Resolving Spatial Variation And Allowing Spectator Participation In Multiplayer VR

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ABSTRACT
Multiplayer virtual reality (VR) games introduce the problem of variations in the physical size and shape of each user's space for mapping into a shared virtual space. We propose an asymmetric approach to solve the spatial variation problem, by allowing people to choose roles based on the size of their space. We demonstrate this concept through the implementation of a virtual snowball fight where players can choose from multiple roles, namely the *shooter*, the *target*, or an onlooker depending on whether the game is played remotely or together in one large space. In the co-located version, the *target* stands behind an actuated cardboard fort that responds to events in VR, providing non-VR spectators a way to participate in the experience. During preliminary deployment, users showed extremely positive reactions and the spectators were thrilled.

Author Keywords: Virtual Reality; Multiplayer; Mobile; Asymmetrical VR; Haptics; Input Devices; Actuated.

ACM Classification Keywords: H.5.1. Information Interfaces and Presentation (e.g. HCI): Multimedia Information Systems - *Artificial, augmented, and virtual realities.*

INTRODUCTION
Starting with multiuser dungeons (MUDs) in the late seventies, online social worlds evolved with the capabilities offered by the Internet into complex virtual spaces for social interaction and play [2]. Introduction of room-scale VR poses several new challenges in scalability and human factors [1] for multiuser virtual spaces. One such challenge, which we address in this paper, is the unavailability of sufficient space for physical movement for some players. Another challenge we address is the inclusion of non-VR spectators into the VR experience, demonstrated in the co-located gameplay version of our implementation. Prior approaches that tackle space limitations lack a match between proprioceptive information from human body movements (e.g., walking, hand movements) and sensory feedback from VR which can reduce a user's sense of presence [3].

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Figure 1. Two users testing the prototype with GearVR. Inset shows the view from the *shooter's* perspective. The virtual snow fort blocks have a 1:1 correspondence with the physical boxes in orientation, scale and count. When a virtual block collapses, the corresponding physical box also collapses.

In this paper, we propose a design approach to the spatial variation problem for multiplayer scenarios i.e, users do not have the same sized play areas, in the form of asymmetric or role-based play. We describe a mobile VR game prototype that enables different roles depending on each user's available physical space. We include two play modes, namely remote play to allow space based roles and co-located play to allow spectating.

The game is similar to a real world snowball fight with two players, one of whom shoots snowballs with a re-purposed Nerf gun, while the other defends themselves by dodging snowballs or hiding behind a snow fort made of actuated boxes (Figures 1, 3a, 3c). The *shooter* only requires standing space, while the *target* needs a larger area for dodging and for the actuated snow fort during co-located play. Our approach is novel for remote gameplay in that most current VR multiplayer games are symmetric experiences where each person plays a similar role, e.g., Hover Junkers, a multiplayer shooter game where each user is a shooter in a room sized ship. While it is a clever solution to the space problem, it is also limited to specific types of gameplay. Asymmetric design is a general concept that can be applied to a variety of genres like puzzles, shooters, or casual games where the gameplay can be split into various roles. Additionally, the co-located play

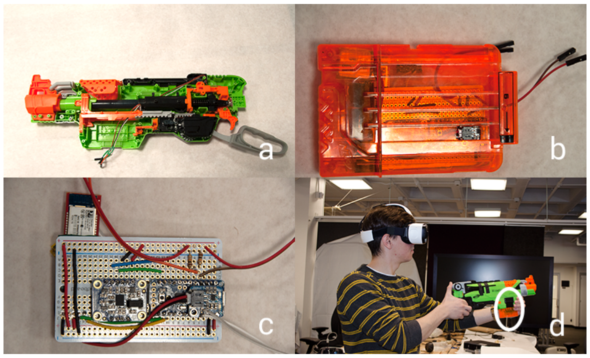

Figure 2. a) Re-purposed Nerf gun as a VR input device that shoots out a virtual snowball on each trigger press. Reloading is detected by attaching a small magnet and a reed switch which is triggered when the gray lever is pulled back. b) Ammo holder with the circuit inside. c) Protoboard mounted with an on/off switch, a 9-DOF IMU, Bluetooth connector, and a battery. d) The *shooter* aiming the modified gun at the *target*. The ammo holder with circuit inserted back into the Nerf gun shown inside white circle.

mode incorporates elements that allow non-VR spectators to become VR participants.

SNOWBALL IMPLEMENTATION

The system consists of three parts namely, GearVR head-mounted displays to view the virtual world, a snow gun that is the input device (Figures 2a, 2d), and the actuated cardboard box fort physical output system, which has a 1:1 correspondence in scale and orientation with a virtual snow fort. The re-purposed Nerf gun acts as a snowball shooter. It is connected via Bluetooth to the *shooter's* GearVR device (Figure 2c). The *shooter* aims by pointing the gun for a more natural experience. On each trigger press, the gun shoots out one snowball and can be reloaded by pulling back on the reload lever after ten shots. We implemented real-time tracking so that the virtual gun movements match the physical gun's movements for a realistic experience. The game can be played both remotely and in the same physical space though the challenges resolved vary i.e., spatial variation vs spectator participation.

In co-located play, the *target* stands behind a stack of cardboard boxes (Figures 1, 3c), each of which is connected to a stepper motor in the controller box via a fishing line (Figures 3b, 3d). Their hands are tracked and displayed in VR using a Leap Motion sensor (*www.leapmotion.com*) attached to the front of the GearVR. The goal of the game is to drop the *target's* health to zero. The *shooter* aims at the *target* who can duck to dodge the snowballs and also hide behind the snow fort. If a particular spot on the virtual snow fort is hit three times with a snowball, that block collapses virtually and so does its corresponding physical box. The *target* can hear the loud sound and feel the real fort collapse as they see the virtual fort collapse in VR while any non-VR users in the same space can see the *target* ducking and the boxes collapsing in response to the pointed Nerf gun of the *shooter*.

PRELIMINARY DEPLOYMENT

We deployed the prototype in our lab for people to experience it during the semi-annual open house. A total of 27 participants tried our system, both as the *shooter* and *target*, for a duration of about 6 minutes each. Reactions were extremely positive and some people turned dodging snowballs into a dance or a workout. Since the participants were in an open space, the spectators were able to participate without the need for HMDs. The snow gun made it obvious that the person was shooting an invisible projectile at the person behind the snow fort and the collapsing boxes indicated that changes in the virtual world were being replicated in the real world.

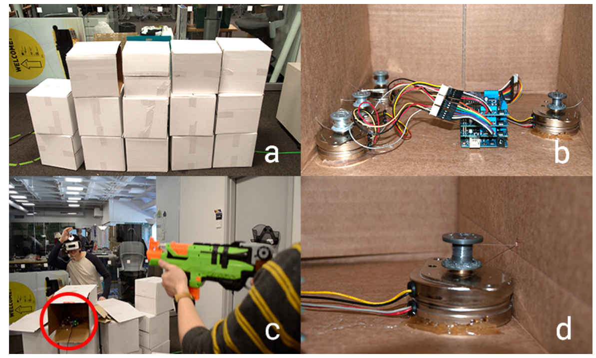

Figure 3. a) Snow fort made of actuated cardboard boxes. b) Stepper motors inside a controller box, each connected via fishing line to a box face. c) Player behind snow fort dodging virtual snowballs. The box inside the red circle is the controller box as shown in c). When the snow fort is hit with a virtual snowball, the appropriate stepper motor spins and retracts the fishing line which pulls on the face of a connected box, making it collapse. d) Motor with 3D printed bobbin. 3' - 4' of fishing line is threaded through two adjacent holes in the motor and wound around the bobbin. The fishing line is connected to a box face at the other end and held taut to hold the box upright.

CONCLUSION AND CONTRIBUTIONS

We described a prototype built to investigate the asymmetric design approach for resolving spatial variation in multiplayer VR games and added a co-located play mode for spectator participation. The system included two roles, a standing role and a moving role and each user experienced the shared virtual world from a first person perspective. In summary, this work provided an example application of the asymmetric design approach for multiplayer VR by contributing (1) the implementation of the hardware, achieved by re-purposing an existing Nerf gun and cardboard boxes, and (2) the software implementation of the client-server architecture for the multiplayer virtual world with real-time hand tracking for all users.

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