Design of Experience and Flow in Movement-Based Interaction

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Abstract. Movement-based and exertion interfaces assume that their users move. Users have to perform exercises, they have to dance, they have to golf or football, or they want to train particular bodily skills. Many examples of those interfaces exist, sometimes asking for subtle interaction between user and interface and sometimes asking for 'brute force' exertion interaction between user and interface. In these interfaces it is often the case that the interface mediates between players of a game. Obviously, one of the players may be a virtual human. We provide a 'state of the art survey' of such interfaces and in particular look at intelligent exertion interfaces, interfaces that know about their users and even try to anticipate what their users prepare to do. That is, we embed this interface research in ambient intelligence and entertainment computing research, and the interfaces we consider are not only mediating, but they also 'add' intelligence to the game. Other issues that will be discussed are 'flow' and 'engagement' for exertion interfaces. Intelligent exertion interfaces, being able to know and learn about their users, should also be able to provide means to keep their users engaged and in the flow of the game and entertainment experience. Unlike the situation with traditional desktop game research where we can observe lots of research activity trying to define, interpret and evaluate issues such as 'flow' and 'immersion', in movement-based interfaces these concepts need to be reconsidered and new ways of evaluation have to be defined.

Keywords: movement-based interfaces, exertion interfaces, ambient intelligence, games, entertainment, human-computer interaction, interaction coordination, design, evaluation.

1 Introduction

Nowadays, when we talk about human-computer interaction, it is not about the mouse and the keyboard anymore. Clearly, mouse and keyboard are useful and needed for many useful and boring tasks, but they do not provide natural and non-intrusive interaction between humans and the environments in which they live and work. The environments in which humans live are now becoming equipped with sensors that collect data about what is going on in the environments and are backed up by computers that integrate and interpret this data. Hence, we have environments that can observe their human inhabitants, can interpret what they know, want and do, and re-actively and

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pro-activily support them in their activities. In these ambient intelligence environments there is an inhabitant (often called a user), but more importantly, this 'user' is one of the many 'agents' that are modeled in such environments. Human inhabitants, (semi-) autonomous human-like agents (virtual humans, robots), and 'intelligent devices' such as furniture and other natural and obvious devices (pets, TV, pda's ...) with embedded artificial intelligence will be considered part of these environments.

User interfaces have been introduced that offer, elicit and stimulate bodily activity for recreational and health purposes. Obviously, there are other applications that can be informed and guided by bodily activity information and that can be controlled by such information. For example, in a smart, sensor-equipped, home environment bodily activity can be employed to control devices, or the smart home environment might anticipate our activities and behave in a pro-active and anticipatory supporting way. Although in home environments there exists freedom concerning when and how to perform tasks, there are regular patterns of bodily activity and therefore activities can be predicted and anomalies can be detected. In task-oriented environments, e.g. an office environment, people probably have more well-defined tasks where efficiency plays an important role. Smart office furniture can provide context and task aware support to a moving office worker.

1.1 Exertion Interfaces

In previous years exertion interfaces have been introduced [1]. In game or entertainment environments the 'user' may take part in events that require bodily interaction with sensor-equipped environments. This can be a home environment, but it can be a city environment as well. For example, in a home environment we can have a user use an exercise bicycle or a treadmill to navigate or play a game in a 'Second Life'-like environment. Clearly, we can inform the user about performance in the past (allowing him or her to compete with him- or herself) and we can inform the user about the performance of other users. In an urban game, mobile devices may be used to inform the users about activities they have to perform or about activities of their partners or opponents in the game. The game can require the gamer to walk, run, or perform other activities, in order to compete or cooperate with others involved in the game. Other types of exertion interfaces have been designed. Some characteristic examples will be discussed later in this paper.

In this paper we assume that exertion interfaces can be anywhere: in home, office, entertainment, sports, fitness, and medical environments, and also in public spaces. The motivation to use them can differ. For example, we can look at exertion exercises to improve health conditions, sports performance, or (therapeutic) physical rehabilitation. Often these interfaces are promoted from the point of view of fighting obesity. But, we want to look at exertion interfaces that are designed to provide fun and that engage a user in a game and entertainment experience, and in which considerations about health, physical performance, and rehabilitation are important, but by-products.

The main aim of this paper is to make an inventory of the issues that need to be considered when we want to embed exertion interface design in the frameworks that have been suggested for game design.

The organization of this paper is as follows. In section 2 we discuss existing exertion interfaces. A state-of-the-art survey is presented, where we look at exertion interfaces that allow direct and mediated interaction. Section 3 of this paper is on 'intelligence' in exertion interfaces. That is, how does the interface perceive and interpret the exertion activities of the user? Obviously, in general this requires interpretation of multi-modal input signals; in particular we look at audio-visual signals and the interpretation of these signals in order to provide the user with relevant (and stimulating) feedback. In section 4 we draw some conclusions and discuss future research.

2 Exertion and Entertainment Interfaces

As mentioned, in this paper we look at exertion interfaces. Exertion interfaces require exertion from the user. In fact, they are designed in order to elicit exertion. This requires an explanation. Reasons to design exertion interfaces are that exertion can be fun, social and satisfying (look at the many people that take part in sport events such as the New York, London, Berlin, or Rotterdam marathons) and that exertion interfaces can help users to improve their physical skills, and can help to improve health conditions.

In this section we give examples of various exertion interfaces. Some inventories of exertion interfaces were made by our students (see [2] and [3]) and in 2007 and 2008 two workshops were held at the Computer Human Interaction (CHI) conferences in San Jose and in Florence. Some of the examples mentioned below are drawn from these papers and workshops. We distinguish three ways of looking at exertion interfaces: adding game experience to exertion, adding exertion experience to games, and, obviously, have an approach where game, entertainment, and exertion experience come together in the design of an entertainment or game environment. Important is that in all these cases exertion and game elements are coupled. Game elements seduce and motivate users to engage in physical activity. Using exertion interfaces has also been called exergaming. Already in the early 1980's we can recognize examples of exergaming, e.g. the Atari Puffer exercise bike or games with foot operated pads.

Clearly, an obvious way to obtain an exertion interface is to connect existing exercise devices (treadmills, rowing machines, exercise bikes) to an activity in a 3D virtual environment or in a game environment. The exercise device can be used to control a game, or to navigate in an interesting virtual environment (e.g., a beautiful landscape, or a Second Life city-like environment). In the virtual environment we can introduce challenges, competition and social interaction with other users. A well-known early example is the Virku (Virtual Fitness Centre) research project [4], where a traditional exercise bike is used to explore interesting surroundings and where environmental sounds are added to these surroundings to increase the presence of the user. Clearly, when a user cycles uphill it will take more effort and when going downhill less effort. In a similar project [5] it was investigated whether an increase in presence (by making the environment more realistic) led to an increase in performance. It turned out that the users not only pedaled faster, but also cycled much further without realizing how much more effort they put in.

In contrast to the idea of connecting an existing exercise device to a game or entertainment environment, we can also look at interfaces where ideas about exertion, games, and entertainment are there from the beginning of the design. One early example, the Nautilus game [6], can illustrate this. In this game a group of players have to work together and control the game (displayed on a big screen, sound effects and light effects) with the group's center of mass, speed and direction of movements that are detected by floor sensors. A more recent floor-sensor controlled game, where an existing game is provided with an exertion interface is a 'space invaders' game developed by the Mixed Reality Lab in Singapore [7]. In this game elderly and children play together and have to follow patterns that light up on the game floor, but they are also able to trigger bombs and rockets that force other players to jump out of the way and use other sub panels on the floor.

One of the best known exertion interfaces is 'sports over a distance', where players from different sites have to hit a wall with a ball [1]. The position on the wall and the force with which the ball hits the wall are mediated and made visible for opponents. A player can earn points by 'breaking' tiles on the wall and can profit from weak but not yet broken tiles that are left by his or her opponent. 'Sports over a distance' can be called a networked exertion interface. The same authors have introduced other networked exertion interfaces. For example, airhockey, table tennis, and, more recently, 'shadow boxing over a distance' [8].

In these latter applications entertainment, including social interaction has been the main reason to build these interfaces. Improving a particular skill in sports (e.g. baseball [9] or Tai Chi [10]) or improving fitness (aerobics [11] or physiotherapy [12]) have also been main reasons to introduce exertion interfaces. Finally, we need to mention the commercially available exertion interfaces. From the success of Dance Dance Revolution, Sony's EyeToy [13] applications and the WII Sports (tennis, golf, baseball, boxing and bowling), we now may expect to see more advanced exertion interfaces in the future, where the systems use more sensors that allow, among other things, audio-visual processing and interpretation of the user's activities and affective state.

An attempt to provide a taxonomy of exertion interfaces is presented in [14]. Recently a special issue on movement-based interaction appeared [15].

3 Intelligent Exertion Interfaces

Exertion interfaces require users to move their body and to use their arms and legs in order to get things done. Intelligent exertion interfaces understand what the user is doing and this understanding is used to provide better feedback.

Intelligent exertion interfaces detect a user's activity and the (possibly continuously) changing environment in which the user operates. That allows them to provide real-time feedback that displays understanding of what the user is doing and experiencing. This makes the difference between many of the current exertion interfaces and the advanced and intelligent interfaces that we see appear in research prototypes of exertion interfaces. In addition, dependent on the application, in intelligent exertion interfaces user feedback should be persuasive, motivating, and rewarding.

Game design requires designing game experience. We need to be aware which issues play a role in experience, how we can adapt them to a particular user during the game, and, in particular for our kind of research, what role does physical activity have in the game experience. One point in particular is what the user can tell us or the interface about his or her experiences. This can be done by conducting interviews, but rather we would like to see automatic detection of the user's experience and the automatic adaptation of the game or exertion environment to improve the experience.

3.1 More Advanced Sensing of User and Activities

As mentioned above, in order to design and implement successful exertion interfaces that know about the experience of the users, we need exertion environments that can detect, measure, and interpret physical activity. In the ball and shadow-boxing games of 'sports over a distance' [1,8], for example, there is no direct sensing of body movements or physiological information. 'Only' the result of the exertion (force, location) is measured and mediated. In contrast - without necessarily leading to a 'better' interface - there is also an interactive boxing interface, where the 'punch' is recognized using gesture recognition with computer vision [16,17].

Hence, there exist exertion interfaces with direct sensing of bodily activity (body movements, gestures, bodily and facial expressions, dynamic aspects of expression, etc.) and of speech activity that accompanies bodily activity (effort and pain utterances, laughs, prosodic aspects of speech utterances ...). Among the sensors are cameras and microphones that allow visual and audio processing of a user's activity. They can provide information about location changes (tracking bodies and faces of individuals) and, among other things, frequency and expressiveness of movements. Other sensors in exertion interfaces can detect touch, pressure or proximity.

Sensing user's activity in ambient entertainment environments is discussed in [18]. Rather than using questionnaires it is discussed how in the near future information obtained with computer vision and other sensors can help a movement-based interface to consider experience related issues such as personality, mood, and also pain, fatigue, frustration, irritation, etc.

One step further is to take into account physiological information obtained from the user. This information can be used both to guide the interaction and to measure the user experience [19,20]. In particular the recently started FP6 FUGA research project [21] is meant to find game experience measures that are based on psychophysiological recordings and brain imaging techniques. Clearly, BCI (Brain-Computer Interfacing) may be an extra source from which an interface can learn about the way the user experiences the interaction (besides using it to control the game as we can expect in the future) [22].

Finally, it should be mentioned that people will not always be willing to give away too much information about themselves, in particular when they see the computer or its embodiment in a virtual human as an opponent rather than as a system that tries to increase a positive gaming or exertion experience [18,23].

3.2 Exertion Interfaces: Flow and Immersion?

When modeling game experience the two issues that often arise are 'flow' and 'immersion'. The theory of flow was introduced by Csikszentmihalyi [24]:

> "a sense that one's skills are adequate to cope with the challenges at hand, in a goal-directed, rule-bound action system that provides clear rules as to how well one is performing. Concentration is so intense that there is no attention left over to think about anything irrelevant, or to worry about problems. Self-consciousness disappears, and the sense of timing becomes distorted. An activity that produces such experiences is so gratifying that people are willing to do it for its own sake, with little concern for what they will get out of it…"

Eight elements or features of this definition have been distinguished and generally it is assumed that these elements should be present in a game. They are: challenging activity that can be completed, facilitation of concentration, clear goals, immediate feedback, deep and effortless involvement, sense of control over one's actions, disappearing concern for the self, and finally, altered sense of duration of time. All these features can be found as prescriptions in present-day game design literature [25], sometimes using more refined features (agency, rewards, narrative …) and they play a role in game experience evaluation. Until now, they have hardly been explicitly considered in the design of movement-based interfaces for exertion and entertainment. A similar observation can be made for the concept of 'immersion'. Immersion [26, p.98] has been described as:

> "The experience of being transported to an elaborately simulated place is pleasurable in itself, regardless of the fantasy content. We refer to this experience as immersion. Immersion is a metaphorical term derived from the physical experience of being submerged in water. We seek the same feeling from a psychologically immersive experience that we do from a plunge in the ocean or swimming pool: the sensation of being surrounded by a completely other reality, as different as water is from air that takes over all of our attention our whole perceptual apparatus..."

Some attempts to provide more details to this definition can be found in the literature. For example, in [26] different types of immersion are identified: sensory immersion, challenge-based immersion and imaginative immersion. Levels of immersion (labeled engagement, engrossment, and total immersion) and how to cross barriers between these levels have been discussed in [27]. Finding out how to 'give hands and feet' to these concepts in movement-based interfaces and how to maximize flow and immersion in these interfaces are important research questions that need to be addressed in future exertion interface research. We can learn from some literature of flow in sports [28] and some recent and limited preliminary research on the design of exertion interfaces [29,30,31,32].

3.3 Multimodal, Joint, and Coordinated Activity in Exertion Interaction

Exertion interfaces emphasize the conscious use of bodily activity (jogging, dancing, playing music, sports, physical exercises, fitness, etc.) in coordination and sometimes in competition with other human users (friends, community or team members, accidental passers-by, opponents, etc.). Real-time coordinated interaction between human partners or between humans and virtual or robotic partners makes exertion interfaces exciting. In our research we are particularly interested in interfaces where the exertion interaction takes place with virtual or robotic characters or where the users are able to attribute human-like embodiment to the interface.

Coordination may be required by the rules of the game, the exercise or the tasks that have to be performed ask for it, but most of all people engage in coordinated interaction because it brings satisfaction and enjoyment. To illustrate this, the following citation is from Clark [33]:

> "A joint action is one that is carried out by an ensemble of people acting in coordination with each other. As some simple examples, think of two people waltzing, paddling a canoe, playing a piano duet, or making love."

Clearly, these are all joyful and engaging interactions. While Clark uses this observation to explore and develop theories of coordinated language use, we think it can be a useful observation when designing and evaluating exertion interfaces. We have studied face to face conversations, multi-party interaction, interactions between a virtual and a human dancer [34], a virtual conductor and a human orchestra [35], and a physiotherapist and her student [36] from the point of view of coordinated interaction [37].

Underlying joint activities are rules and scripts. To learn these and to put them into practice requires social intelligence, guided by empathy, moods and emotions. Despite many research results from social and behavioral sciences, computational models of joint activities are hardly available. This makes it difficult to design interfaces that aim at providing a similar interactional experience between real humans and virtual humans or robots, as is provided in a real-life human-human exertion activity, as in dancing, paddling, playing quatremains, and making love. Endowing the computer with a human-like appearance strengthens the expectation that the computer will take part in joint activities in human-like ways. Hence, there is a need for computational modeling of human joint activities. We replace one of the human partners in a joint exertion activity by a computer (i.e., a robot or a virtual human). Hence, we need to model joint exertion interaction in order to have the computer behave in a natural and engaging way.

In addition to rules that underlie joint activity there can be a need to align the interaction to external events over which the interaction partners do not necessarily have control. E.g., if we have a human and a virtual dancer then their moves have to be aligned with the music. Similarly, a virtual conductor and his human orchestra follow the score; a virtual aerobics trainer and human student have to align their movements to some kind of rhythm, often supported by upbeat music.

In our present research we investigate ways to measure engagement by looking at the degree of coordination between the activities of a human and a virtual partner in exertion and other entertainment interfaces [37]. In this research, supported by [38,39,40] we investigate how to make entertainment interactions more engaging by looking at interaction synchrony, where, on the one hand we aim at disturbing this synchrony in order to introduce new challenges, and on the other hand we aim at convergence towards coordinated anticipatory multi-modal interaction between human and artificial partners and their environment. Evidence that this approach will be successful is yet insufficiently available. Moreover, there are so many different types of exertion and movement-based entertainment interfaces that a comprehensive hypothesis about the role of interaction synchrony can not be expected to be given.

Design of experience and flow now receives much attention. Most research however is still about ways to characterize complex concepts such as experience, immersion, engagement, and flow. Exceptions are becoming available. For example, when we see the mentioning of 'altered sense of duration of time' in the description of flow, then indeed we can interview gamers about the time they think they have spent during a game with the actual time that has been measured. Interesting hypotheses related to our point of view on the role of interaction synchrony can be found in [41]. There the authors hypothesize that when players are immersed in a game their eye and body movements are different from those in a non-immersed situation. Obviously, again, there are many types of games and for video games where the gamer controls a game using mouse and keyboard or a joystick we have a quite different situation when the gamer is using a Wii remote control or a Wii Fit.

In our 'implicit' hypothesis on interactional synchrony we explicitly link this difference to the synchronization that is or is not present between gamer and game events. Notice that the main characteristic of 'flow' is the balance between challenges and skills. We can look at this as being able, as a gamer, to maintain a perfect coordination between eye, finger, and body movements on the one hand, and game/exercise events on the other hand. Obviously, when the game/exercise events are displayed by a virtual human, this coordination (or the disturbance of coordination to start up a new convergence of movements) becomes human-human non-verbal interaction coordination.

4 Conclusions

We surveyed characteristics of movement-based (or exertion) interfaces, i.e. interfaces that require and stimulate bodily activity. We discussed future research in this area by zooming in on sensor technology, intelligence and well-known game design and game experience principles. It was argued that for future development of interesting exertion (sports and entertainment) interfaces it is useful to embed this research in game design and game experience research. In addition we looked at a possible role for coordinated interaction research in the design and the evaluation of exertion interfaces.

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