Timing Issues in Physically Interacting RoboGames.

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ABSTRACT

In Physically Interactive RoboGames (PIRG) human players interact with autonomous robots in a game context, where all have to move to play their respective roles. As in regular children games and in videogames, timing plays a fundamental role both for the performance in the game, and for the relationship that is established among players. In this paper, some experiences about designing timing aspects in different PIRGs are reported, and it is put in evidence when timing is critical and its design needs special care. Timing aspects are described and discussed.

Categories and Subject Descriptors

L.1.1.6 [**Human-centered computing**]: Human computer interaction (HCI)HCI design and evaluation methods[Laboratory Experiments]; L.2.1.3 [**Human-centered computing**]: Interaction designInteraction design process and methods[Activity centered design]; L.2.3 [**Human-centered computing**]: Interaction designEmpirical studies in interaction design

General Terms

Robogame, Interactive game, Timing

1. INTRODUCTION

A particular kind of interaction between autonomous robots and people has to be designed to implement Physically Interactive RoboGames (PIRG). These are games where one or more autonomous robots play with people and other agents (e.g. computers, pets) in a physical environment where they have to move. In PIRGs, we may have *direct interaction* between people and robots, when persons directly play with robots, or *indirect interaction*, when the human player interacts with the autonomous robots through a physical avatar, such as a tele-operated robot.

In both cases, timing plays a crucial role for the success of the game, both because it may strongly affect performance, and because it may induce different paces and this may shape the relationship between player and robot. This is fundamental to engage the human players and make them have fun from the interaction.

In this paper, some timing issues, faced in the design of some PIRGs, are presented; they have been selected to be representative of different game types. Then, general considerations about the design of timing in this particular class of Human-Robot Interaction applications are discussed.

2. TIMING IN ROBOGAME DESIGN

In this section, four different robogames developed in recent years at AIRLab-POLIMI are presented: Jedi Trainer 3.0, RoboWII 2.1, RoboWII 2.0.L, and RoboTower. For each of them, a short description is provided, and focus is put on timing issues that have been more or less successfully managed.

For all these games, the *duration* of a game session was designed so to keep it in a range of few minutes, to take into account both the tension induced by the game, and the physical involvement of the human player, who may have to run, or move fast, thus requiring some time to recover.

2.1 Jedi Trainer 3.0

Jedi trainer 3.0 is inspired by a scene of the first Star Wars saga movie "Episode IV - A New Hope", where the young Luke Skywalker is trained on the Millenium Falcon by Obi-Wan Kenobi to master the use of the preferred weapon of Jedi kngihts: the light saber. A drone is flying around Luke, blasting at him laser shots that have to be parried by using the light saber. In the Jedi Trainer 3.0 game [5], the drone is a Parrot quadricopter [3]. It makes a sound recalling the laser blast sound when it shots. It always aims at shooting at the Jedi chest. The Jedi trainee wears a blue frock and holds a red tube representing the light saber. When the drone shots, the human player should place the light saber in front of the chest. The drone elaborates an image received after the shot, and it identifies the position of the red tube w.r.t. the blue uniform: if the red line intersects the chest, then the Jedi trainee scores a point, otherwise, the drone scores the point. In Figure 1, a picture of the game is reported.

Figure 1: The drone and the Jedi trainee playing JediTrainer 3.0. On the bottom right the image taken by the on board camera, on the left the interpretation of the image in terms of color blobs. The green rectangle on the top of the blue one is the target where the drone is aimed at blast its laser shot.

The fist timing consideration for this game has to do with the time from the shot to the evaluation of the image. Both the reaction time needed to perceive the laser blast sound, and the time needed to bring the light saber in front of the chest were considered. These gave an inferior limit to the time lag between shot and image capture for analysis. The superior limit was defined by considering that the parry action should come fast enough after the shot to be interesting: if the human player could take a lot of time to parry, the action would not be challenging, so not interesting, and the player would not be engaged, since the task would be evaluated as trivial. The time lag was related to the difficulty level of the game: the minimum (about 400 ms) was for the most difficult level, the maximum (up to 800 ms) was for the easiest one. These timing considerations can be considered as related to the *performance*.

Another aspect that was considered was the timing of the drone action. The drone's strategy can be summarized as: "Stay at a given distance to the player, randomly select a direction (left or right) move in that direction for a random, short time, then select another direction, and so on." Here, some timing considerations have been done. The first is about the time between two decisions concerning the direction to take. This was randomly selected in a given range, and it is long enough to give the human player the time to understand that the robot is taking a consistent decision. This is related to *credibility*, which is in turn related to the trust in the intelligent behavior of the robot; this is important to establish a peer relationship, and, again, obtain interest and engagement.

Moreover, due to color classification problems (related to the on-board camera quality) the robot may incorrectly detect the color blob corresponding to the player's frock. Since it uses the dimension of this blob to estimate the distance to the player, and this dimension can change a lot from one image to the next one, it was decided to estimate the dimension basing on the last few images, thus reducing the possibility of sudden changes in the behavior of the robot. However, these are still possible, and might frighten the players if the drone is rushing against them. Therefore, this distance adaptation mechanism was regulated to decrease the speed in the direction of the player and avoid the frightening effect, which is related to the *reaction time* of the player w.r.t. the drone speed, and its shape (not discussed here). The incorrect evaluation of the blob dimension happens more often when the player is more active and moves a lot. By carefully tuning the mentioned approaching speed, an adaptation of the drone behavior to the player's was obtained: if the player is moving a lot, also the drone is moving a lot, alternating the approach and leave movements w.r.t. the player, who is actually moving in the same way. If the player is brave and cool, also the drone is more calm and perform movements that are interpreted as a strategic way to find an opening in the guard.

2.2 RoboWII 2.1

RoboWII 2.1 is another PIRG requiring direct interaction. A 30 cm high robot should reach a target place to bring a secret message. The user can try to block it by facing it in a duel with a weapon that could be a pistol, a rifle, or a katana, all represented and actuated with different gestures of a WIIMote [4] sensor. On his side the robot can shoot at the player by evaluating the image of its camera. Depending on the result of the duel, the robot can decide to continue to its target, possibly confronting again with the player once the weapons are recharged, or to try to reach one of the friend's towers to recover safely from the got wounds. In figure 2 is reported a scene of the game.

Figure 2: A picture of a phase of the RoboWII 2.1 game. The human player is shooting, with his WIIMote, at the robot, which is about to reach the target base, the yellow cylinder on the back.

In this game, timing is really critical, since the selected robot cannot run fast. Therefore, the time required to the human player to reach the robot is usually short enough to be considered as negligible, and it cannot be considered as a part of the challenge for the user. This is a case where the robot's *actuation time* reduces the trust in it as a valid opponent or game companion. In this case, other challenging aspects had to be introduced to make the game interesting, such as the possibility to select among different weapons having different effects and requiring different abilities, the need to perform gestures to perform the selection, to charge the weapons, and to use them. All these activities, besides increasing the cognitive load for the human players, also introduce delays, thus making a little bit more even the *activity pace* between the two opponents.

Another timing issue concerns the *no interaction time* that might be functional to the game (such as the recovering time at friend's towers in this game), and, thus, credible w.r.t. its role (the robot needs at least 10" to recover), but it should not be too long to avoid leaving the human player inactive for too much time.

2.3 RoboWII 2.0.L

RoboWII 2.0.L is again a PIRG, but, in this case, the human player participates indirectly, through an avatar robot. In this game, there are two Lego robots [6]: one is autonomous and has to survive for a given time (*duration of a task*); the other one is remotely controlled by gestures done with a WIIMote in the human player's hand. The human player has to make the avatar reaching the other robot and hitting it on a specified part of its back with its scorpion-like sting. In Figure 3 are reported the two robots.

(a) (b)

Figure 3: The autonomous prey (3(a)) and the remotely controlled predator (3(b)) playing in the RoboWII 2.0.L game. The red plate on the prey is the target for the predator's sting, visible on the top part of its body.

In this case, the limited time to perform the task puts some pressure on the human player, which is limited in the avatar's actuation by the need to perform correctly the gestures with the WIIMote. Moreover, due to technical issues related to the communication to the avatar, these gestures take some time to be actuated (*actuation time*). Although the robots are really slow, and the players can just make their gestures standing aside the playground, the game resulted surprisingly engaging, because the task of making the avatar reaching the autonomous robot is not trivial. Moreover, it was verified that implementing in the autonomous robot a strategy that may need some time to be detected (not to short, not too long (*opponent behavior detection time*)), then the cognitive load of the human player is sufficient to obtain engagement.

2.4 RoboTower

The last game we present is again a PIRG requiring direct interaction. It is inspired by the videogame Rock of Ages. Here, the 30 cm high robot has to ruin down the towers of the human player in three minutes (*time limit to complete a task*). Human players can only delay the robot by putting cards, selected from a deck they have in hands, in front of the robot that can read them when it passes over them. Each card represents either an action that the robot has to execute (go back, turn around) or a deficit for its sensors (go blind), or a stop for an amount of time. The red tower is the player's home and when ruined he loses; the other towers are production plants that are used to recharge the delaying cards, and make them again playable, after a given time proportional to the number of active plants. In Figure 4 the robot, the cards and the towers are reported.

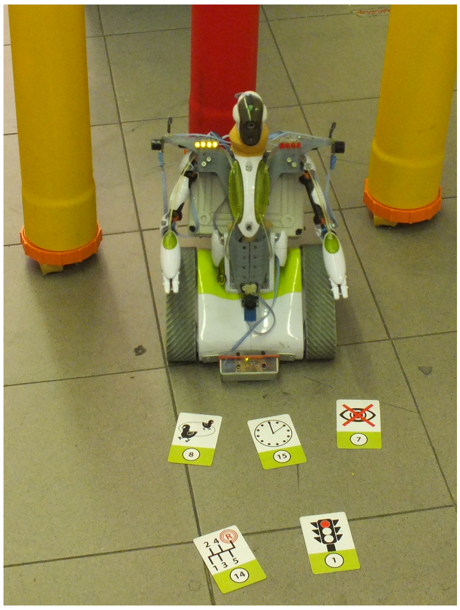

Figure 4: The robot, the cards and the towers used in RoboTower.

Also in this game timing was relevant to put pressure in the action of players, and this was enhanced by adding a large screen with time and a clock sound on the playground. The robot is quite slow (30 cm/sec), but the playground is quite small (about 6x4 meters, adjustable) and time to reach the target is not high.

Again for technical reasons, the detection of the cards by the robot is not sure, so players are always quite rushing in putting cards, since their plans can be disrupted by a missing lecture. This makes this game a really engaging one. Young children usually play directly on the ground, thus having a more close relationship with the robot, but also making their actions more clumsy, and interacting also with the distance sensors of the robot, which brings to "strange" behaviors. The pace is so fast, that almost none understood that the robot is programmed to avoid obstacles, so they could have considered direct interaction, not mediated by cards, to keep the robot far from the towers. Older people play standing, thus their game is a little bit less hasty, but the main dynamics is the same. Urgency is so high that, so far, only few players have planned the use of their cards, while most of them play the first card of the deck considering they have no time to select a possibly more appropriate one. In this game, the timing is not urgent, but *timing perception* has been designed to engage players.

3. MODELING

From the experiences reported in section 2 it is possible to list some of the timing aspects to be considered when designing PIRGs.

Some of them are related to the *structure* of the game.

- *Duration of the game*. A game should reach its end in a time that guarantees to keep the players involved and to make them enjoying it. This depends on the activity to be performed. In the PIRG case, the physical interaction of the user should also be taken into account to define the game duration so that the player can come to the end with a proper fatigue requirement.
- *Duration of a task*. In a game, one or more tasks should be achieved. The duration of the task has to follow the same rules as the duration of the game. In addition, the duration of the task can be appropriately defined to put some pressure on the players, which can engage them, and rise their interest, since this is related to challenge, and limiting the time available for a task is a way to make it challenging.
- *No interaction time*. In some games, some time might be dedicated to activities to be done by the single player, without any interaction with the others (e.g., a solution of a problem, a recovering procedure). If these activities have to be done by human players, enough time has to be left for their accomplishment, but not too much to make them less challenging. If they have to be performed by the robot, the player should be involved at the same time in some other activity, or the time dedicated to this should be short enough to avoid to make the human player becoming bored, but long enough to be credible w.r.t. the storyboard of the game.

Some timing aspects are related to the *performance* of both the human and robot players.

- *Reaction time*. The time each player needs to react to an external event can be a constraint to be considered in game design. The human player's reactions in a physical interaction can be *instinctive*, thus requiring few hundreds of milliseconds to be activated, or may require some *cognitive* activity (e.g., reasoning, recognition), whose duration may span also some seconds. In PIRGs, since they are often designed for a lively interaction, the cognitive load is usually relatively small, and a time around one-two seconds for a cognitive response from the human player in a challenging situation is often considered as appropriate.
The reaction time of the robot player mainly depends on the time to recognize a situation, which is related to the time required to elaborate signals, which in turn depends on the complexity of the data to be analysed and on the available computational power. Since PIRGs are targeted in principle at a mass market comparable to the one of videogames, the robots should be low cost, with simple sensors, and the available computational power might be as low as the one provided by Arduino-like processing systems [2], up to that of an external laptop, tablet or smart phone. This might be a time constraint to be considered in game design, possibly justifying the related delays in the story.
- *Actuation time*.Also actuation time may concern both the human and the robot player. For people, they might be constrained by some devices to dedicate time to perform an action (e.g., to perform a gesture with a WIIMote). This might be desired to put some challenge in the game, and also to reduce the power of the human player w.r.t. that of the robot, so to make the game more even.
For the robot, the actuation time might be a constraint given by the selected mechanical implementation, or might even be desired to reduce the power of the robot. For instance, if a robot could run fast enough to reach a target before a human player, it might be the case to reduce its speed so that the player can compete with it with some possibility to win.

Some other timing aspects are related to the establishment of a *relationship*.

- *Opponent behavior detection time*. Playing with artificial entities is engaging if the human player forgets the status of the opponent and attribute to it some human-like abilities. In particular, human players would like to play with entities that show some intelligence and intentionality. A way to achieve this status is to understand why the entity is performing an action, and, in general, what is its behavior, and what it aimed at. This may require an amount of cognitive activity proportional to the complexity of the behavior. In the mentioned experiments turned out that a random behavior is perceived as not interesting: the player believes that it is not worth to spend time with a silly entity. A too complex behavior is perceived as a random one, mostly because in PIRGs there is not much time to reason in a cool way on all the aspects of the perceived actions. The good behavior is one that requires a short time to be detected: not too short to consider the robot as "too simple minded" to play with, but also not too long to dismiss the cognitive activity of trying to understand it while the player is confronting the robot.

- *Credibility*. Each action should have a motivation, and should be credible w.r.t. the perceived motivation. Timing of the action should be consistent with this. For instance, if the robot seems to take a decision about what to do, the consequent action should last until there is a good motivation to change it. For instance, in RoboWII2.0.L, if the autonomous robot would change its movement direction randomly, there would be no apparent reason to motivate the change, and the robot would be perceived as silly. On the other side, in Jedi Trainer 3.0, a random decision about the direction to take is consistent with what the robot is doing: trying to find a hole in the trainee guard.

- *Activity pace*. Each player is assumed to do actions with a purpose for the game. Since they are interacting, the activity pace should be similar: a different pace, a different time between the selection of subsequent actions, would be perceived as if one would be favored w.r.t. the other one. Uneven games, in one sense or the other, are usually not appreciated.

- Timing perception. In interaction, timing is a subjective perception, and it can be modified by the interaction mood, or media, or by external devices. If there is an exchange, its pace can be modified by a "modeling and lead" strategy (e.g., [1]). If there is a time limit to perform a task, the perception of its urgency might be increased again by taking a faster pace in all movement changes, or also by simply giving relevance to the time-to-end, e.g., by adding rhythmic lights, sounds, or clocks.

4. CONCLUSIONS

In this paper, some timing aspects to be considered in the design of Physically Interactive RoboGames (PIRG) have been discussed. PIRG is a particular type of Human-Robot Interaction application, where timing is extremely relevant both for the performance in the task and for the kind of relationship that has to be established between human player and autonomous robot in order to engage the first and provide an enjoyable gaming experience. We have identified some timing aspects and discussed how they can affect the quality of the game.

Other PIRGs, are under development to further study these aspects. Some of them are inspired to traditional videogames such as PAC-Man and Mario Kart, and put in evidence that timing in physical systems is different from timing in a videogame: physical interaction is generally slower, but more demanding in term of attention, so time has to be shared between the game conduction and the management of physical aspects. Other games are requiring physical performance, such as Basketbot (Figure 5), where an autonomous, mobile basket robot interacts with a human player that has to score a point by throwing a ball in the basket. Here, the game has to take into account also the fatigue of the player, possibly detecting it from the paying style. Actions, speed, and timing have to be tuned accordingly.

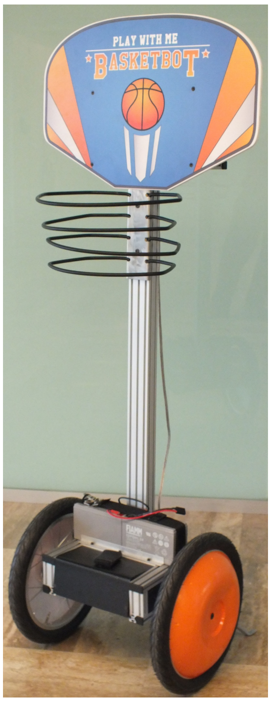

Figure 5: Basketbot, a mobile basket, implemented as a balancing robot, that interacts with the human player.

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