignette

- Popular method of cybersickness reduction
 - Applications with high detail and/or movement in peripheral areas of vision
- User tends to react to High peripheral detail / movement by moving their eyes instead of their head
 - Employ vignette to limit users FoV, focusing on the center of HMD lenses
- Post-Processing shader draws vignette radius according to movement speed





Next Steps: How To Measure the Effectiveness?

- Within subjects user study to measure effectiveness of cybersickness mitigations
 - Measure general severity of cybersickness while using CosmoScout VR
- Navigation tasks with and without developed mitigation methods
 - Interplanetary 6-DoF-Navigation with and without grid
 - Automatic navigation using old and new movement, potentally also testing teleportation
- Measuring cybersickness severity and feedback to the navigation methods
 - Continuous evaluation of cybersickness over time inside simulation
 - Feedback and evaluation of features during and after navigation tasks
 - · Feedback and SSQ after session

