Purpose-Centric Appropriation of Everyday Objects as Game Controllers

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Abstract

Generic multi-button controllers are the most common input devices used for video games. In contrast, dedicated game controllers and gestural interactions increase immersion and playability. Room-sized gaming has opened up possibilities to further enhance the immersive experience, and provides players with opportunities to use full-body movements as input. We present a *purpose-centric* approach to appropriating everyday objects as physical game controllers, for immersive room-sized gaming. Virtual manipulations supported by such physical controllers mimic real-world function and usage. Doing so opens up new possibilities for interactions that flow seamlessly from the physical into the virtual world.

As a proof-of-concept, we present a 'Tower Defence' styled game, that uses four everyday household objects as game controllers, each of which serves as a weapon to defend the base of the players from enemy bots. Players can use 1) a mop (or a broom) to sweep away enemy bots directionally; 2) a fan to scatter them away; 3) a vacuum cleaner to suck them; 4) a mouse trap to destroy them. Each controller is tracked using a motion capture system. A physics engine is integrated in the game, and ensures virtual objects act as though they are manipulated by the actual physical controller, thus providing players with a highly-immersive gaming experience.

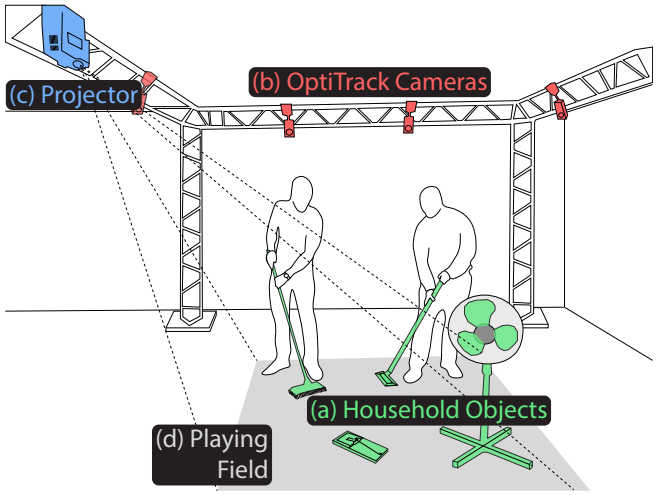

Figure 1: The game setup consists of (a) household objects with reflective markers, (b) an OptiTrack system, (c) a projector, and (d) the game environment projected onto a floor.

Author Keywords
Immersive games; Tangibles; Everyday objects; Purpose-centric interactions.

ACM Classification Keywords
H.5.2. [User Interfaces]: Input devices and strategies, Interaction styles.

Introduction
Traditionally, a generic handheld controller has been the primary method to interact with the content and characters of video games. They are integrated with buttons, joysticks, or directional pads, to enable user input and game controls. The popularity of sensor-based input has given rise to controllers that interpret physical motions of users, to enable interaction with the game. In such systems, users perform pantomimic gestures to interact with the game. For instance, in a tennis game on Nintendo Wii, the user holds an imaginary racket and makes pseudo-realistic arm motions to manipulate a virtual ball. Room-sized gaming has opened up new possibilities for blending physical and virtual environments. As demonstrated in RoomAlive [3], such gaming environments provide extremely immersive experiences to users, and open new up new possibilities for gameplay and interactions. To physically interact with the virtual world in such an environment, we need to move away from the aforementioned pantomimic gestures, and investigate different possibilities to provide players more realistic gaming experiences.

Touch interactions such as grabbing, punching, or kicking virtual objects is one technique for providing these realistic experiences. While they satisfy the requirements for some games, these interactions are still quite limited. Several categories of video games support multiple virtual tools, gadgets, and equipment, for gameplay. For instance, first-person shooters provide players with a range of weapons, each exhibiting its own appearance, function, and ability. Using a generic game controller, it is trivial to switch between different tools, and use them as deemed appropriate. To bring this aspect to physical room-sized gaming, we envision the usage of various everyday objects, each with its own qualities, functions, and affordances. Previous approaches (e.g. [1]) of employing everyday objects as input devices have focussed on mapping affordances offered by objects to analogous digital input. For instance, since the cap of a bottle resembles a knob, the turning motion is mapped to manipulating a digital input knob. Instead of focusing purely on these affordances, we suggest that the physical controllers should have virtual renditions that mimic actual purpose and function of the object in the real-

world. In the example with the bottle, this would mean the game takes advantage of its real-world function of dispensing fluids, to provide an appropriate virtual interpretation. Doing so could aid in seamlessly transitioning from the physical to the virtual world, and has the potential to enhance the immersive experience.

To illustrate our concept, we present a mixed-reality room-sized game, using household objects as controllers. *Household Survival* is a 'Tower Defence' styled game, where players employ a set of household objects to fend off enemy bots, and protect their base. Each of the household objects has unique virtual attributes that are representative of their real-world function. Our implementation uses a motion capture system to track physical objects, and a floor projection to render the virtual scene (Figure 1. The physics engine, implemented in the game, translates users' manipulation of the household objects into realistic interactions with the game world. While our implementation illustrates the concept using a small subset of household objects, we believe that this can be generalized, and any physical object can be mapped such that the virtual utility of the object is representative of the real-world purpose. Doing so can extend the concept to different styles of games, and cover a large variety of physical objects, each exhibiting their own unique abilities and nuances.

Related Work

This work builds on previous research and developments in immersive gaming, tangible interactions using everyday objects, and the blending of physical and virtual environments.

Technological advancements in sensor-based input and vision-based systems have led to commercial success of devices such as the Nintendo Wii and Xbox Kinect. These have improved the immersive experience of screen-based video games. PlayAnywhere [4] used a projection-based system to enable gaming on table surfaces. More recently, and most relevant to our work, RoomAlive [3] illustrates the possibilities of room-sized gaming, where the physical and virtual spaces blend into each other. Players can interact using touch interactions, instrumented pointing devices such as a gun, or standard game controllers. In contrast, we propose the use of uninstrumented everyday objects to enable physical interactions that blend with the virtual environment.

The use of everyday objects for tangible input to computer systems has been explored previously. iCon [1] is a platform that enables the utilisation of everyday objects as instant tabletop controllers. It allows mapping actions such as click, drag, and rotate, to tangible interactions such as lift-and-place, move, and twist. While it takes into account the affordances offered by the physical object, the real-life purpose of the object is not considered. [5] provides a toolkit that enables the use of everyday objects as input devices to video games. Users can specify their own moves, or interactions, to control the gameplay. Again, while it promotes the use of household objects, it does not specifically consider the real-world purpose of these objects.

Our work emphasises the integration of both function and style if interaction with everyday objects in immersive-room sized gaming experiences, in a way that the real-world purpose of physical objects is taken into account.

Everyday Objects as Game Controllers

We have developed an immersive room-sized game prototype titled 'Household Survival' to serve as a testbed for the proposed *purpose-centric* interactions. A 'Tower Defence' styled multiplayer game is implemented, where players aim to fend off enemy bots, to protect their base (Figure 2). Bots

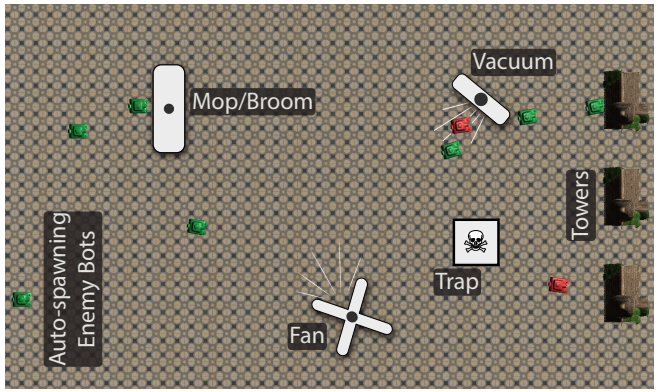

Figure 2: Top-view of the game scene. Physical objects are represented by their footprints (in white). Bots spawn from one end of the playing field, and approach players' towers, located at the opposite end.

are spawned continuously, and approach the players' base, located on the other end of the playing field. Each player uses one of the everyday objects as weapon, to divert the path of the bots, obstruct them, or to destroy them.

As a proof-of-concept, we present a set of physical controllers, using everyday household objects, which we have integrated into our game prototype (Figure 3). Our game uses four different household objects as weapons, to fend off enemy bots. Each of these has its own capability, which mimics the purpose of the object in real life.

1. **Floor mop or Broomstick**: A floor mop or classic broom is used to sweep aside the enemy bots. It allows players to accurately drag virtual objects across the play field, to a desired location.

2. **Pedestal Fan**: A pedestal fan is used to blow away

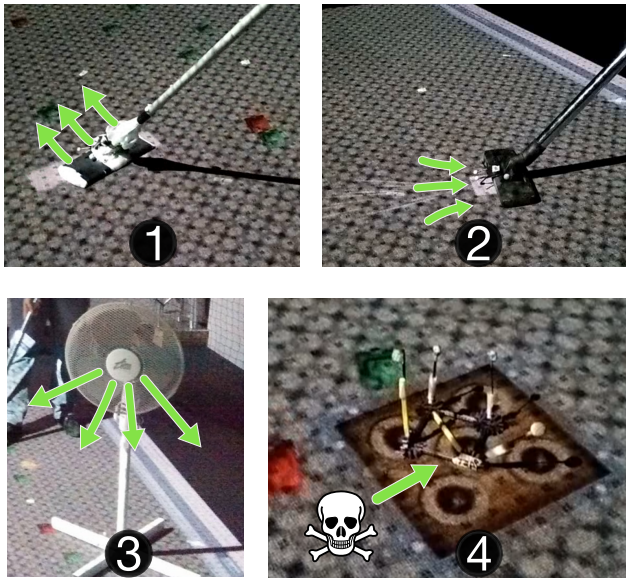

Figure 3: Household objects used as game controllers (weapons). Players can use (1) a floor mop (or broomstick), (2) a vacuum cleaner, (3) a fan, or (4) a mousetrap to fend off enemy bots. The arrows indicate the resulting physical forces emulated by the game engine.

game objects. Unlike the mop, the fan blower does not allow for fine-grain control over the direction in which the objects are dispersed. Instead, they are scattered in the direction of the blowing air.

3. **Vacuum Cleaner**: Objects in the vicinity of the nozzle experience the suction forces of a vacuum cleaner. When these objects are close enough, the vacuum cleaner pulls them into the tube, hence destroying them.

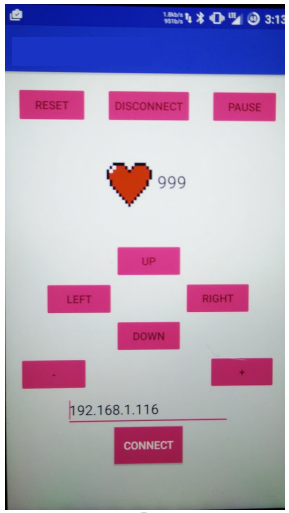

Figure 4: The smartphone app (a) and Android Gear app (b) enable users to fine-tune calibration, track scores, and provide other game options

4. **Mousetrap**: Made using K'nex components [1], this is used to trap objects that go over it. Like a traditional spring-loaded trap, the game's mousetrap can not continuously capture objects. Instead, it can do so only when it is in the 'loaded' state. The game uses a visual overlay, rendered over the physical object, to display the active and inactive states.

The above four objects allow for compelling physical interactions in our game prototype, and provide a testbed to illustrate our concept.

We also envision the integration of several other everyday objects. These have not been implemented by us, but can be easily integrated. For instance, water bottles and mugs have been used by previous works to provide input actions such as clicking, or rotating a knob [1, 2]. However, the real-world purpose of bottles and mugs is to contain and dispense liquids. Our game design would hence use these objects to pour out liquids, and submerge or drown opponents. Additionally, it could be used to collect ephemerally-flowing objects such as reward coins. [2] also use a pen clicker to manipulate a slide deck. Instead, our game design would allow players to draw boundaries around opponents, direct them along drawn paths, or sketch out new obstacles. A clothes iron can be used to smooth out wrinkles from a terrain, or to burn opponents. As a last example, a hair dryer could also be used to blow away objects, or to dry up wet terrains.

While affordance-centric integration of everyday objects into virtual environments enables the users to easily recognize what interactions are possible, it does not immediately reveal the resulting interpretation, in the digital realm.

[1] http://www.knex.com

Purpose-centric integration, as illustrated with the aforementioned household objects, can help users in immediately recognizing, or envisioning, the effect of physical interactions in the virtual environment. This enhances the user experience and playability, and, in addition, improves the usability of everyday objects for digital interactions.

Implementation

The implementation of the 'Household Survival' games consists of accurate tracking of physical objects, physics-based game logic, and floor projection of the scene.

Object Tracking

Reflective markers are attached to each of the everyday objects, and they are tracked, as rigid bodies, using an OptiTrack Motion Capture System. This allows us to accurately estimate the position and orientation of the objects, in relation to the playing field.

Field Calibration

Two stationary rigid bodies mark the field extremities. These are used for calibrating the playing field, at the start of the game. An accompanying smartphone application (Figure 4a), implemented for Android, allows users to fine-tune the calibration of the field and physical objects.

Physics Engine and Unity Game

Data captured using the tracking system is interpreted by the game. The physics engine takes into account physical characteristics and nuances of each everyday object, and accordingly enables interactions with game objects. The game itself is implemented using the Unity engine, in .NET/C#. We use a ceiling-mounted short-throw projector to display the virtual environment on the floor.

Scoreboards and Game Options

Players have two options of keeping track of the current

score. Firstly, a scoreboard is rendered on the game scene. The position of this scoreboard is represented by a tangible object, and can be moved around by players, if it obstructs the field view. Additionally, an accompanying Android Wear application (Figure 4b) enables users to glance at the scoreboard, on their smartwatch, and provides game options such as pause and restart.

Conclusion and Future Work

Our work stresses upon the importance and benefits of *purpose-centric integration* taking the real-world purpose of everyday objects into account for virtual usage. When designing for immersive experiences that blend the physical world with virtual experiences, this improves the overall user experience. Our domain of focus is room-sized gaming, for which we apply purpose-centric integration by using household objects as game controllers. While our implementation touches upon one type of game ('Tower Defence'), other game styles are yet to be explored. In our proof-of-concept, we integrate a small subset of everyday objects into the game prototype. Initial informal demonstrations show users are able to immediately interact with the game using already known mappings from the everyday objects that are available in the room.

Our current work has not formally evaluated the approach we have proposed in this paper. In the next step, we can validate the concept of 'purpose-centric' interactions, by conducting studies that firstly evaluate usability and learnability aspects of this approach—we predict that our approach can improve usability since it enables users to immediately associate a tangible object's virtual function based on real-world experiences. Secondly, further studies should also compare perceived immersion with traditional controllers and with tangible objects, appropriated in a purpose-centric fashion. To expand the scope of our work, future work can comprehensively look into a wider range of objects, and summarize them by their physical properties and functional attributes. Doing so can provide game designers with a design space, and guidelines, for integrating these objects into their games. Finally, to open up further possibilities integrating physical objects into digital environments, it can be beneficial to develop end-user tools that allow users to not just map input to output interactions, but also specify the appropriate physics in the virtual world.

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