Moving in Virtual Reality: Peripheral Blending and Particle Flow Fields

Lunar Psychophysics Virtual Reality Laboratory
Department of Psychology, The Catholic University of America, Washington, D.C.
Alexandra Filiault, Elizabeth Reid, Kathleen Palmer, Katherine Rahill, M.A. & Marc Sebrechts, Ph.D.

Motion Perception

In visual perception, the human eye processes and filters visual sensory information that enables us to perceive and detect motion in our environment. Motion perception is the process of inferring the speed and direction of elements in a scene based on visual, vestibular and proprioceptive inputs.

In Virtual Reality (VR), the direction of motion is induced by rendering flow fields (vectors) that are projected to our central and peripheral field of view in a virtual scene. These motion vectors provide the essential information about the motion of virtual objects within the environment and our movement through it. The following sections of this poster describe types of motion individuals experience in the real world and how we render motion in virtual worlds.

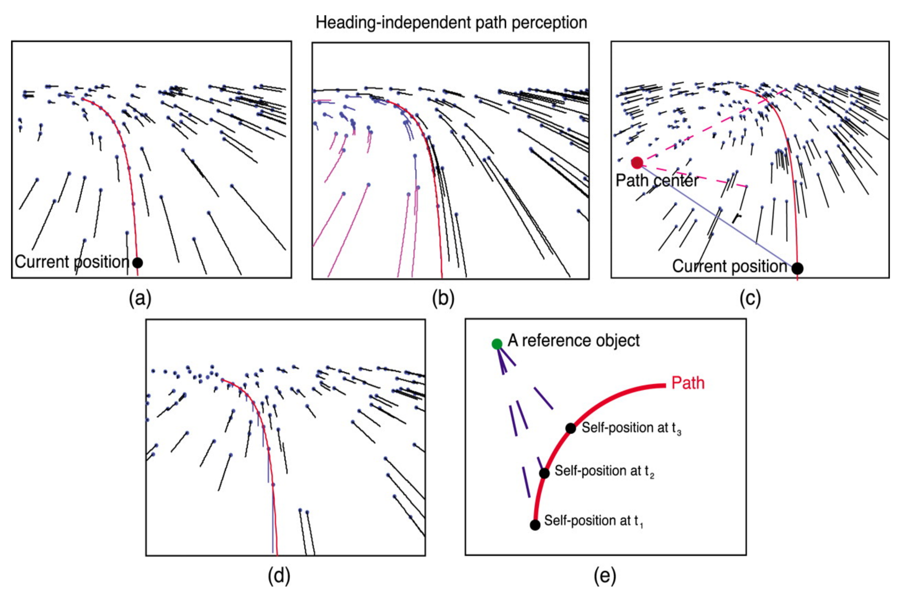


Figure 1. The main types of directional ego motion from (a) a current position the visual field along the path of travel, (b) heading independent path perception, (c) motion in relation to a nearby still object from the center of a path, (d & e) self-position points along a path trajectory in the visual field (Cheng, 2011).

Optic Flow

<u>**Optic Flow**</u>:

- Movement of visual information delivered to the "optic array" of the eye that provides sensory input about what type of movement (e.g., rotational or directional is taking place).
- The visual processing of motion cues, such as heading and speed information are patterns formed by differences in light intensities reflected on the optic array of the retina.
- These patterns are used to dictate the apparent motion of an object, a surface, or edges in a visual field.
- Individuals can determine their heading (or direction of self-motion) based on the information provided from optic flow.
- As an observer moves through a stationary environment, self-motion generates a pattern of visual outflow on the retina which specifies the direction of self-motion (vection).

<u>**Radial Motion**</u> (Upper-left hand image):

- First optic flow component in VR that contributes to motion perception
- Flow begins in the center radius and moves outward (e.g. rays of sunshine)

<u>**Translational Motion**</u> (Upper-right hand image):

- Second optic flow component in VR that contributes to motion perception
- Movement from one place to another (e.g. moving from left to right)

<u>**Circular Motion**</u> (Lower-left hand image):

- Movement along the circumference of a circle
- Can be uniform with a constant rate of rotation and speed, or nonuniform with varying rates of rotation

<u>**Spiral Motion**</u> (Lower-right hand image, Archimedean Spiral):

- Outward movement from a fixed point in the center of the visual field; this motion is at a constant speed

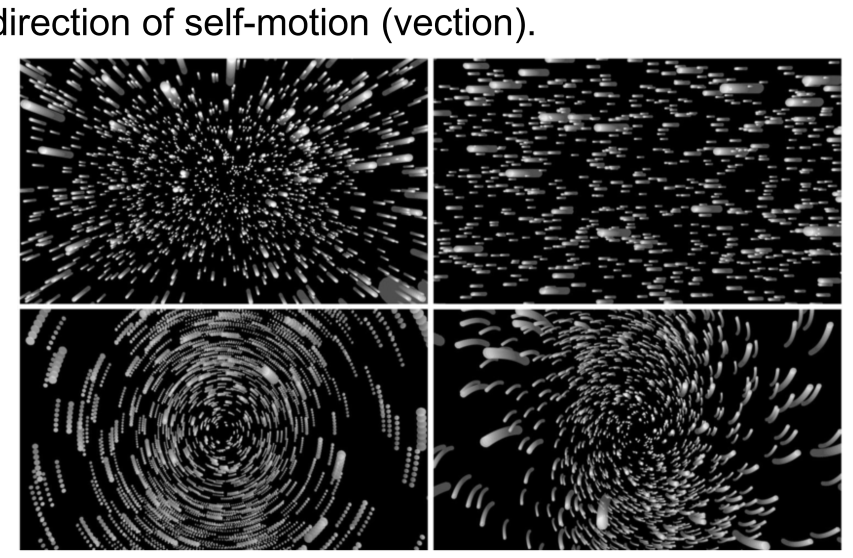


Figure 2. Optic flow fields (Palmisano et al., 2012)

<u>**Laminar Motion**</u>:

- Movement in a consistent motion in any direction
- Same as ego motion in the Kygo "Carry Me" VR demo

<u>**Rotational Movement**</u>:

- Movement in the same direction along a fixed point
- Third main optic flow components in VR that contribute to motion perception
- Similar to spiral and circular motion

<u>**Directional Movement**</u> (or heading):

- Movement in a fixed direction; similar to translational motion and laminar motion

KYGO "Carry Me" VR Experience

Given the rapid advancements in VR technology, this interactive demonstration highlights the implementation of two technical suggestions for optimally inducing motion perception with optic flow cues:

(1) Rendering **particle flow field patterns** of different light intensities that stimulate motion detectors in the visual system.

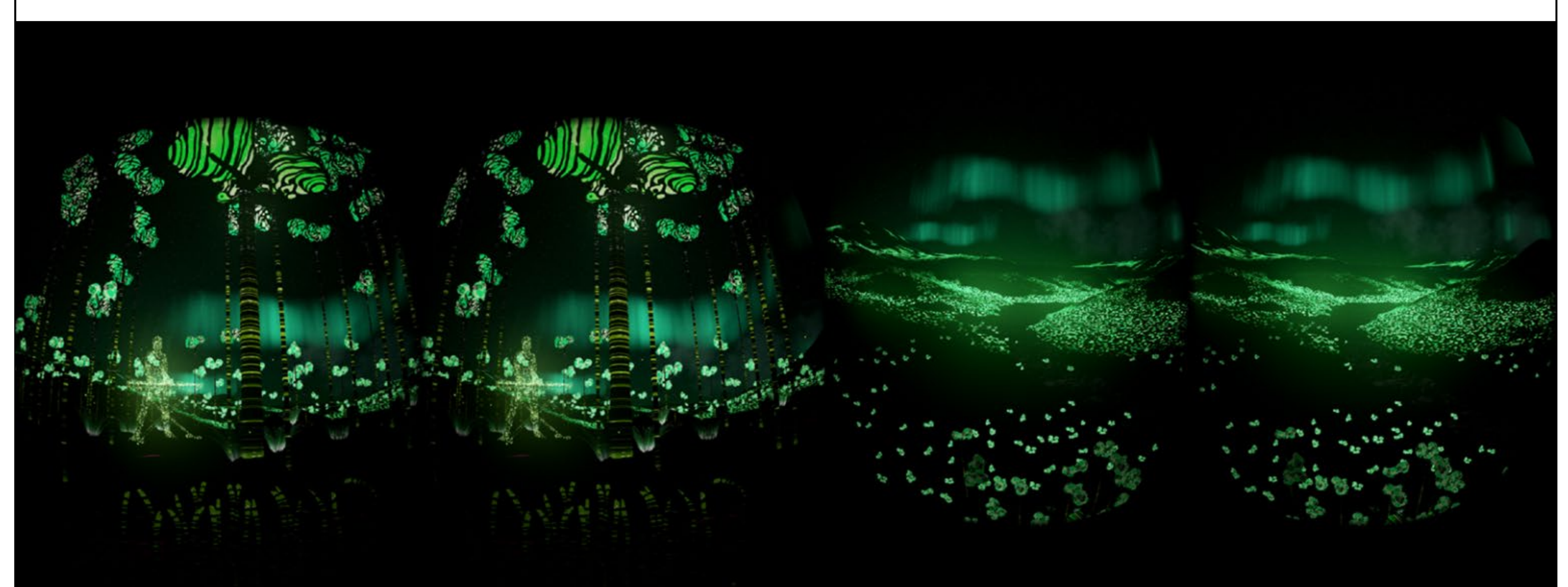
(2) **Peripheral blending** which displays motion vectors in the far edge of the peripheral display, a concept known as laminar optic flow.

What to Expect

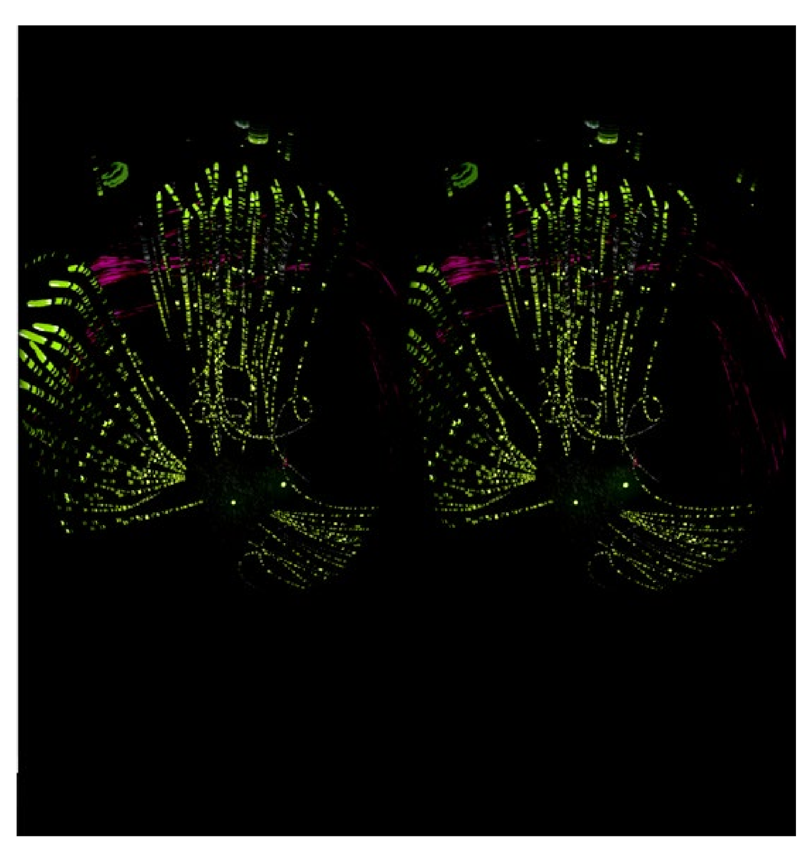
360º experience: in this immersive VR experience, the user can explore this environment in a 360 degree space while standing or sitting.

Allocentric and Ego motion: Particle flow fields that move uniformly in composition to induce egocentric and allocentric motion of surrounding objects.

Peripheral blending techniques: high resolution rendering that provides smooth transitions between dynamic virtual scenes.



Optic flow induced motion: light patterns that scatter across the visual field in a highly coherent manner induce the perception of motion independent of radial, translational and laminar motion.



Radial and translational motion: particle flow fields that move upwards from the central radius underneath your feet will induce the perception of slowly moving upward.

Laminar motion: particle flow fields will induce a constant sense of upward motion with a laminar gain that is slightly less than a 1 to 1 ratio with real world motion.

High contrast patterns of different light intensities: the light patterns across different landmark objects provide visual cues that enables the user to experience rotational movement.

Particle Flow Fields in Virtual Reality

Although the process of motion appears straightforward to most observers, it has proven to be a difficult problem from a computational perspective, particularly for rendering simulated motion. In the context of VR, there are three main optic flow components that contribute to motion perception: radial rotation, rotational motion and translation. The visual manipulation of these optic flow cues is considered a contributing factor in successfully replicating movement in VR research (e.g. Richardson & Collaer, 2016; Bruder et al., 2017).

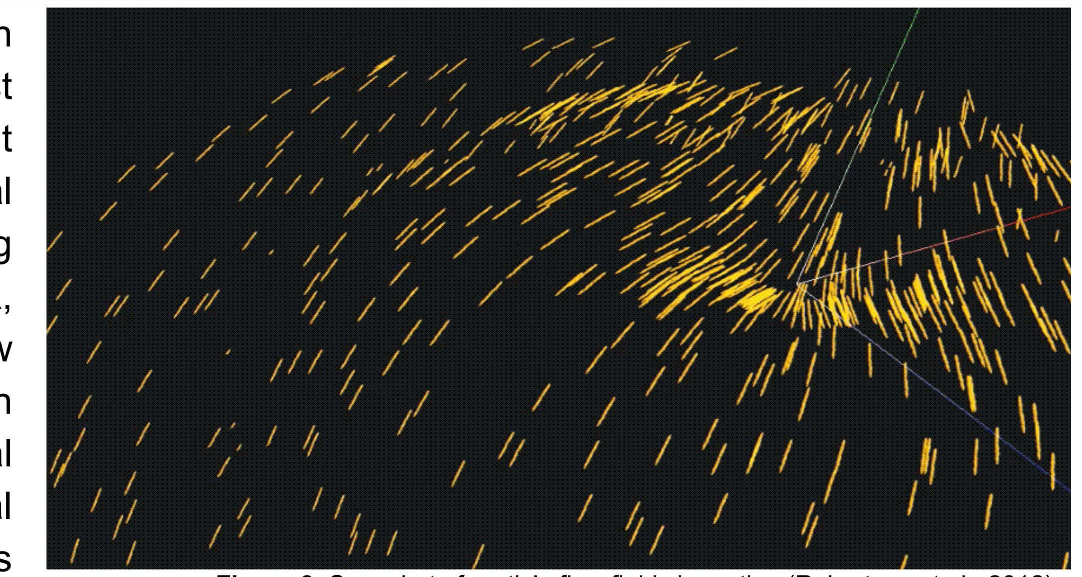
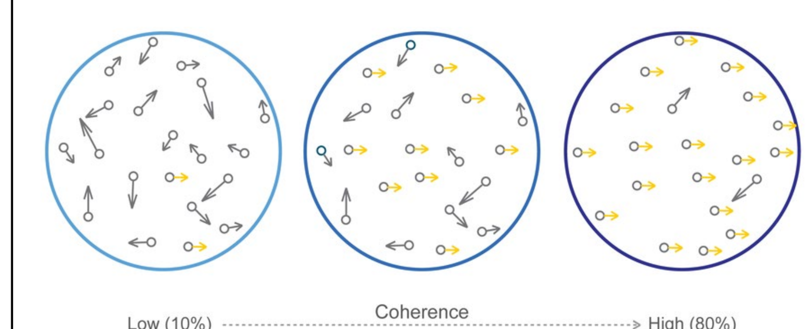


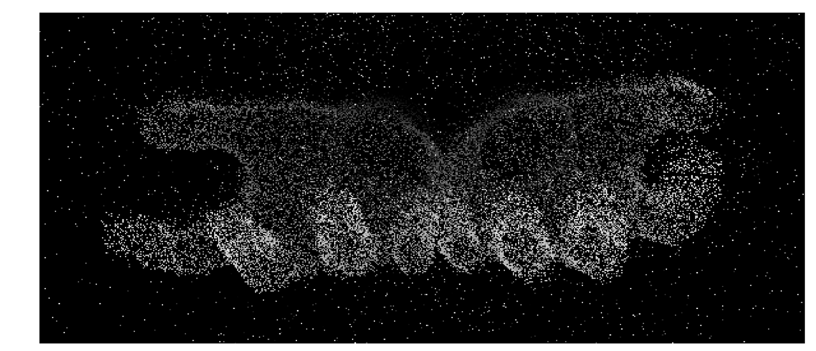
Figure 3. Snapshot of particle flow fields in motion (Robertson et al., 2012)

A common approach that is based off of optic flow theory is rendering particle flow field patterns of different light intensities that stimulate motion detectors in the visual system.

Since standalone or commercialized VR headsets do not yet have the capabilities to render all the necessary motion cues that we experience in real life, the visual rendering of flow fields is often experienced as slightly incoherent or "***slower***." The threshold for motion detection in VR is variable depending on the type of motion a developer is trying to induce. If the particle flow fields are ***low** in coherence and density* (i.e. not all moving in the same direction; see figure 3), then motion may be harder to detect than when the ratio of particle flow fields are moving in the same direction. For example, when particle flow fields are ***high** in coherence and density*, this enables the recognition, identification and detection of moving objects in VR (see figure 4).



Robertson et al. (2012)
Figure 3. Flow field patterns of coherence and density



Robertson et al. (2012)
Figure 4. Rendered image with high flow field coherence and density

Virtual Motion and Sensory Conflict

Until recently, the manipulation of virtual motion has been difficult to replicate in Virtual Environments (VEs). This is because motion perception in a virtual context can significantly differ from the real world and this **sensory conflict** can induce simulation or "motion" sickness.

Issues with **tracking errors or latency** can also present conflicting information about movement between what is presented in the VE and experienced in the real world. This is often because of the intersensory conflict that occurs when people's **internal biological mechanisms** which detect motion, such as in the vestibular system, which is in conflict with what the person is visually experiencing.

Akiduki et al. (2003) found that symptoms of motion sickness got worse when the visual-vestibular conflict was introduced. The significant time lag between a VR experience and these subjective symptoms of motion sickness suggest that the inputs for these systems are processed in different pathways, which then causes the **autonomic symptoms and postural instability**.

Palmisano et al. (2017) showed that the way head movements are tracked have a large effect on virtually induced motion sickness. When this tracking is delayed, it creates a conflict between **visual and vestibular motion** which creates greater subjective feelings of motion sickness. Our demo controls for this by utilizing VR software and technology that properly tracks the participant's head movements to minimize latency errors in this demonstration.

It has also been hypothesized that **vection** could also cause motion sickness. Kuiper et al. (2018) found that changes in vection over time doesn't cause visually induced motion sickness on its own, which implies that there is additional research to be explore to figure out the true causes of motion sickness and sensory conflict in VR.