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Helical Soundscape
Reinforcing Azimuth Gain for Redirected Seating

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Abstract

Redirected Seating (RDS) is a special case of Redirected Walking (RDW), when virtual dilation of physical excursion allows a smaller physical space to simulate a larger virtual space. We extend a previously developed proof-of-concept of RDS with integration of a complementary soundscape featuring a helical musical scale. We propose a way to estimate magnitude of suspension of disbelief, a mixture of virtual and redirected experience.

CCS Concepts

• ***Human-centered computing*** → *Interaction design theory, concepts and paradigms;* ***Virtual reality; Mixed / augmented reality;*** • ***Hardware*** → *Sensors and actuators;*

1. Introduction

Humans use a variety of ways to estimate their body orientation. The dominant sensory modality for such tasks is vision, using visual landmarks as if they were fiducial markers and situation awareness to estimate position. In the process of orientation estimation, the brain integrates multiple sensory inputs, including visual cues, vestibular signals, and potentially magnetoreception. However, when conflicting information is present, the brain typically prioritizes the most reliable and detailed source of information. Optical flow and visual vection, which provide high-resolution and contextually rich data about the environment, can override conflicting signals. Such visual dominance ensures that orientation estimation remains precise and accurate, even in complex or ambiguous sensory situations.

The vestibular system, through the otolithic system in one's inner ears, acts like a gyroscope. Proprioception — awareness of the position of one's limbs as mediated by muscles, ligaments, and tendons — contributes to spatial awareness. Magnetoreception, ability to detect the Earth's magnetic field, has been discovered in various animals albeit subconsciously and not well developed, perhaps through magnetite in the brain.

Redirected walking (RDW) is a VR technique to enable realistic walking within a limited tracking space by subtly manipulating the mapping between virtual and real environments to make a physically smaller space seem bigger. In an earlier contribution [NSC24], the authors developed an immersive environment that explored virtual azimuth gain [WZZ*23] to forgive limited physical rotation. A swivel chair, perhaps against a wall, as seen in Fig. 1, might have limited rotatability, but redirected seating (RDS) can virtually amplify rotation. We developed a plausible virtual scene

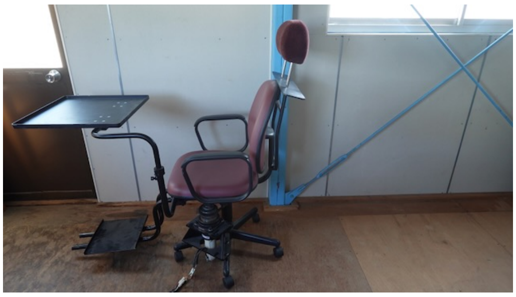

Figure 1: $^{S}_{c}ha_{i}r^{e}$ *rotary motion platform, against wall, inhibiting full and indefinite rotation, especially with projecting desktop and footrest.*

to justify limited excursion and inability to spin indefinitely. For static standpoint (actually "sitpoint"!), yaw gain can be hidden in rotation, not masked by head motion as in general RDW. Assuming that complementary and coherent cues can strengthen illusions, we introduce a soundscape to reinforce that coiling sensation.

2. Experience

At run time, the user selects a chair orientation corresponding to one of four cardinal directions: facing the inner core (Statue of Liberty), down the (left-handed) helical path, outwards from the inner core, and up the helical path. Such orientation may be changed during the excursion, which adjustment is animated by virtual rotation of the platform and with it one's own virtual direction. Since foot shuffling to spin a swivel chair is necessarily circumferential, and physical rotation is around the pivot point of the chair, which is slightly in front of one's vertical axis (parallel to the spine), per-

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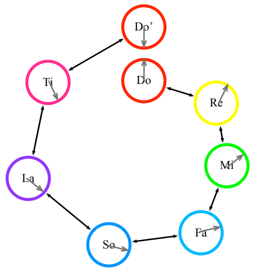

Figure 2: *Physical rotation and virtual revolution, encoded by major scale and color wheel.*

haps the most natural relative position is with one's back to the axial core. Since the helical musical scale is projected into egocentric space, redundantly encoded with both tone (8-note major scale) and direction. The closure represented by the 8^{th} note of the scale spanned by the octave establishes a "bracketing" context, like a closing delimiter such as a right parenthesis, reinforcing the boundaries of the experience. Since the notes of the major scale are uniformly spaced across the helix [Hoo22], the effect of continuous chair rotation across a half-turn is like a *glissando* across the white keys of a piano through an octave. Visible spheres representing the point-sourced scale notes are arranged at the same elevation and with the same pitch as the helicoidal ramp, but with variable radius. The grand piano notes rendered as the rotating chair enters each sector have sustained duration, so their acoustic tail can be heard even as new notes are triggered.

Various strategies have been used to track chair rotation, including electromagnetically and optically [CDHM07]. We deploy one of the XR controllers as a chair tracker, mounted to either armrest with a custom-designed, 3D-printed PLA cradle to be visible to the headset.

3. Analysis

The torque needed to twist a pivot chair, designed to rotate with minimal effort, is too weak to "auger" a human body mass up any considerable slope, but situational suspension of disbelief allows the sensation of inclined ascent, along the virtual ramp around the central object, summiting in a single (half-)revolution, as shown in Fig. 3.

Mechanical analysis suggests parameters that reflect the depth of such self-deception. A 1.25 N·m torque at an effective radius of about a quarter meter, from seat swivel axis to bipedal shuffle side-step contact points on the floor, implies 5 N of tangential force (since torque is the product of moment arm and linear force, $\tau = r \times F$). The mechanical effort of lifting a typical body mass of, say, 80 kg (neglecting weight of the chair) a differential elevation

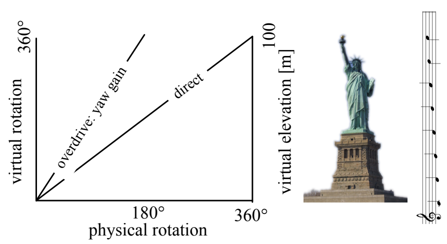

Figure 3: *Unwrapped helix for direct and RDS with musical cues*

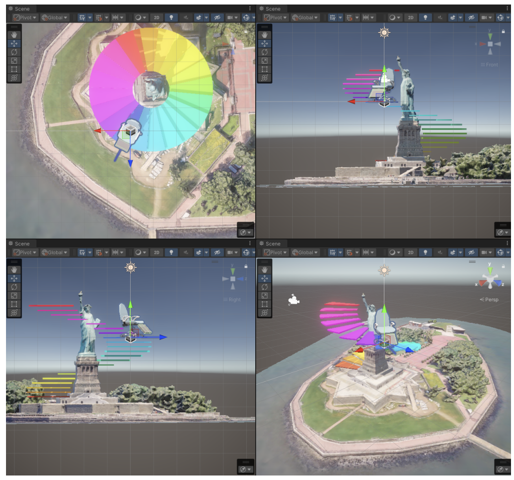

Figure 4: *Views of the helical soundscape, helicoidal ramp, and central object.*

of 100 m requires 80 kJ (since work is force times distance, and force is mass times the gravitational constant, 9.8 m/s^2), so that 5 N would need to be continuously exerted over 16 km. The radius of the helicoidal ramp is 40 m, so each revolution at the severe pitch of 100 m traverses about 270 m and almost 60 turns would be required, not $\frac{1}{2}$ (actual: physical) or 1 (RDS-amplified: virtual). Therefore, the cognitive dissonance resolution can be thought of as having a magnitude of about 100, half of which is due to the virtual screw, half of which is due to azimuth gain.

4. Conclusion

In the future, we will compare the various configurations through formal psychophysical experiments. The conditions of such comparisons will correspond in part to the parameter settings. We will also test using the motorized chair. Since it has a foot rest, the user should be even more separated from physical proprioceptive cues that could interfere with sensation of amplified rotation, and also conflicting sense of facing outward due to having to pivot the chair with one's feet vs. the virtual cardinal direction.

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