depend on the location of the interactive object relative to the elements of the specific roles. Thus, colours are assigned to roles, and roles are assigned to actions. The App includes by default values for those assignments but they can be redefined as needed or preferred.

Next we summarise the roles our App supports and the actions assigned to them by default:

Good: this role corresponds to something that is, in a generic sense, positive for your interactive object (such as something that your object can eat, something that your object can beat, somewhere where you object can rest, etc).
Action: visually change the colour of an element with the role "good" when it is reached by an interactive object. Note that this is just visual feedback to make it clear that the object have reached that good element. The semantic meaning of this action is given by the kids and it depends on the particular game/scenario.

Bad: this role refers to something that is negative for your interactive object (monster, hole in the floor, etc).
Action: visually highlight that an element with the role "bad" has collided with an object.

Solid: this role corresponds to something that the interactive objects can not pass through (wall, floor, closed door, etc).
Action: the object stops when it collides with a solid element.

Interactive objects: apart from the elements contained in the picture (the ones recognized by their colour), the other players' interactive objects are elements of the game with a corresponding role and related action.
Action: the object stops when it reaches another interactive object; the objects are animated for a very short time to provide visual feedback about the collision.

Note that we avoided including other more specific roles such as entrance and exit. Instead, we rely on the kids' responsibility in order to deal with this kind of issue. For instance, they can write "entrance" and "exit" in particular locations of the labyrinth when crafting it, so that other kids know where to put the interactive objects when starting the video game and where they should get to exit/win.

3. CASES OF USE

In this section, we present a few examples of games we have already physically crafted and digitally tested in the App. The examples illustrate three different kinds of situation our approach facilitates.

3.1 Typical videogames

Here we show a typical kind of videogame (labyrinth game) that can be created very easily by using our approach. A labyrinth can be physically crafted by one or several kids and its digital counterpart is well suited for being played by one player. An appropriate interaction technique for this kind of videogame is the accelerometer (tilt). Actually, this is the interaction mechanism usually employed in labyrinth videogames when played in mobile devices.

One of the simplest and quickest ways to create a new labyrinth is by drawing it. Figure 1 shows a labyrinth drawn with a blue marker on a piece of paper. By using our App, once the player takes a picture of the drawn labyrinth with the tablet's camera, the picture appears as the scenario of a new digital video game. The user should take a ball out of the labyrinth by using the accelerometer to control the ball. In that case, blue colour is assigned the solid role in the App. The App allows the user to choose among three different kinds of view: the original picture (Figure 1, top), the scenario recognised by the App from the picture (Figure 1, bottom left), and a mixed view that shows the original picture highlighting the elements recognised by the App (Figure 1, bottom right). The first view is the most enjoyable one, as it gives the player the impression that he is playing on a real scenario. The other two views are useful right after taking the picture of a physical scenario, as they allow checking whether the scenario is well recognised by the App from the picture.

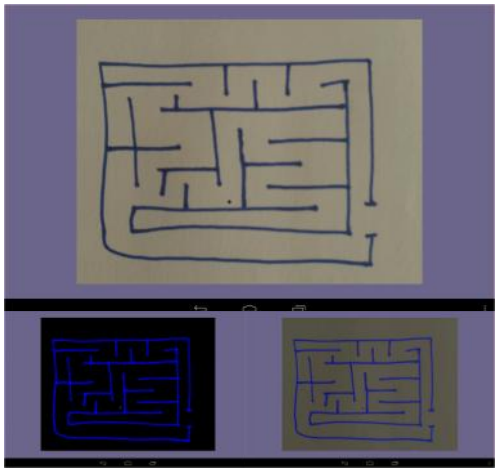

Figure 1. The App provides three views: original picture (top), recognised scenario (bottom left) and mixed view (bottom right).

As shown through the previous example, the creation of new scenarios is very easy. That allows the user to focus on the design process. The users can create more artistic (Figure 2, left) and personalised (Figure 2, right) games in a simple manner.

Figure 2. More artistic and personalized scenarios.

Figure 3. A labyrinth can be collaboratively created with Lego pieces. A photograph of it can be played in our App.

Apart from drawing, a labyrinth scenario can be crafted with any other coloured materials. For instance, Lego pieces are very adequate for the collaborative creation of a new scenario. Several kids can sit or lie around a Lego platform and collaboratively create a new labyrinth such as shown in Figure 3 (top). Figure 3 (bottom left) shows a kid playing with a physical labyrinth created with yellow Lego pieces placed on a blue Lego platform. A wooden ball is used in that case. Figure 3 (bottom right) shows another kid playing with the digital counterpart of the same scenario. In that case, the yellow colour (instead of the blue one) is assigned the solid role in the App. Note that the kinds of interaction employed in both the physical and the digital versions of this particular labyrinth are similar (tilt).

This example illustrates also another quality of our approach. It confers persistence to otherwise ephemeral creations. Lego constructions have normally a short life. A just finished construction will be deconstructed as soon as its pieces are required for a new construction. Our approach gives certain persistence to physical creations by converting them into digital games.

Finally, as shown in Figure 4, a labyrinth can be created by using a mixture of different kinds of materials. By combing a few elements, a simple scenario can be easily crafted by (and for) very young children (Figure 4, left). Older children can add more elements to get a more elaborated scenario (Figure 4, right). Note that, in those cases, the blue and red colours were assigned the solid and bad roles in the video game respectively. The goal of the game is to take a ball out of the labyrinth by using the accelerometer to control the ball and avoiding the red elements.

Figure 4. Mixture of materials. Left: cotton cord, buttons and Lego pieces. Right: adds pieces of thin plastic cord.

3.2 Traditional physical games

This case illustrates how certain classic physical games can be easily converted to digital games. "Las chapas" is a traditional outdoor game that used to be played on the street by kids of earlier generations in Spain. Now, this physical game is still being played in some Spanish primary schools as an activity framed into the physical education subject.

The game elements are basically some bottle caps ("chapa" is the Spanish word to refer to a bottle cap) and a circuit drawn on the floor by the kids themselves. The circuit was traditionally drawn with chalks. Now, in the schools, the circuit is normally created with coloured adhesive tape.

Once the circuit is created, the game consists essentially of a bottle cap race. First, all the bottle caps (one per kid) are put on the start line. Then, the kids take turns hitting their bottle cap with their index finger (following a pre-defined order). If a bottle cap goes outside the circuit, it should be put back on the point from where it left the circuit. The first one reaching the finish line is the winner.

Figure 5 (left) shows two kids playing the traditional physical game. Figure 5 (right) shows a picture of the circuit that can be played as a videogame in our App. The blue colour is assigned the solid role. As a consequence, the interactive objects (one ball per player representing its bottle cap) cannot get out of the circuit. Thus, the elements outside the circuit do not mind (whatever their colours are), since they cannot be reached by the interactive objects (as the objects cannot pass through the blue limits of the circuit). The most appropriate interaction techniques for this game are push and slingshot.

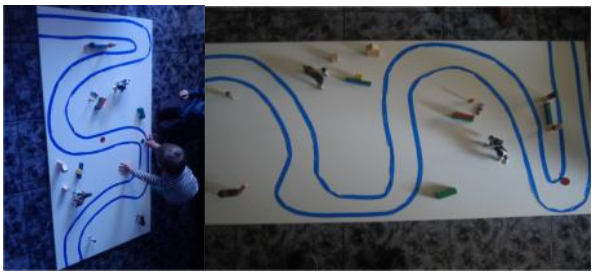

Figure 5. "Las chapas", a traditional Spanish game that can be easily converted into a digital game in our App.

3.3 New games

This case shows how our approach facilitates the creation of new games. We describe the process we followed in order to design a new game which can be played both physically and digitally. Our initial idea was to design a game vaguely inspired by sports where several players use the same ball for scoring into the opponent goal. We started by sketching a game scenario in a piece of paper (Figure 6). Our intention was rapidly sketching a first scenario so we could play the game in the tablet to validate the idea.

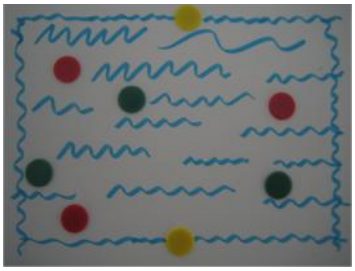

Figure 6. Sketch of the initial idea for the new game.

The rules we envisioned for the game are as follows. The game is intended to be played by two players. There are two goals in the scenario, each per player. The goals are the two yellow buttons located on opposite extremes of the scenario. Both players play with the same ball. In other words, both players share the same interactive object in the video game. The objective of the game is reaching the opponent's goal. First, the ball is located in the centre of the scenario. Then, the players take turns hitting the shared ball, trying to approximate the ball towards the opponent's goal. The ball collides with the blue lines. Once a player hits the ball, if it reaches the opponent's goal, the player wins (the opponent looses) and the game finishes. Otherwise, if the ball reaches a red element, the player looses (the opponent wins) and the game finishes. If not, if the ball reaches a green element, the player is allowed to hit the ball again. In any other case, the turn passes to the opponent (the opponent will hit the ball).

We took a picture of the sketched scenario and played the game in the tablet. The blue, green and red colours were assigned the solid, good and bad roles in the App respectively. The interaction

technique we considered appropriate for this game is slingshot. By playing the game, we realised that one of its rules was not suitable for the scenario. If players take turns alternatively and each player hits the ball once per turn, the game duration was too long. Thus, we changed that rule so that each player hits the ball three consecutive times per turn. With this slight change, the playability improved greatly. The games were shorter and more enjoyable.

As we enjoyed the video game, we wanted to play it in other scenarios. In order to facilitate the generation of variations of the scenario, we crafted a version of the physical scenario where all its elements are moveable. In particular, we created magnetic coloured elements by combining both coloured foam and cuttable magnets. Then we could easily create new scenarios for the video game just by repositioning the elements on a metallic surface (such as a dishwasher door) and taking them a picture (Figure 7).

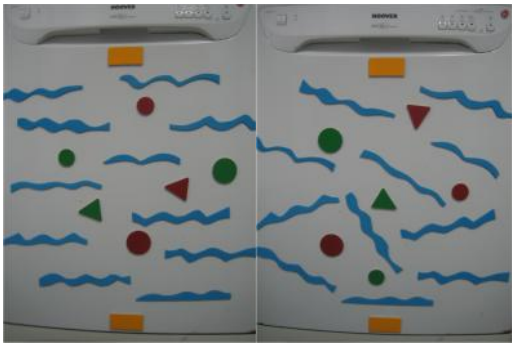

Figure 7. The use of moveable magnetic elements facilitates the creation of scenarios for the video game.

After some time playing the digital game, we wanted to play a physical version of it. Thus, we arranged the magnetic scenario elements on a horizontal metallic surface (see Figure 8). We used a wooden coloured ball as interactive object. For throwing the ball, each player should blow to it through a drinking straw. When the ball collides with the magnetic elements it rebounds due to the elements height.

Figure 8. First version of the new physical game.

After a short time, we refined the design of the physical game so that it is more adequate and coherent from the interactive and aesthetic point of views. The new scenario recreates a water world with elements such as islands, marine animals and waves (see Figure 9). Instead of balls, we use crafted paper sailboats as interactive objects. This change is coherent with the physical interaction technique (blowing). Two interactive objects (instead of one) are now employed, and the goals are treasures. The interactive objects are pirate sailboats that try to obtain the opponent's treasure. The sailboats are not magnetic, the rest of elements are. The kids can relocate the elements from game to game. The green elements are islands where the pirates can rest, and fishes the pirates can hook to eat. The red ones are dangerous elements (shark, giant octopus). And the blue ones are waves the sailboats collide with.

Figure 9. Refinement of the new physical game.

4. CONCLUSIONS

We aim to provide kids with elements and mechanisms that allow them to create their own play. By using the presented technology, the kids can create new whole entertaining experiences very easily. They are responsible for creating the game scenarios, but also for defining the game rules and controlling its compliance.

Our strategy is to provide a very simple approach that allows the creation of many different games. The technology is intentionally simple. We intend to provide the minimum interactive elements and general game roles to represent a playable digital version of a physical scenario. The use cases that we have presented in the paper demonstrate the great potential of the current technology. We are working on the extension of the model with a few new game roles that expand the repertoire of types of game the kids can invent.

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