A Demonstration of Conveyor World: Mixed Reality Game on Physically Actuated Game Stage

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Abstract
In this research, we develop an immersive mixed reality game environment using an actuated surface as a game stage. One game player creates the game environment by arranging tangible objects; those objects linearly flow and interact with a virtual character manipulated by another player. We expect that game enjoyment could be leveraged while being highly immersed into mixed reality game world. Also, new kinds of interaction between two players with different game roles are expected. The prototype was pilot-tested and planned for demonstration.

Author Keywords
Mixed Reality; Actuation; Tangible User Interfaces; Game Design

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
As interactive technology develops, ways to blend the real and virtual worlds have been widely explored. Free of the limitations of a display, augmenting tangible properties encourages natural behavior, resulting in seamless user interaction. Particularly in the entertainment domain, mixed reality is thought to be a

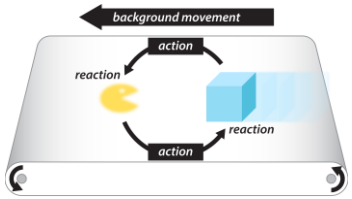

Figure 1. Interaction between real and virtual on moving conveyor belt system

promising game area in which people become highly immersed for enjoyment. While an immersive mixed reality game interface aims to create a well-balanced combination of real and virtual worlds, in most cases, the virtual elements mainly change their conditions and representations over real objects. A tangible game property can become active and responsive through programmed actuation logic. Utilizing actuated tangibles as game components can emphasize the physical properties of objects and thereby contribute to mixed reality game interface design by enhancing the reality of the game experience.

In this paper, we capitalize on the use of a conveyor belt system to enhance the physical properties of objects. By utilizing the conveyor belt in a mixed reality environment, even mundane objects can act as interactive objects (see figure 1). We developed a prototype named "Conveyor World", a multi-player projection-based mixed reality game that uses a real-world conveyor belt as a moving game stage. Through this concept, we expect game players can be more immersed into the world between the real and virtual worlds while mixed reality game components of the world act and reacts each other.

Related Works

Existing mixed reality games are mainly designed in a manner that emphasizes representations of virtual properties. Various projects have tried to integrate physical properties into game interaction for effective blending between real and virtual worlds. For example, IncreTable used robotic components for their dynamic game environments [5]. Game systems that involve movement in a specific direction, such as Nuts Rider, used a moving surface with miniature toys as the background of a virtual racing game [1]. World Locomotion developed a locomotive display sliding along a horizontal rail [2]. These studies focus on enhancing game immersion by physically actualizing virtual contents. Actuation helps when dynamically configuring a tangible user interface (TUI) because it broadens the design possibilities by improving the level of consistency between virtual and real properties [4,6].

This research, by utilizing a wide range of tangibles for actuation, ranging from the game surface to tangible game pieces, enabled seamless mixed reality that leverages game excitement and presence in the mixed reality system.

Conveyor Belt as Actuated Game Stage

To implement an actuated surface as the background for a mixed reality game, we utilize a conventional conveyor belt system. The spatial length of the conveyor belt can provide different mixed reality game environments depending on the position and duration of an object on the belt. While an object is being conveyed along the belt, a game interface can be supported that constitutes a dramatic transition between the real and virtual worlds. Also, the continuous one-way movement of the conveyor belt is reminiscent of game backgrounds common in traditional video games. As in traditional video games such as Galaga and Skyroads, a flow of the background toward the game player provides a constant challenge, eliciting a sense of tension and thrill. Using the conveyor belt approach in a mixed reality configuration can serve to move the game background motion out of the flat display and into the physical world.

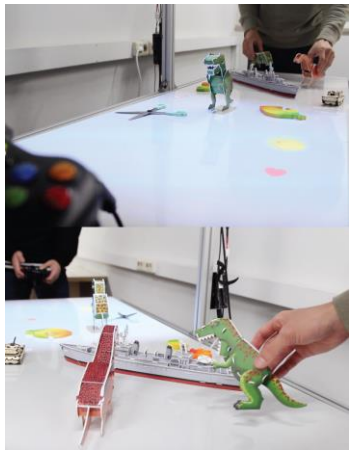

Figure 3. The Conveyor World system supports mixed reality game interaction on the moving conveyor belt using two players who play different roles

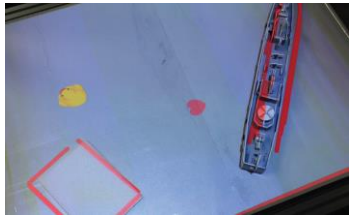

Figure 4. Tangible objects that are extracted as bounding boxes for mixed reality game interaction

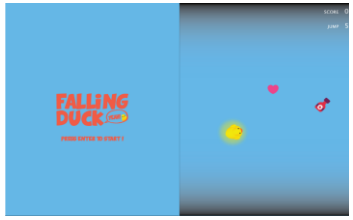

Figure 5. Mixed reality game named 'Falling Duck' on Conveyor World system

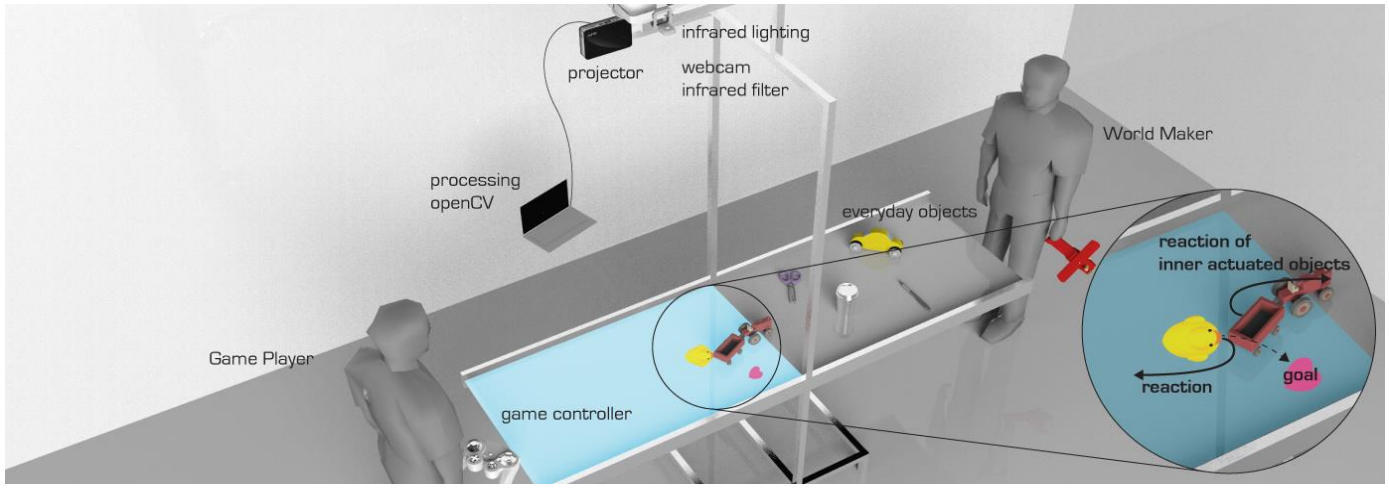

Figure 2. System configuration of Conveyor World design concept

Conveyor World

Conveyor World

We developed a prototype called Conveyor World, which is a mixed reality game system concept that relies on the actuation of physical game properties. Here we describe our decisions and development of hardware and software of the Conveyor World system.

Hardware Design

In this system, we implement a projector-camera system over a conventional conveyor belt system (see figure 2). We employed a conventional conveyor belt system (1500 mm × 580 mm × 750 mm in size) with an aluminum chassis. To instrument the projector-camera system, the belt is fully covered with IR-reflective film, which enhances the process of detecting objects on the belt. The projector and a webcam were placed 2.3 m and 2.7 m from the floor, respectively. In this system, high-speed object detection was achieved by minimizing the surrounding disturbances using infrared(IR) lighting and an infrared optical filter (850 nm wavelength). Various tangible objects, including everyday objects, model objects and actuated objects, are provided for the World Maker role. In particular, the objects with embedded motors were developed to exhibit a shaking motion as their internal motor rotated in response to a wireless signal using Jarduino BT mini microcontroller.

Software Design

The computer language named Processing and the computer vision library OpenCV were used to program the software[3]. Tangible objects in the game are extracted as outlined bounding boxes by the game engine (see figure 4). Then, information about the object obtained through OpenCV can be utilized in the game code to detect collisions between the extracted object and projected digital contents. The virtual game contents of Conveyor World system were developed using the processing-compatible Fisica library.

Game Roles: the World Maker and the Game Player

We configured the game system with two different roles: one for manipulating real objects and one for

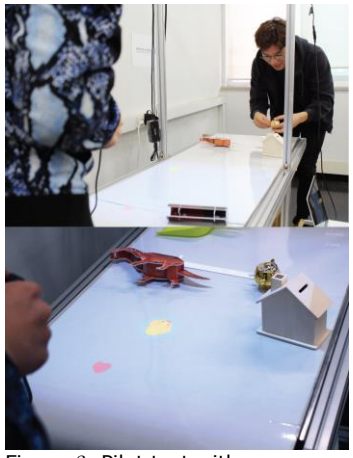

Figure 6. Pilot test with participants grouped together

manipulating virtual objects. The two players are separated, one on each side of the conveyor belt. The World Maker role operates tangibles (real objects) while the Game Player controls the virtual components. The World Maker freely arranges various types of physical objects at the starting point of the belt, and the Game Player manipulates the projected virtual game character using a gamepad. Motivated by 'The Flat World', the Game Player role controls a virtual duck character that attempts to avoid tangible objects and climb to the top of a waterfall. As the objects placed by the World Maker move, they play a role as tangible obstacles that block the virtual character. While exchanging game roles, the Game Player manipulates the virtual character for the purpose of achieving a higher "heart score" than the opponent and must jump over the introduced items to survive from falling.

Pilot Test

We conducted a pilot test with participants using our current implementation of Conveyor World (see figure 6). We ensured that the game system was working properly in actual game play condition. The results from the pilot test supported our assertion that our mixed reality game system on physically actuated background encourages players to be immersed into game play between real and virtual worlds. Participants commonly mentioned that the conveyor belt system plays a major role in providing an animated game environment.

Conclusion

This paper introduces a mixed reality game with physically actuated components that uses a conveyor belt as a game stage. The proposed system aims to provide an immersive game experience with consideration of actuated tangibility for seamless interaction between tangible and virtual properties. We hope our work inspires in configuring physical actuation as game component in the field of mixed reality game.

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