Phygital Play

HRI in a new gaming scenario

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Abstract — **This paper addresses the issue of screen time, a growing phenomenon triggered by the spread of digital devices, which may cause a health impact. The reduction of screen time emerges as a requirement, especially in games. For this reason, the paper offers an overview of the current Phygital game trend, through some related projects that highlight the potential of physical features in virtual games in terms of attraction and engagement. A new gaming framework is proposed as a step forward in the virtual-physical contamination. The proposed project consists of a projected playground, on which people and robot(s) can physically interact. The role of the robot is enhanced entrusting it different roles, from a companion, to an adversary, to the avatar of a remote player. By abstracting the inherent complexities and providing common functionality, the proposed framework aims to simplify the development of games that wish to exploit both digital and physical elements.**

Keywords-Phygital; Game; Entertainment Robotics; Mixed Reality.

I. Introduction

Nowadays games are evolving in accordance to the technological and digital development, taking into account the spread of personal devices, wearable technologies and distributed intelligence. The diffusion of such products in everyday life is also changing the way people interact with the environment and with other people, on behalf of a pervasive virtual dimension. In particular, the growth of new generations, the called *digital natives*, is strongly influenced by technology and by the Internet, especially in the way they communicate, socialize, learn and play [2]. For example, in the past most games, mainly cards, board or word games, had a maximum duration of a few hours and the strategies to be carried out were fixed. On the other hand, today's games, mostly videogames, can take up to 100 hours of playtime and become, level by level, more complex [2]. Consequently, people, especially young, spend an increasing amount of time in front of a screen. Moreover, a multitude of other activities can be carried out online, such as watching movies, working, following a recipe while cooking, shopping or booking hotels. Such an addiction to displays generates sedentary behavior [4] and impacts on psychosocial wellbeing. For these reasons, the entertainment world today is dealing with this virtual dimension and is focusing on a crucial topic: the relationship between physical and digital aspects while playing. Indeed, on one hand we are witnessing the evolution of traditional games, which are, increasingly often, redesigned including digital features. On the other hand the world of virtual games is experiencing a transformation oriented to the reintroduction of the physical dimension. For example, the Osmo Company faced the issue of reducing screen addiction in children by designing devices that, when attached to an iPad, allow the user to interact physically with some elements such as *Tangram,* the classic puzzle game, and to have digital feedback on the screen [18].

II. Motivation

As previously stated, nowadays many activities, including playing videogames, require a dramatic increase in the amount of *screen time* [7] which, in some extreme cases, leads to a real addiction [3]. These kinds of activities encourage the intake of sedentary behaviors, namely defined as the amount of time spent with minimal body movement [4] at the expense of physical activity, favoring the development of health issues, such as obesity or metabolic syndrome [7]. Despite the concerns about such issues are already common in most of the parents, it is nevertheless difficult to entertain children in their spare time and at the same time take care of daily business. Therefore, the easiest solution for most of the parents is usually to entertain the children with television or video games. For this reason, it becomes increasingly necessary to introduce the physical dimension during game activities. With regard to this, this project introduces the use of robots that, together with people, assume the role of game players in a projected playground. The choice to reduce sedentary behaviors, engaging children in games, through the use of robots is supported by the results reported in several research works. Kidd, for example, explored the effects on human-robot interaction with a particular focus on presence, which appears to be crucial in terms of engagement. The physical presence of the robot, in fact, allows people to feel that robot shares their physical space, and this condition, compared to videogames, increase the trust and the persuasiveness of human towards the robot [1].

III. Related work

The exploration of the physical dimension in game environments is a topic that has been faced frequently by

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researchers. In *PlayTogether* [6], for example, Wilson and Robbins designed an interactive tabletop system, which allows people to play table games (such as chess) together from remote locations. In this project the tabletop is projected on a real table surface by a commercial projector, located in front of a player who interacts with real checkers. The system is replicated in a remote location, giving the two players the illusion of physically interacting with each other. The idea of interacting with physical objects can also be found in *Twinkle* [9], a game interface that uses physical flat surfaces as an environment for the interaction between real objects and virtual characters. The characters are displayed also in this case through the use of a camera and a handheld projector. Projections as gaming environments are further emphasized in *RoomAlive* [16], a prototype for an immersive and augmented entertainment experience. In this game, several building blocks, composed of a projector and a camera, cover all of the room's floors and furniture, creating an interactive and responsive game scenario. Another step forward in the relationship between physical and digital is represented by the introduction of robots in the gaming environment. This aspect has been explored, among others, by Robert et al. in their research about Mixed Reality [13]. They developed a game scenario in which the playground is split in two parts: one half is projected on the floor and the other is displayed on a screen. On the screen, some characters push a ball out of the screen, where it is then projected on the floor. The interaction in the physical world happens through a robot, aesthetically identical to the characters on the screen, called Miso. The characters play a Pong-like game with the robot, which is guided by the user through a joystick. In this way, the game allows the embodiment of the user into the robot and the embedding of the virtual into the physical reality.

IV. THE PHYGITAL PLAY CONCEPT

Both in the scientific and in the consumer world, games are experiencing an evolution oriented to the contamination between physical and digital dimensions. Indeed, it is increasingly common to bring the act of playing back to the real world, combining digital tools with physical elements, as witnessed by the related works described before. These kinds of applications can be ascribed to an emerging trend called *Phygital*, that concerns the overall connectivity phenomenon in which everyday objects are interlinked and connected to the environment, collecting information from it and adapting their performance [15]. This scenario and the previously exposed projects show some common characteristics that can be assumed to be crucial in the creation of a **phygital gaming scenario**:

A. Mixed Reality

Robert et al. defined *mixed reality* the process in which both the virtual and the real world are encompassed and merged, in order to produce new environments where physical and digital items coexist and interact in real-time [13]. Especially in games, it is possible to identify two main categories of items: surfaces and objects. The surfaces used as base for applications are in most cases real-world surfaces [6], such as floor or walls, on top of which the playground is projected. Objects, on the other hand, can be either purely virtual or real.

B. Camera-projector combination

Mixed reality can be achieved by using a camera combined with a projector. The use of cameras is already widespread and well established, whereas the use of projectors is now witnessing a large increase, as evidenced by the mentioned projects. Indeed, in some cases portable, pocket-sized projectors have been introduced [9]. On one hand projections can transform any room into a playground [16]. On the other hand cameras allow to scan the environment and to understand what happens during gameplay, especially with the introduction of low cost, depth-aware cameras. These tools allow for continuous feedback between perception and action, making the game constantly adaptive.

C. Connectivity

The adaptability in the game, in addition to the camera and projector systems, is enabled by several algorithms with different functions, such as environment mapping or object and person tracking [16]. These cognitive abilities are usually entrusted to a server. As such, these three elements (camera, projector and server) need connectivity in order to communicate with each other.

V. THE PROPOSED SYSTEM

In this paper a framework is proposed that would enable third-party developers to create games exploiting the *mixed reality* concept. The framework would abstract the complexities arising from the use of a camera-projector system and provide high-level features to easily manipulate both virtual and physical elements. The proposed phygital gaming scenario, as shown in Figure 1, consists of a projector, a depth-aware camera and one or more robots. The system allows the user to play different games, such as *Pong*, in a mixed environment, interacting with both virtual and physical elements. The virtual contents, such as the playground and the other game elements, are projected on the floor, whereas physical interaction takes place with one or more robots. Differently from other projects, the proposed system would allow both people and robots to be players of the game and interact as rivals. In this way, the robot would assume entirely the role of companion. As an example, in the *Pong* game both ball and playground would be projected on the floor whereas the human and the robot players would stand on the sides. Both of them would have to move from side to side in order to hit the ball. One of the peculiarities of this proposal is that it would allow the user to play with any robot available, such as *Sphero* [14] or *Roomba* [5]. To this end, the experimental phase will involve the use of a cloud-based robotics platform that would take care of instantiating the correct drivers for each robot. The possibility of scalability in terms of installation options is also being evaluated: from single-projector-single-camera systems suitable for a house's living room, to multiple-projector-multiple-camera systems that could be installed in bigger rooms within a recreation center.

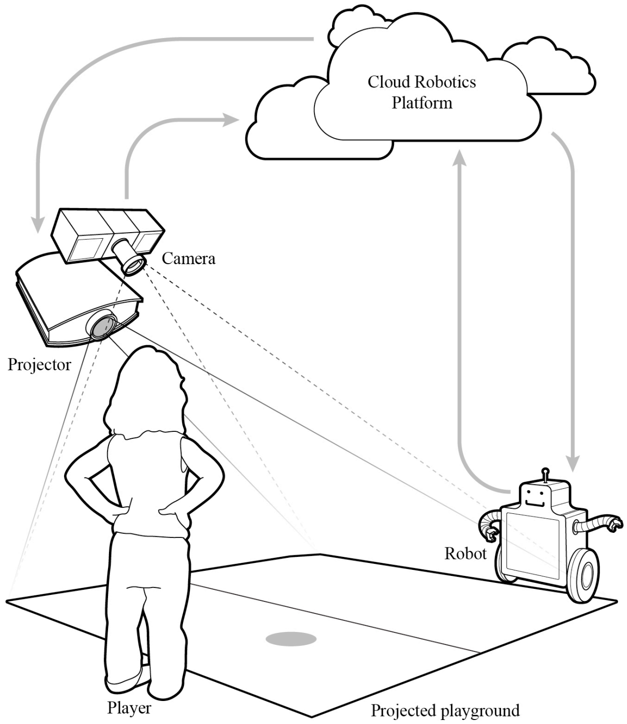

Figure 1. Phygital gaming scenario.

The proposed system's software architecture aims to be powerful enough to provide game developers with high-level concepts and, at the same time, to be flexible in order to allow for future additions of different input methods, such as gesture and speech recognition. Furthermore, it should not limit the potential that games developed on such a platform could reach. Considering the cloud-based nature of the platform, it would be possible to implement even computationally complex algorithms without the need of updating the user's hardware or software.

A. *Software Architecture*

The system's software architecture was designed to be implemented within the Robot Operating System (ROS) [8], in order to take full advantage of its modularity and to integrate it seamlessly with the cloud-based robotics platform, which is based on ROS as well. The proposed input pipeline architecture is shown in Figure 2. The blocks in the diagram can be thought of as ROS nodes, whereas the connections represent ROS topics. Starting from the physical sensors, the first layer of abstraction is implemented by the sensor-specific drivers, which publish the raw data in a common format. The second step in the pipeline is the basic processing of sensor data. In this phase, raw data is transformed and elaborated into more meaningful high-level information, such as a player's or a robot's position computed from the RGBD stream. Data sources can be either a single sensor or multiple sensors, in order to allow for sensory fusion at a lower level. In the latter case, information about the system physical setup might be needed (such as the position of the different sensors), and is provided by a shared data source. As of now, such information is manually provisioned, but in future developments it could be learned autonomously through one or more calibration procedures. Foreseeing the possibility of having multiple projectors or cameras located in different places, it is necessary to establish a common coordinate system (COS) in order to describe correctly the position of the various elements interacting with the game (i.e. the player(s), the projections and the robot(s)). Such a coordinate system could also be used to pinpoint the areas that can be used by the game components and those that cannot (because, for example, there are walls, furniture or other obstacles). Because of this, positional data needs to be converted from the local sensor-centric COS to the global one. After this last elaboration step, all information is streamed through a WebSocket using the RosBridge protocol [11]. This way, the actual games can be developed using any available game engine that is able of communicating through a WebSocket. Moreover, the games can use this same protocol to communicate with and control the robots.

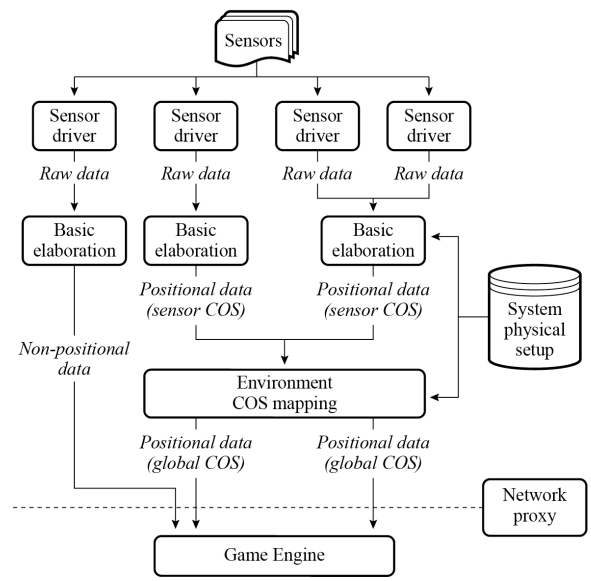

Figure 2. Input pipeline diagram.

In order to transparently handle the complexity that arises from the use of one or more projectors, the architecture of the output pipeline was designed as shown in Figure 3. The rendered scene in provided by the game itself as input to the pipeline. The following steps strongly depend on the system's physical setup, information about which is provided by the same data source discussed previously. At each frame, the input image should be split into parts (potentially overlapping), to be outputted by the different projectors (unnecessary in case of a single-projector installation). Each part should then be converted from the global COS to each projector's COS. Finally, various transformations should be applied to the resulting images, in order to compensate for distortions and artifacts arising from the system's physical setup, such as the projector angle relative to the floor, floor geometry and color. This should ensure that the projected image is as similar to the original (intended) one as possible, regardless of the physical configuration. The software platform should be completed by providing, other than the input and output pipelines, libraries for the most common game engines. These libraries should encapsulate the RosBridge protocol stack, allowing communication with Ros, and provide high-level concepts such as rigid bodies that are moved by the player's or robot's position input.

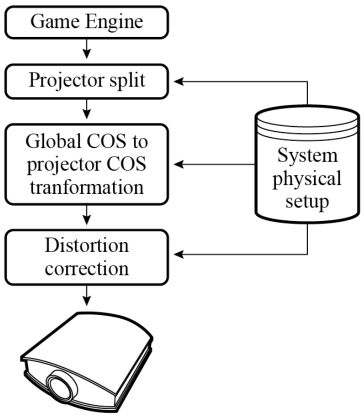

Figure 3. Output pipeline diagram.

One last aspect that has been considered during the design process is the possibility of connecting multiple systems through a network. This would enable many different types of interaction, such as two users playing against each other from different places (both using the same system) as in the case of PlayTogether [6], or a user interacting with the game through a tablet or smartphone interface while another one is playing. The system should be able to handle input coming from the network transparently and, similarly, to output the relevant data to the network when necessary. The transparent input process is easily handled by adding a network proxy node to the system, as shown in Figure 2. This node would receive data from the network, convert it to the proper format and inject it into the local system as if it were coming from a sensor. The high-level components would thus see this information coming from the input pipeline as if it were produced locally. This would allow interaction through the network even with applications that are not network-aware. On the other hand, in order to send locally produced data to a remote peer, the application must be aware of the possibility and activate it explicitly. To this end, another network node should be developed, which would provide the possibility of registering certain data streams to be sent to a remote peer as well.

Finally, in order to have consistency between local and remote data, an initial parameter negotiation phase has to occur between the peers. In particular, during this step, the systems should establish a shared coordinate system, which could be the intersection of the single coordinate systems used by the peers. This would ensure that only one COS is being used by all peers (thus expressing all positional data with the same reference frame), and that all playable and unplayable areas are accounted for (so that, for instance, a player could not move a robot or projection to an area that is unreachable by another player, perhaps because it is blocked by an obstacle).

B. *Robots*

The Cloud Robotics Platform allows to instantiate the correct drivers for a multitude of robots, which can be mainly of two types: DIY with an open architecture, such as *Arduino robots* [17], or commercial products, such as *Roomba* or *Sphero*. This choice depends on the willingness to make the system versatile, adaptable and scalable.

C. *Cloud Robotics Platform*

The Cloud Robotics Platform implements custom protocols in order to connect the different kind of robots to the corresponding containers residing in virtual machines [12]. This solution allows access to the game platform without the need of a dedicated console, such as a *Play Station* or an *Xbox,* which would make it fixed in a certain environment. Furthermore, the choice to move the service logic to the cloud makes this solution extensible, upgradable and open to future developments.

VI. Preliminary Results

The proposed system has been partially implemented and Figure 4 shows the current setup running with a sample game. Player position is obtained by using the OpenPTrack library [19]. Robot position is currently tracked using a marker tracking library, but a more robust and versatile solution is being developed. Sample games are being developed with the Unity game engine [20].

Figure 4. Phygital game system: first setup. On the left: projected playground with robot; on the right: depth-aware camera mounted on higher level.

A small RosBridge client library is being developed for Unity, along with the high-level concepts discussed previously. The main difficulties, at the moment, are automated system calibration and correct scaling. Currently, the system is being calibrated by projecting a checkerboard pattern, detecting its corners and calculating the offset for the bottom-left corner of the projection. That point becomes the origin of the global COS. The real-world size of the projection (needed to scale items correctly) is still measured by hand, but an automated procedure is being developed as well. The issue of correct scaling relates to the real-world size of virtual elements. Since the games will be dealing with physical entities, such as robots, the size of their virtual counterparts must match exactly their real-world size. This implies that certain game elements have to be scaled according to the desired dimensions, the projection's size and its resolution. Scripts are being developed for the Unity library that take care of correctly rescaling items once the necessary parameters have been calculated and made available. Finally, a calibration procedure is being developed to detect and correct deformations introduced by the projector.

VII. FUTURE WORK

In the near future the first phase of experimentation will be carried out, in which the effectiveness of a single camera-projector module will be tested with a simple game, such as Pong. Subsequently, a family of game apps will be developed in order to explore the engagement ability of the proposed system with a focus on HRI aspects, such as robot feedback, speed and typology. Finally, the software architecture will be extended in order to enable network functionality, allowing people to engage in game-play remotely. This phase will be particularly interesting also from an acceptance and engagement point of view, due to the fact that the robot would not assume the role of companion but will rather become an avatar for the remote player.

VIII. CONCLUSIONS

Even if the proposed phygital gaming framework is still in a preliminary stage, it represents a significant step forward in the field of phygital game applications. Previous projects have explored the possibility of having immersive, real-world surface based playgrounds, to engage remote players in traditional physical games and to give physicality to game characters through a robot. In this project, instead, the robot interacts with the user as a player, assuming the role of opponent as opposed to being just a tool of the game. This feature, in addition to the ones mentioned before, should engage children in game activities that would reduce the time spent in front of a screen, thus limiting sedentary behaviors. As a final note, the proposed system is not meant as a prototype of a gaming solution, but rather as a demonstrative and validating experiment for a new generation of game platforms that could relate with existing games and robots as well as trigger the development of new, ad hoc products. This system would enable a wide range of applications, not only for entertainment but also in the educational field. One of the possible developments, indeed, would be for school or afterschool activities, which require the extension of the system to multiple users. Other contexts in which would be interesting to test this system are hospitals, in particular in the pediatric wards, where children have to spend a large amount of time and tend to assume sedentary behaviors. Finally, even in the home environment the introduction of a camera-projector combined system would enable a wide range of new services. This system could enable an evolution in the fruition of the home environment, adapted to the user habits. This would relate to many aspects of daily life, from entertainment activities, currently carried out by television and consoles, to the creation of interactive worktops, such as those developed in Microsoft research projects [10].

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