Classifying Input for Active Games

Tadeusz Stach, T.C. Nicholas Graham, Matthew Brehmer, Andreas Hollatz
School of Computing
Queen's University
{tstach, graham, 4mb14, andreas}@cs.queensu.ca

ABSTRACT
Active games are video games that involve physical activity. Active games capture input via a variety of devices such as accelerometers, cameras, pressure sensors and exercise equipment. Although active games have become highly popular, the interaction styles they support are poorly understood, and largely driven by the capabilities of individual hardware devices. In order to allow for a standard development approach, a better understanding of the interaction found in active games is required. We have investigated existing commercial and academic games in order to classify input for active games. Our classification abstracts input from hardware, providing a better understanding of the interaction itself. Our ultimate goal is to make it easier to develop active games independently of underlying input hardware.

Categories and Subject Descriptors
H.5.2 [User Interface]: Input devices and strategies, Interaction styles;

Keywords
Active video games, exercise video games, exergaming

1. INTRODUCTION
Active games, video games that involve physical activity, have become tremendously popular in recent years. Examples of active games include Wii Tennis, Dance Dance Revolution and Frozen Treasure Hunter [13]. Nintendo's Wii, a console designed to support active gaming, has sold over 45 million units to-date, strongly illustrating the popularity of such games [9]. Recently announced motion sensing technologies, such as Microsoft's Project Natal and Sony's motion controller, have further increased the interest in active gaming.

Despite this commercial success, the interaction techniques underlying active games are as yet poorly understood. Most active games are designed for a specific hardware platform: Wii games are based on input from accelerometers and IR tracking, while EyeToy games are designed around camera input. This is analogous to the early days of graphical user interfaces, where programmers needed to deal directly with mouse input rather than using high level widgets such as menus and scroll bars.

We address this problem by presenting a classification of input techniques in active games. We identify six input styles, abstracting the details of hardware from the interaction itself. To develop the classification, we reviewed 107 active games, drawing from commercial, academic and "fantasy'' game designs, and extracted the common forms of interaction.

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This high-level classification represents a first step towards standardizing the input types that active games provide. Understanding these input types can allow diverse technologies (e.g., camera vs accelerometer) to provide the same programming interface. While several frameworks have been proposed for specifying the capabilities of input devices in general [2, 3], this paper represents the first attempt to categorize the inputs used in active games in a hardware-independent way.

We start by reviewing existing hardware used in active video games and the forms of input they capture. We then present our classification of input for active games, and provide illustrations of how the classification can be used to describe existing games. Finally, we summarize implications for designers.

2. ACTIVE GAMING HARDWARE
Although a relatively new form of entertainment, active gaming is supported by numerous special-purpose input devices. These include accelerometer and camera-based devices, modified exercise equipment, and touch-sensitive pads.

Accelerometers and gyroscopes: A typical six degree of freedom accelerometer reports acceleration in the three spatial axes and rotation around those axes. Accelerometers are used in Nintendo's Wii Remote and Nunchuck (see figure 1A), and several academic games [1, 11] to detect and interpret different kinds of motion. Nintendo's Wii Motion Plus improves accuracy using gyroscopes.

Vision: Cameras can be used to capture players' positions and movement. Basic vision systems include the Sony EyeToy (see figure 1B) and the PlayStation Eye. Several academic games use one or more cameras to track player movement [4, 5, 8]. A related approach is to use a camera to track infra red (IR) tags (e.g., the Dodge-It game [12]). Vision can be augmented with other technologies to improve its accuracy. For instance, vision is combined with ultrasound in Sony's newly announced motion controller, and with 3D imaging in Microsoft's Project Natal

Exercise Equipment: Some active games adapt traditional exercise equipment, for example using the gear and pedaling speed of a bicycle to power an in-game avatar. Commercial systems include the PCGamerBike (see figure 1C), Fisher-Price Smart Cycle, and the Gamercize products. Stationary bicycles have also been used in academic games such as Frozen Treasure Hunter [13] and Heart Burn [10].

Pads and Mats: Several popular games use large pads or mats, placed on the floor or mounted on a wall, to capture user input. These peripherals typically include touch sensors to capture contact (or weight distribution) in a particular region of the device. For example, Dance Dance Revolution uses a floor mat to determine when a player steps on a particular square of the surface (see figure 1D). Other commercial pads and mats include the Nintendo Power Pad, the Wii Balance Board, and the XaviX J-Mat. The Remote Impact game uses a wall mounted pad to capture players' kicks and punches [7].

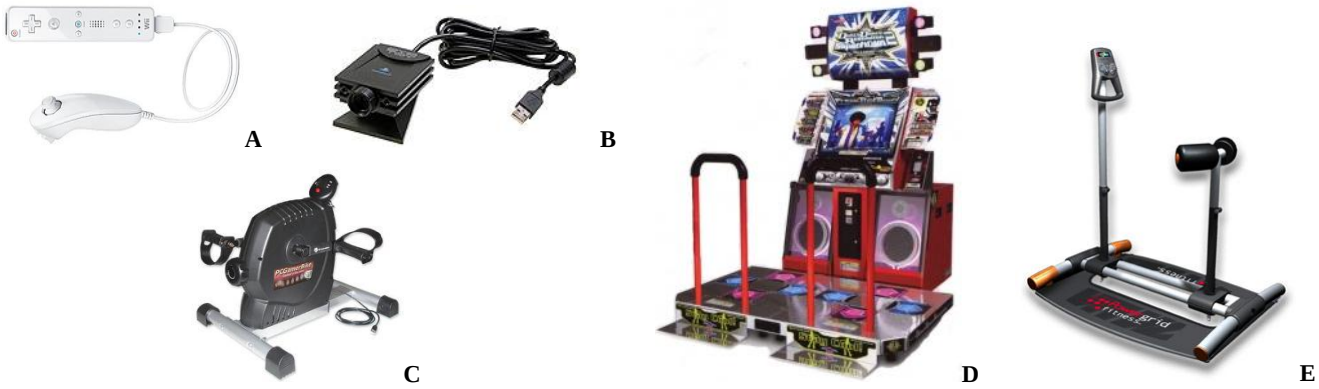

Figure 1: Active gaming hardware examples. (A) Nintendo Wii Remote and Nunchuck, (B) Sony EyeToy, (C) PCGamerBike Mini, (D) Konami Dance Dance Revolution, (E) Powergrid Fitness Kilowatt

Special Purpose: Other hardware has been created for specific active games. For instance, the Powergrid Kilowatt game controller (see figure 1E) is a resistance training device which acts as an exaggerated joystick [8]. The FlyGuy game [8] requires a specially developed hang-gliding harness to play.

3. METHOD

To develop our categorization of input in active games, we analyzed the input techniques used by 107 active games (including training systems such as Wii Fit and EyeToy: Kinetic). From this data, we abstracted a set of input styles. We examined a broad spectrum of games drawn from three categories: commercial games, research prototypes, and fantasy game designs. These categories allowed us to consider proven game designs, designs originating from research laboratories, as well as imaginative blue-sky designs.

Commercial games fell into three sub-categories: Wii, EyeToy, and "other." The Wii games cover a broad set of titles using the Wii Remote and Nunchuck, the Balance Board, and a combination of both. The EyeToy category contains an exhaustive list of active games using the EyeToy camera. The "other" games category is made up of active games tied to specific commercial equipment such as the PCGamerBike, the XaviX J-Mat, and Microsoft's Project Natal.

We examined 17 games reported in the academic literature. These include mixed-reality games and games designed to promote physical activity. We restricted this category to games that could be played in the living room, and therefore did not include ubiquitous games.

In order to explore interactions that may not exist in currently available games, we additionally surveyed a set of "fantasy" game designs, provided by five researchers working in an academic video game lab. Since the researchers did not have to actually implement the games, they were limited only by their imagination. This increases our confidence that our categorization may also address games of the future.

Game Type		Total
Academic		17
Commercial	Wii	35
	EyeToy	15
	Other	17
"Fantasy"		23
	Combined Total	107

Table 1: Total number of game types investigated.

In total, three researchers investigated 107 active games (see table 1). We played those games which were available and reviewed descriptions and videos of those which were not. We described the input for each game in a hardware-independent fashion. From this raw data, we abstracted a set of general input types. Most active games involved a combination of input types.

Our criteria for identifying input types were:

- The input type must be hardware-independent. We define this by requiring that it must be possible to capture the input with at least two existing input technologies.
- The input type must be seen in at least three games.
- The set of input types must be orthogonal, and must cover the inputs seen in the examined games.

4. INPUT CLASSIFICATION

After reviewing the input techniques found in the set of 107 games, six common forms of input emerged: gesture, stance, point, power, continuous control, and tap. Here we define each of the input types and describe their use in games.

4.1 Gesture

A *gesture* is a movement of the limbs, head, or body within a defined pattern. The location and orientation of the body is normally irrelevant to a gesture, but timing is important. For instance, players of Wii tennis must hit a tennis ball using a forehand or backhand swing gesture with a Wii Remote. The force of the swing determines the speed of the returned ball. Gestures specify commands, not real-time control. When a gesture is complete (e.g., forehand/backhand swing), it is communicated to the application, which executes an associated command (e.g., avatar performs forehand/backhand swing).

4.2 Stance

Stance captures a player's physical position at an instant of time. A stance is not an action, but describes the placement of the player's feet, hands, and body. For example, in Wii Fit Yoga players must complete a series of poses. Players stand on a Wii Balance Board and hold their bodies in a required position, which is captured in approximate form based on their distribution of mass. Similarly, in Posemania, players are required to take on dance positions in time to music [11]. The player's position is determined from a set of accelerometers attached to her wrists, elbows, knees and ankles.

Game Type	Input Classification					
	Gesture	Stance	Point	Power	Continuous Control	Tap
Academic	6	1	0	2	8	1
Commercial	42	19	5	8	8	12
"Fantasy"	21	15	4	1	0	0
Total	69	35	9	11	16	13

Table 2: Input classifications found for each game type examined.

4.3 Point

Pointing requires players to direct attention to an on-screen entity. Players point by aiming a finger, hand, or hand-held device at a region of interest. Pointing is used as input for the Secret Agent game found in EyeToy: Play 2. Players must point with their finger at a series of on-screen icons in order to collect them. In Call of Duty: World at War for the Wii, players aim their weapons by pointing the Wii Remote at the screen.

4.4 Power

Power represents the raw physical energy exerted by the player. Power is often tied to movement of the player's in-game avatar with input typically captured continuously over a period of time. A wide variety of input technologies can be used to provide power. For example, the PCGamerBike can be mapped to a set of input controls for the World of Warcraft game. Intensity (measured as pedal speed in RPMs) translates into three possible speeds for a player's avatar: stationary, walking, or running. Conversely, in Heart Burn [10], power is measured using a heart rate monitor, where current heart rate (indicating how energetically the player is exercising) regulates in-game speed.

4.5 Continuous Control

Continuous control input slaves body movement to an in-game entity. With continuous control, it is possible to capture movement in two or three dimensions. For instance, in the Body-Driven Bomberman game [5], the movement of a player's character is determined by the players position in a physical space. A top-mounted camera monitor's the player's position and maps it to a virtual position in the game. Thus, a player continuously guides her avatar as she walks/runs in the physical world. Similarly, in Microsoft's Burnout Natal, players steer a car by turning an invisible steering wheel with their hands.

4.6 Tap

A *tap* input requires a player to touch an object or location in the physical world, and is captured at the moment of contact. For example, the Remote Impact game [7] uses a wall mounted pad to capture players' punches and kicks (i.e., taps). Two distributed players face their own individual pad reflecting a projection of their opponent. Each player uses her hands or feet to strike the projected image of her opponent. The tap's location is used to determine if a strike is a hit or miss, while its intensity determines how many points the player is awarded for a hit. Similarly, in Dance Dance Revolution, players use their feet (and hands!) to tap locations on the floor in time to music.

4.7 Summary

The six input types presented above describe all of the active inputs found in the 107 active games we investigated. Many of these games also use traditional (inactive) inputs, such as button presses; these were not considered in our study.

Table 2 summarizes the distribution of inputs over our three game categories. We see that in this particular set of games, gesture and stance inputs are particularly prevalent. This is because of the popularity of the Wii platform, whose hardware is particularly adept at capturing gesture and stance. Nevertheless, with a few exceptions, all identified input types occur in all three game categories, and are represented numerous times over all. In the following section, we use this input classification to demonstrate how active games can be designed independently of the peripherals used.

5. ILLUSTRATIONS

To illustrate its effectiveness, we use our input classification to analyze two existing active games. This analysis shows that typical games combine multiple input types, and that these types can be considered independently of the hardware used to implement them.

5.1 We Ski

We Ski uses the Wii Remote, Nunchuck and Balance Board for input. In the game, players guide their skiing avatar down a virtual slope. The player holds the Remote and Nunchuck as if they are the handles of a set of ski poles, moving them up and down to push the avatar forward, and rotating them to make the avatar tuck into a crouching position. When standing on the Balance Board a player is able to control the direction of her avatar by leaning left or right.

These interactions fall into the gesture and stance input types. The pushing motions and the wrist rotations performed with the Remote and Nunchuck are gestures, while a player leaning side-to-side on the Balance Board takes on a series of bodily poses which translate into a set of stances.

Although the gestures in We Ski are captured via accelerometers (i.e., Wii Remote and Nunchuck), and stances are delivered by pressure sensors (i.e., Balance Board), the game could be implemented using different hardware. For example, an EyeToy camera could be used to capture a player's stance based on the position of her head and body. Similarly, arm gestures performed by a player could also be interpreted using vision techniques such as provided by the Sony motion controller.

5.2 Frozen Treasure Hunter

Yim and Graham created the Frozen Treasure Hunter game in order to promote physical activity [13]. Two players share the control of an avatar as they collect virtual items. One player controls the forward momentum of the avatar by pedaling on a recumbent bicycle, and steers using a gamepad. The other player uses a Wii Remote and Nunchuck to swat away virtual projectiles thrown at the avatar. The pedaling of the player on the bike translates into power input, while the swatting motions performed by the other player are classified as gesture inputs.

These inputs could be delivered using a variety of other hardware devices. For example, heart rate monitors have been proposed as effective devices for measuring a person's physical effort in active games (e.g., [10]) and therefore can deliver power input. The gestures used in Frozen Treasure Hunter could alternatively be captured using a vision based tracking system.

6. DISCUSSION

Our survey is based on existing games (and "fantasy" designs), as well as technical demonstrations of the recently announced next generation of motion capture devices (i.e., Wii Motion Plus, and Microsoft's Project Natal). Although new peripherals promise a revolution in the design of active games, the input they provide is described by our classification. For example, demonstrations of Microsoft's Project Natal show players using their full body to deflect virtual balls, while early prototypes of the PlayStation motion controller allow players to directly control hand-held weapons (e.g., swinging a mace). These actions map to direct control, gesture, and stance inputs. Therefore, the next generation of active input controllers does not change the types of active input that are possible, but rather improves the accuracy of their detection. The upcoming generation of devices does appear likely to change the input styles that are most widely used. Our analysis of existing commercial games showed a high occurrence of gesture and stance inputs (due to the current capabilities of the Wii and EyeToy); however, we expect future games to include more direct control inputs as a result of improved motion capture technology.

In determining the input classification, we explicitly excluded pervasive games [6], in favour of games that could be played in the living room. Given the advent of fast networks and portable devices with global positioning systems and accelerometers (such as the iPhone), it would be an interesting extension to the classification to include this style of game. We speculate that the main additional input would be locomotion, movement that takes a player from one physical location to another.

The core contribution of our input classification is that it helps identify the types of inputs that may be delivered to active games, independently of the underlying hardware that may be used to control the game. Beyond its contribution to the understanding of active input, the classification can be beneficial in the implementation of active games. We have begun to develop a framework to allow developers to program active games based on the six input types described in our classification. This opens the possibility of developing games independently of the underlying hardware. Designers should be able to create active games without having to consider the manner in which input is captured, allowing them to focus more on game content and story.

7. CONCLUSION

Currently, when designing an active game, developers must first consider what input hardware the game will use. Therefore, active game designers are limited to the capabilities of a specific hardware device. This situation limits creativity and the portability of active games. In order to address this problem we developed a classification of active gaming input.

In our development of the active game input classification, we examined interaction techniques in 107 active games. We were able to extract six major inputs types used in active gaming: gesture, stance, point, power, continuous control and tap. We believe that our input classification is the first abstract presentation of input in active games.

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