

# Enhancing Theme Park Experiences through Adaptive Cyber-Physical Play

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**Abstract**—In this vision paper we explore the potential for enhancing theme parks through the introduction of adaptive cyber-physical attractions. That is, some physical attraction that is controlled by a digital system, which takes participants’ actions as input and, in turn, alters the participants’ experiences. This paper is thus divided into three main parts; 1) a look at the types of attractions that a typical theme park may offer and, from this, the identification of a gap in an agency versus structure spectrum that recent research and industry developments are starting to fill; 2) a discussion of the advantages that cyber-physical play has in filling this gap and a few examples of envisioned future attractions; and 3) how such cyber-physical play can uniquely allow for adaptive attractions, whereby the physical attraction is personalized to suit the capabilities or preferences of the current attraction participants, as well as some foreseeable design considerations and challenges in doing so. Through the combination of these three parts, we hope to promote further research into augmenting theme parks with adaptive cyber-physical play attractions.

## I. INTRODUCTION

The theme park environment is a unique space for HCI investigations [1]. When compared to other social environments, such as the home, they are generally much larger and more public. When compared to similar large scale social environments, such as museums, they are generally more focused on entertainment and joyful emotions. When compared to similar public entertainment environments, such as theaters, they typically don’t rely solely on audio and visual content but rather elicit pleasure through physical sensations. Thus, people go to theme parks for novel experiences that are otherwise unattainable and so these centers of entertainment could potentially play host to many of the novel HCI prototypes that are introduced every year as well as innovations that are designed specifically for theme parks.

However, despite this intriguing space of possibilities, Marshall et al. [2] highlight the limited amount of HCI research in theme parks. This is most likely due to the high bar of entry; in order for researchers to gain access to these facilities they need to establish industry partnerships with theme park operators who have significant commercial commitments. However, if industry partners can be encouraged to participate in such innovation, then there is potential to redefine the theme park experience and inspire broader innovation. In a demonstration of this, Pausch et al. [3], in partnership with

the Disney EPCOT Center, conducted a long-term experiment into 3D virtual reality rides that has informed advancements in entertainment technology and game development practice in the last two decades, such as the use of head-mounted virtual reality systems and improved authoring tools for animators.

In this paper we present what we believe to be a promising opportunity within theme parks. It involves investigating new attractions that would bring *structured play* to the theme park, for which there are currently few occurrences of. By structured play we mean game-like experiences where there are rules and objectives but where participants have agency through varied forms of interaction and the ability to form complex strategies for success. Computer supported physical games, or *cyber-physical play*, would be one option for introducing these types of structured play experiences to theme parks. Cyber-physical play here refers to games where participants play a physical manner but where the rules and state of the game is mediated by some digital system. This could also be referred to as *ubiquitous play* [4] and implies a form of digital gameplay that uses non-standard input and output mechanisms. Stemming from the definition of *ubiquitous computing* [5], the goal here is for participants to focus on their physical and social interaction with other participants rather than focusing on their interaction with a computer system.

Furthermore, this paper goes on to highlight how such cyber-physical play attractions can be uniquely *adaptive*, using the principles of personalized games [6] to allow for a single attraction to respond differently to each participant based upon that participant’s preferences or physical capabilities. This would allow the attraction to be appropriate to wider audience by creating tailored experiences for each individual participant, something that is promoted by Rennick-Egglestone et al. [7] but that we have yet to witness in a theme park attraction.

The layout of this paper is as follows: Section II of this paper opens this discussion with the motivation for the work by identifying the gap in the agency-structure spectrum of existing theme park attractions, which is beginning to be addressed by recent developments in both academia and industry. We then propose in Section III that cyber-physical systems are well placed to contribute to filling this gap by providing various degrees of structured play that are currently missing from modern theme parks. This section also uses envisioning

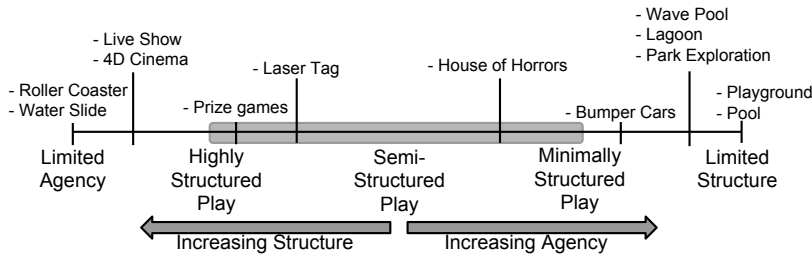


Figure 1. A spectrum of increasing participant agency (left to right) and increasing attraction structure (right to left). Plotted on this spectrum are existing popular theme park attractions.

practice [8] by providing examples of potential cyber-physical attractions in a water theme park environment. Finally, Section IV presents adaptive gameplay as one of the primary benefits of cyber-physical play and the design considerations and challenges that will need to be addressed in the creation of an adaptive physical game.

## II. BACKGROUND

In this background section we motivate the investigation of cyber-physical attractions by examining existing theme park attractions and attractions that are emerging from academic and industry research with reference to an agency-structure spectrum. In doing so, we identify a gap in the current attraction offering that cyber-physical play can fill, bringing novel experiences to the theme park experience.

### A. Agency vs. Structure in Games

The agency versus structure problem is typically found in the social sciences where *agency* is defined as an individual’s ability to “act independently and to make their own free choices” while *structure* is defined as “the recurrent patterned arrangements which influence or limit the choices and opportunities available” [9]. In relation to gameplay, structure can be thought of the rules of play enforced by the game engine while agency is a player’s ability to make choices within the game [10]. Rigby and Ryan [11] state that humans have an intrinsic need for agency but also that for agency to be appealing, there must be meaningful choices to make; ones that we feel will have an impact on the outcome of an interaction.

Mandryk and Inkpen [4] similarly describe how agency in ubiquitous play can promote mental growth in children but also highlight that as we grow older, we seek more structured experiences. Children are able to imagine worlds that don’t exist and to easily invent rudimentary game rules and it may be that their choices in free play seem meaningful to them, even if they do not appear so to an outside observer. However, as we grow older, we experience more structured play that is constrained by rules and objectives envisioned by others and that generate a similar experience between multiple players. Here, striving towards an agreed positive outcome (such as a win condition) makes our agency during the game meaningful, not only to the participants but also to spectators.

### B. The Agency-Structure Spectrum for Theme Park Attractions

Figure 1 shows some popular attractions that may be found in a theme park on a spectrum of increasing participant agency and decreasing attraction structure. Note that here an increase in agency does not mean that the choices available to the participant are more meaningful, just that there are more choices available for them to do what they want and when they want. Inversely, an increase in attraction structure means that there are more rules, objectives, time frames, and interaction mechanisms that are enforced by the attraction design and that constrain the number of choices that a participant would have.

We acknowledge that agency and structure could be represented in two dimensions, rather than the one dimensional spectrum shown in Figure 1. For some local comparisons between neighboring attractions on this spectrum, agency and structure may be complementary or at least not proportionally opposing. For example, laser tag is both more structured and provides more autonomy than a typical prize game (see below for more details). Despite this, overall there is typically a trend of trade-off between agency and structure in this context and so not much information is lost by representing them as opposing forces.

For an attraction with limited agency to be entertaining it must, by nature, be highly structured. Standing still in an empty space without at least some structured attraction such as a movie being visible has both limited agency and limited structure but is not the type of experience consumers would pay for. Likewise, increasing a participant’s agency requires the structure of the interaction to be reduced to allow for more user choices. In the case of the cyber-physical entertainment experiences sought in this paper, there are currently limits to how much structure can be reduced as there are typically only a handful of ways for a participant to provide input to a digital game engine.

Many of the experiences described below that fall on either end of this spectrum are common in theme parks around the world and provide valuable entertainment. However, there can be a feeling of gratification that comes from completing a structured task through one’s own agency, such as completing a challenge in a video game or winning at a physical sports, yet such experiences are rare in theme parks. We argue in the following sections that this type of agency in a structured experience is missing within most modern theme parks. There

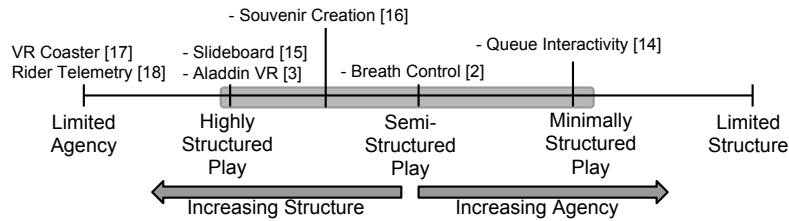


Figure 2. The same agency-structure spectrum but with emerging attractions proposed by academia and industry.

are those attractions with limited agency (water-slides, roller-coasters, 4D cinemas) and those that have limited structure (wave pools, playgrounds, park exploration) but little in between. Thus, the core motivation of this paper is to encourage future work in the middle area of this spectrum, shown by the highlighted box, by investigating varying degrees of cyber-physical structured play that could occur within a theme park.

### C. Common Theme Park Attractions

While being among the most popular attractions at a theme park, roller coasters and water slides have very little agency, with every participant having a nearly identical experience except for each individual's own physiological responses. These attractions provide entertainment through adrenaline induced by the perception of physical risk and the forfeit of control [12]. Meanwhile, live shows and 4D cinemas provide marginally more agency than roller coasters as participants can leave the attraction at any stage during the show. On the other side of the spectrum, playgrounds and pools allow for free play where visitors can create their own games and explore the environment however they wish. Wave pools and lagoons are slightly more structured in that they have timed events or water flow directions that help shape visitors activities. Likewise, theme park layouts are typically structured to influence visitors' subconscious decisions for where to explore but otherwise in all these cases the visitors have the same level of agency that they have in any other public setting.

There are a few existing attractions in the middle space of this spectrum but most of them have not been updated for many decades. Bumper cars enforce a time limit for each round of play and restrict how participants interact with each other but otherwise there is free play within those constraints. A house of horrors has a set path length that participants must follow and triggered events as they pass by but there are still not many rules or challenging objectives throughout the experience. Meanwhile, at the other end of this middle space, both prize games and laser tag are highly structured with rules, time limits, win conditions, and means of interaction but the ability of participants to devise a variety of complex team strategies in laser tag means that there is more agency in this attraction than in prize games.

### D. Emerging Theme Park Attractions

While the above common attractions are found in most theme parks around the world and continue to be refined,

very few of them fall within the middle section of the agency-structure spectrum. However, there are emerging theme park attractions put forth by both industry leaders and academia that are increasingly filling this gap. These attractions are shown plotted against the agency-structure spectrum in Figure 2. It is worth noting that many of these attractions are also cyber-physical play experiences, typically with a digital system keeping track of the state of play based upon the participant's actions and provide feedback. This further highlights the potential for such prototypical cyber-physical systems to fill this gap, which is discussed more in Section III.

As mentioned earlier, an investigation into integrating virtual reality (VR) into a theme park was deployed at the Disney EPCOT Center in 1994 and consisted of a head-mounted display (HMD) and a unique physical interface that allowed the user to fly on a magic carpet through a virtual representation of the movie Aladdin [3]. This gives a structured game with a restricted amount of agency over the trajectory of play.

Disney also continues to adopt a variety of digital technology in their theme parks to integrate their animated characters with attractions [13] and to entertain the queues that are waiting for an attraction [14]. These typically have structured means of interaction but are also typically free play games where there are no goals and instead simply encourage guests to interact with the surrounding fantasy environment.

Water park manufacturer White Water have recently designed an interactive water slide game called Slideboarding [15], which has so far been deployed to Wet'n'Wild Las Vegas. As with Disney's earlier mentioned studies [3], this development indicates a move toward introducing more game-like experiences to theme parks that give participants more agency over traditional attractions. In both cases, the theme parks have gone beyond the use of typical game controllers and instead developed novel interaction interfaces to provide park guests with an experience that they would not likely encounter outside of a theme park. Marshall et al. [2] also investigate giving participants direct control over the ride itself by introducing a unique control interface to a mechanical bull ride where the intensity of the ride is determined by the participant's breath, requiring them to control their own physiological responses to thrill in order to stay on the bull longer. Meanwhile, Anstead et al. [16] propose the use of a tabletop touch interface to turn the act of compiling and purchasing photo souvenirs from a theme park into a game.

Some of the emerging cyber-physical attraction lie outside

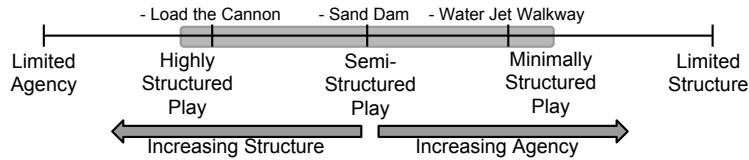


Figure 3. The same agency-structure spectrum but with emerging attractions proposed by academia and industry.

of this middle section of the agency-structure spectrum but nonetheless propose novel ways of experiencing common theme park attractions. Wagner et al. [17] have recently been investigating upgrading the roller coaster experience by giving participants a VR-HMD. This has not only provided entertainment benefits as it allows for riders to experience the roller coaster in exotic virtual environments but has also produced some surprising results regarding human cognition where the VR visuals closely relate to physical forces that human body is experiencing. Schnädelbach et al. [18] also augmented a thrill ride but did so for the entertainment of spectators rather than the participant themselves. The authors relay visual, audio, and physiological data about the current rider to spectators on the ground in order to share the rider’s experience with a wider audience and to gain insight into the physical and mental response of thrill rides.

### III. CYBER-PHYSICAL STRUCTURED PLAY

We believe that there is an opportunity for cyber-physical systems to manage structured play experiences that would occupy the middle of agency-structure spectrum. With the large throughput of park visitors, using park staff to referee a structured game-like attraction may be infeasible, costly, limited in potential, or prone to human error. However, using computers to mediate player interactions allows for an attraction that can accommodate a continuous stream of visitors in the same way that a game engine and server can handle large numbers of multiplayer instances. Furthermore, an agent that senses and reasons about the surrounding environment and the current participants can interact with them in both proactive and reactive manners. Thus, the agent mediates the flow of the experience in the same way that a game master would [19], potentially using player modeling techniques and probabilistic events to enhance the experience for the current set of participants [20] while still allowing players agency in the way they achieve their goals, much in the same way that digital games do.

Ishii et al. [21] refer to this type of interaction as computer supported cooperative play (CSCP), which encourages the use of ubiquitous computing principles to enhance physical play. We suggest that theme parks are ideal for exploring these types of experiences as they have resources and infrastructure to absorb the costs and complexities of installing a new attraction that may only hold the interest of each park visitor for less than a few seconds or minutes; a typical occurrence for attractions such as roller coasters. Such financial and time costs are prohibitive if each individual user must purchase

and install their own equipment for each new physical game in which the novelty may wear off quickly. It’s also worth noting though that the CSCP title is somewhat inaccurate as these attractions can also have competitive elements in them, albeit lighthearted competition that doesn’t spoil the joyful, family friendly environment of a theme park.

#### A. Examples of Potential Attractions

In this section we give some example attractions that could introduce cyber-physical structured play to theme parks, with one example for each of the three zones named zones in the middle of the agency-structure spectrum - minimally structured play, semi-structured play, and highly structured play. Here, we envision [8] a future where cyber-physical attractions are among theme parks’ offerings. Here we focus on a water theme park as we feel it addresses an unexplored market for HCI; Slideboarding at Wet’n’Wild Las Vegas [15] is only example of the inclusion of interactive digital technology at a water theme park that we have witnessed. We have also previously identified digital water-play as promising future area of study in HCI [22]. These potential cyber-physical attractions are also plotted along the agency-structure spectrum as shown in Figure 3.

##### *Minimally Structured - Water Jet Walkway*

Utilizing the space between existing attractions, this water jet walkway would be modeled after the classical trick fountains found in Salzburg and St. Petersburg <sup>1</sup> by unexpectedly spraying visitors with water jets as they walk along a relatively narrow path. The experience would be modernized by having the water jets target only some individuals based upon movement or vocal behavior. The entertainment of such a simple attraction is in feeling water on a clothed body, having the surprise of unexpectedly being splashed with water, and the social enjoyment of seeing others get wet. The only objective here to get from one end of the walkway to the other but even this objective can be ignored and the visitor can continue to interact with the water jets for as long as they please. Thus, the game is exploratory and bordering free-play as visitors attempt to discover what is triggering the water jets and how to cause their friends and family to be sprayed instead. The primary structure is then the means of interaction as an attraction designer must decide what actions trigger the water jets.

<sup>1</sup>Trick fountains: <http://about-st-petersburg.com/the-peterhof-fountains-the-trick-fountains/>

### *Semi-structured Play - Sand Dam*

Taking place on a man-made beach, this game would require a solid structure to form multiple interlocking canals through the sand and leading to the water, each the width of a typical sand castle. There would be one water source at the top of this network of canals and multiple exits out into the water, each marked by a gate. The game involves players building sand dams to redirect the water source to an indicated exit gate (such as one that is lit-up) within a given time before another gate lights up. This is considered semi-structured because there is an objective to the game and a recommended means of completing the objective but there are no rounds, no score, and no rewards or penalties for success or failure other than perhaps basic audio feedback. Players can come and go as they please and it can be played by one person or large groups. It is suggested to build sand dams but players could also simply attempt to use hands and feet to redirect water. The game encourage cooperative strategy between players and makes use of the feeling of being on land but having cool water (and sand) rushing through one's hands.

### *Highly Structured Play - Load the Cannon*

This is a fully structured game that plays out in rounds with a fixed number of players on a single team that play against a virtual adversary. The game takes place in a waist deep pool with one or more water cannons aimed at the adversary at the end (or in the center) of the pool. The adversary could be represented as an animated projection on a water curtain or a water soluble structure such as an ice-sculpture or a foam pit. Additionally, throughout the pool are anchored floating interaction points that light up from time to time. The objective is for players to touch a RFID bracelet, such as those described in [7], to a lit-up interaction point and then to a cannon. When the cannon is loaded, it fires a water jet at the adversary to cause damage. All the while, the adversary can verbally taunt participants to establish a narrative and launch its own attacks to distract players in the form of water jets, generated waves, mist, or other water effects. This game promotes exertion as players attempt to push through the resistance of the water, creates feel-on-skin penalties by splashing players, it has win and lose conditions to encourage effort from participants, and it encourage cooperative teamwork and strategy building.

## IV. ADAPTIVE CYBER-PHYSICAL ATTRACTIONS

By crafting a theme park attraction as a cyber-physical structured game, not only would there be increased interactivity within the attraction but there would also be an opportunity to redefine how a theme park attraction is experienced by a group of dissimilar minds and physiques. Not all theme park visitors are the same; there is the inexperienced but energetic child, the adrenalin seeking teenager, the mature young adult, the exhausted parent, the accommodating grandparent, a mixture of all of the above and anywhere in-between.

Currently, many theme parks attempt to appeal to as many potential audiences as possible by creating attractions that appeal to different preferences and by designing each attraction

to be suitable to as broad of an audience as possible. However, the alternative to this would be to allow an attraction to observe those that are currently participating and adjust the parameters of the interaction to cater to individual preferences, all of which could be managed by the digital component of a cyber-physical attraction. The idea of a personalized theme park was initially explored by Rennick-Egglestone et al. [7], who suggest that not only can theme parks be improved by recommending existing attractions based on subjective profile data of the park visitors but that individual attractions could also be adapted based upon the physiological data of the participants.

We refer to such attractions as *adaptive attractions* but note that they are not limited to the use of physiological data. Instead, we build upon the notions of adaptive [23] and personalized games [6] that are emerging in digital games research. In such adaptive digital games, a player's performance, preferences, or affective state are monitored or dynamically predicted through machine learning based upon subjective, physiological, or gameplay data [24]. Using this information, the game is adapted during play to increase entertainment or induce a desired emotional reaction. Similarly, there are opportunities for automated adaption within all three of the example cyber-physical structured play attractions given earlier: Who should be targeted by water jets and other effects? How long should a canal exit gate be lit-up? How much damage will each cannon shot do to the virtual adversary?

Strictly speaking, performance-based adaptation is not a new concept in HCI and it is one of the benefits of exertion gaming [25] over traditional sports. If a game can judge the physical performance of a player, the parameters of the game can be adjusted in a manner similar to many dynamic difficulty adjustment solutions in digital games [26], either balancing a multiplayer handicap [27] or making the objectives of a singleplayer game easier or harder to achieve [28].

Many of these examples of adaptive physical games use rule-based transformations of physiological data to parameter settings. There are, however, also opportunities to explore machine learning based player preference modeling techniques [29] in physical play. We have not witnessed this type of player modeling for adaptive gameplay in cyber-physical systems.

## V. DESIGN CONSIDERATIONS AND CHALLENGES FOR ADAPTIVE CYBER-PHYSICAL ATTRACTIONS

In the following subsections we discuss some design considerations and potential challenges of integrating player modeling based adaptive gameplay into a cyber-physical theme park attraction. The player modeling field is still in an exploratory stage of knowledge building in digital games research and so best practices are yet to be established. This imprecise nature would be exaggerated by both the physical and multiplayer setting of a cyber-physical theme park attraction.

It is also worth noting that the type of adaptive cyber-physical attraction we are aiming for here can be described in terms of a computationally intelligent agent system [30]. Here, a computational agent senses its surrounding physical

environment and plans future actions to either react to the current environmental state or proactively manage predicted future states. Thus, the foreseeable complexities in this section are discussed simultaneously through the lenses of embodied agent systems and personalized games via player modeling.

#### *A. A Multiagent System with Asynchronous Goals*

If the human participants are treated as unknown agents of the system rather than part of the environment that the computational agent is acting within, then the problem becomes a multiagent system [31]. However, rather than the agents (both natural and artificial) being strictly cooperative or competitive, there is instead likely to be asynchronous objectives. While the participants are acting to achieve game objectives, the computer controlled agent(s) is instead attempting to improve the quality of the participants' experience, though perhaps in the guise of being competitive. Therefore, in order for the artificial agent to make judgments of how to improve the experience, it may need a representation of a typical player, of different types of players, or of each individual player. This is then another perspective on the relationship between the agent system and player preference modeling; the game agent will need a working model of the player [32] or a representative computational agent [33] to compare potential actions against and predict the future quality of the experience as a result of those actions.

#### *B. Means of Adaptation*

Recent examples of personalized games research have adapted various aspects of the gameplay experience, such as the narrative of the game [34], in-game weaponry [35], level structure [36], and behaviors of non-player characters [37]. The digital environments in these examples afford opportunities for the procedural manipulation of nearly all aspects of the game [24].

However, the same level of control is not possible in physical environments. There are limited means of conveying a narrative to a large audience during gameplay, procedural construction of physical objects is not as achievable as the procedural generation of digital content, and the behavior of non-player characters is bounded by the usual interaction constraints of modern robotics. In short, there are limited ways that a cyber-physical attraction can provide feedback to the player and therefore there are fewer opportunities to adapt that feedback than in digital games. In order for adaptation to be present in a cyber-physical theme park attraction, it is likely that considering how the experience is able to dynamically change would need to be considered as a core component of the experience and accounted for from the outset of the attraction design.

#### *C. Lack of Data Collection Phase*

In a theme park, the turn-over rate of visitors is high and each visitor has a limited amount of time to interact with each attraction. This may be anywhere from the short time it takes to go down a water-slide to the longer length of a

stunt show. The former reduces time between participating visitors to a minimum while the latter can entertain a large audience in a single session. If a more interactive, game-like experience were to be introduced to the park, it would need to adhere to similar restrictions order to allow as many visitors to experience it as possible.

The player modeling cycle typically starts with data being collected about each player, then processing that data with a player model, and finally adapting the game. This sequence then repeats to continually refine the player's experience. In digital games, data for player modeling is typically either collected over long periods of continuous play or over multiple rounds of gameplay. However, the relatively short time that each park visitor has with attraction puts a hard limit on the amount of data that can be collected. Additionally, each visitor may only experience the attraction once and so it cannot be assumed that there will be multiple play sessions to learn from.

#### *D. Lack of Data Collection Methods*

Yannakakis and Togelius [24] identify three common forms of data for player modeling: gameplay, subjective, and objective (physiological). Out of these, subjective data is likely the most inappropriate in a physical theme park setting. Subjective data collection consists of asking the player to provide direct feedback about their experience, typically in the form of multiple choice questionnaires. However, asking players to complete a questionnaire prior to play or during play would disrupt the flow of park visitors. Additionally, there would need to be a means of associating a player's recorded subjective data with their physical presence in the game environment so that certain changes to the game can be target at them individually in a multiplayer setting. As a potential solution to this, Rennick-Egglestone et al. [7] provide each theme park visitor with an RFID bracelet that could be utilized to identify a player's profile during play.

Physiological and gameplay data are both more appropriate and lend themselves better to existing sensing capabilities of physical agents. However, both still have limitations in this context. In order to capture physiological data in a theme park attraction, the participating visitors will need to be equipped with wearable devices. Pausch et al. [3] provide an example of issuing participants of a virtual reality attraction with game interfaces by using a combination of disposable and sterilizable re-usable components.

In digital games, gameplay data takes the form of the player's in-game actions. Individual actions (moves, jumps, attacks, making a narrative choice, etc.) or macro performance metrics can be logged and learned from. This data comes from how the state of the virtual world is affected by the player's input. However, depending on the method used for sensing a player's physical actions in a cyber-physical game, the player's effect on the virtual world may be coarser, resulting in fewer potential gameplay metrics to learn from. This is then the counterpart to the means of adaption problem above; while there may be limited ways for the computational agent to provide adapted feedback to the player, there may also be

fewer data sample dimension regarding the player that the computational agent could observe, learn from, and make decisions on.

#### E. Sensing and Effect Uncertainty

Building on the above, not only are there likely to be less dimensions to learn from but the data may also be less reliable. In digital games, when a player presses a button on a gamepad, there is no confusion by the system about what action the player is attempting to make. For every input, there is a deterministic result on the game state. The state-space for a digital game may be immense or essentially continuous but there is no ambiguity of which state the game is currently in.

However, as with many embodied agents, a cyber-physical attraction may suffer from sensor noise and actuator fault. This means that it may not always be possible to precisely determine the participants' locations or actions and that any agent controlled actuation may not have the desired effect. Furthermore, both sensing and actuation may have delays that are caused by technological limitations. Poole and Mackworth [30] list this uncertainty as one of the primary factors that can increase the complexity of an agent system. Here, predicting players' preferences and future actions is difficult enough in fully observable environments, let alone when there is imperfect knowledge. Thus, any modeling and planning techniques used in this environment will need to be able to cope with the partially observable environment [38].

#### F. Multiplayer Environment

In order to maximize the amount of time allowed for data collection for each player and to increase the throughput of theme park visitors, it is desirable to have a cyber-physical attraction be multiplayer. Player modeling in multiplayer games is typically done in competitive games to balance the skill level of the players over multiple rounds of play [39]. However, as previously mentioned, it cannot be assumed that visitors will participate in the same attraction more than once.

How should an attraction adapt when there are multiple preference sets in the same session of play? Adaptive multiplayer gameplay is also an under-explored research area for digital game as well and making advances in that domain may aid in pursuit of similar adaptation of physical play. However, one approach may be to consider an entire team of players as a whole by, for example, detecting how well they collectively complete objectives and then increasing or reducing the difficulty of the game as needed. An example of treating a team as a whole for adaption purposes can be found in the game *Left 4 Dead* [40] where both teams' joint performance in a map determines the layout of enemies and pick-ups in future maps.

However, the positive performance of the team may be a result of just one or two members and so increasing the intensity of the agent's interactions may aggravate those who are not looking for such a challenge. It would instead be better to adapt to each participant individually. An example of this in digital games is the rubber-banding and pick-up

items in *Mario Kart* that help or hinder each player differently depending on their position in the race [41]. However, tracking individual performance requires a means of differentiating the participants, which can be difficult in a noisy physical environment. A potential solution to this is to again use individual RFID bracelets (as mentioned above with regard to recording subjective player data) that could be utilized to track participant interaction on an individual basis.

## VI. CONCLUSION

Theme parks are centers for unique forms of entertainment, the kind that are either too expensive, too large, or too experimental to experience in our own homes. We argue that theme parks are an ideal environment to prototype cyber-physical entertainment innovations, allowing for both experimentation with a diverse user base as well providing publicity to cutting edge technology and envisioned futures. A few theme park owners and attraction developers are already investing in doing just this [3], [7], [15], [17] and 'The Void'<sup>2</sup> was recently proposed as a new type of amusement park that focuses solely on cyber-physical play by overlaying virtual worlds over physical structures through the combination of virtual reality head-mounted displays and motion tracking of participants.

Not only can theme parks showcase cyber-physical innovations but their attraction offerings can also benefit from them. Cyber-physical structured play can be introduced into theme parks to create physical game-like experiences, where participants play in a physical environment or otherwise interact with a novel interface while the game rules and state of play are maintained by a computer system. In doing so, such attractions could fill the gap in the agency vs. structure spectrum of typical theme park offerings, allowing for structured experiences that are guided by a computer but that afford participants more agency in how they interact with the attraction, similar to the agency-structure balance of video games.

Ultimately, such a cyber-physical attraction can also be designed to be adaptive, providing varied experiences that are predicted to be suitable to the preferences or capabilities of the current participants. This intersection between the research fields of cyber-physical systems and personalized games could produce attractions that simultaneously target a broad audience of theme park guests.

We foresee a new wave of ad-hoc adaptive cyber-physical attractions that can be introduced to a theme park with little disruption to the typical operation of existing attractions or the need for costly capital works. Designing such attractions would allow for a relatively quick turnover of small attractions, changing the landscape of the theme park every few months for regular visitors, prompting exciting marketing opportunities, and creating entirely new on-going jobs in experimental attraction design and development. To that end, the current paper and our future work strive toward creating a set of design guidelines to facilitate the rapid prototyping and deployment of groundbreaking cyber-physical theme park attractions.

<sup>2</sup>The Void: <http://thevoid.com/>

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