An augmented reality game for energy awareness

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Abstract. Energy efficiency requires a behavioral shift towards sustainable consumption. Such a change can be supported by persuasive IT applications, which employ a variety of stimuli to increase the energy literacy and awareness of consumers. We describe FunergyAR, an Augmented Reality digital game targeting children and their families. FunergyAR incorporates Computer Vision and Augmented Reality components within traditional game mechanics and can be used either in a standalone manner or together with Funergy, a card game designed for improving energy savvy behaviors in children.

Keywords: Augmented Reality · Serious Games · Energy Awareness.

1 Introduction

Consuming natural resources responsibly is a key objective for achieving the 2030 UN Sustainable Development Goals [1], which aim at ensuring access to affordable, reliable, sustainable and modern energy and at fostering sustainable consumption and production patterns.

It is now commonly understood that achieving the objective of more sustainable energy (and in general resource) consumption is a multi-faceted effort, which requires the joint use of complementary stimuli, including economic incentives, education towards efficiency, social pressure, and elicitation of personal values. One promising approach to dispatch such stimuli is the use of persuasive digital applications, especially mobile applications, which have the potential of impacting the daily habits of users and thus of nudging their behavior towards sustainability goals. Within the broad spectrum of persuasive IT applications, Games with a Purpose (GWAPs) have emerged as a potentially effective approach. A GWAP exploits the well-proved engagement power of games to attain a non-gaming ("serious") objective. However, designing a GWAP that can effectively attract, engage and retain people, especially young players, who are the most promising target of a behavioral change effort, remains a challenge. GWAPs must face the competition of a menagerie of commercial, professionally developed games, which target their audience with enormous marketing investments. Therefore, it is imperative that GWAPs, which are mostly developed for non-commercial purposes, find an alternative way to reach their audience, based on an original mix of technology, game mechanics, and content.

In this paper, we describe the design of FunergyAR, a digital game for promoting energy efficient behavior in kids, which aims at finding a new way to attract, engage and retain players, by exploiting an original mix of technology (Augmented Reality, boosted by Deep Learning Computer Vision methods for real time object recognition on low-power devices), game mechanics (a digital game with a well-proved mechanics coupled to a "traditional" card game), and content (collaboratively developed energy quizzes and saving tips).

The paper is organized as follows: Section 2 surveys the related work and provides the background of the project; Section 3 illustrates the design of FunergyAR; Section 4 describes the evaluation plan of the game and discusses the ongoing and future work.

2 Related Work and Background

2.1 Games for energy awareness and sustainability

Games have been applied in different ways for environmental awareness, their motivational and engaging characteristics are key elements to retain user attention while delivering information, e.g., about energy saving. An example of such games is Power House, an online game in which the player must assist the other characters in their day-to-day activities. The player oversees turning on and off appliances (lights, TV set, computer, etc.) and keeps track of the activities of every member of the family to reduce waste. The point system is based on the ability to minimize the amount of electricity consumed by the family [2]. A similar approach is used in ecoPet [3], where the player must take care of a virtual pet's needs in a energy efficient way. Social Power [4] is another mobile game application blending social interactions and game mechanics to steer people towards long term behaviour changes in energy consumption. When a player registers to the game she is automatically assigned to a team, and given a set of individual and collective challenges, such as energy saving goals for which progress can be tracked. Some tasks require coordination with the team members. The application delivers information about how to make efficient use of the energy in the households and in shared spaces, such as schools and libraries. The users receive points and badges for their achievements and contributions to the teamwork. EnerGAware [5] is a mobile simulation game in which the objective is to reduce the energy consumption of a virtual house with respect to previous week. The player can execute actions such as changing the location of the lamps in a room or turning off appliances, or actions that are specific for a given time, such as during the World Environment Day. At the end of every week, the players receive points based on the energy saved. Virtual money can be used to buy more efficient devices and continue saving energy. The players can visit their neighbours' houses to help those that are less efficient or to learn from those that are better at saving energy.

FunergyAR differs in the use of Augmented Reality to engage players in the exploration of the surrounding world, in search of energy-related tips and knowledge collectively produced by the community of participating schools, and

in the possibility of playing the game in an integrated manner with the Funergy non-digital, card game.

2.2 Augmented Reality applications for consumers

Mobile augmented reality (Mobile AR) has increased its popularity thanks to the emergence of consumer grade AR-enabled devices and to the possibility of using AR apps also on plain mobile phones. Also the offer of frameworks for building AR browsers and applications is growing, including such platforms as Google ARCore [6], Wikitude [7], and blippAR [8]. The survey in [9] reviews AR applications for maintenance and assembly in several industries: aviation, mechanical maintenance, consumer technology and production plants. It illustrates the most popular technologies, among which mobile apps total the 30% of the reviewed solutions, and pinpoints the most relevant technical limitations. The retail industry has also started exploring AR. Examples include Ikea Place [10] and Amazon Home [11], which enable the users to visualize furniture catalogues and virtually place pieces on their room space. They also provide identification features for searching products that are similar to the furniture identified in pictures taken with the app. Several AR applications for tourism have been developed. Specifically for trekking tourism apps such as Peaklens[12] provide a location-based mobile outdoor solution that provides users with information (name, altitude, etc.) about the mountains they are looking at through the camera. PeakLens exploit a computer vision module, the location and orientation sensors of the phone, and the Digital Elevation Model (DEM) of the Earth to estimate the visible panorama from the user viewpoint and retrieve the information about the mountains in view. The fashion industry exploits AR and computer vision to let customers virtually try makeup [13], clothes [14] and shoes [15].

FunergyAR applies the AR paradigm to the design of a GWAP for energy awareness and literacy, exploiting two popular mechanics (treasure hunt like search and trivia quizzes) to engage young players towards sustainability.

3 The FunergyAR Augmented Reality Game

FunergyAR is an Augmented Reality game for low-power devices, which exploits a well-proved game mechanics, trivia quizzes, to deliver content aimed at promoting energy literacy and awareness and suggest practical ways to save energy.

The design of FunergyAR is based on the following principles:

- The game should leverage an emerging technology trend, Augmented Reality boosted by object recognition tools on mobile devices, to attract the attention of millennials and stand up within the myriad of digital games available.
- The game should be playable in a standalone manner, as any other digital game, or in a hybrid configuration, coupled to a non-digital game, to leverage the increasing interest and market growth of tabletop and card games [16].
- Support should be given not only to the single-player mode, but also to a collaboration-competition interaction by stakeholders, e.g., by schools.

3.1 Game mechanics

FunergyAR blends the Augmented Reality interaction paradigm with the trivia quiz game mechanics. The idea is to let players, typically school pupils in the 6-12 age range, to explore the world surrounding them and "query the objects" for hints on how to save energy and for knowledge tips about energy in general.

Figure 1 shows the home page of the game, which comprises a menu listing two play options: the former (*Take a picture*) starts the AR exploration game play, whereas the latter (*Single Player*) permits the user to use the game in a standalone fashion, by responding to a sequence of quizzes with increasing complexity.

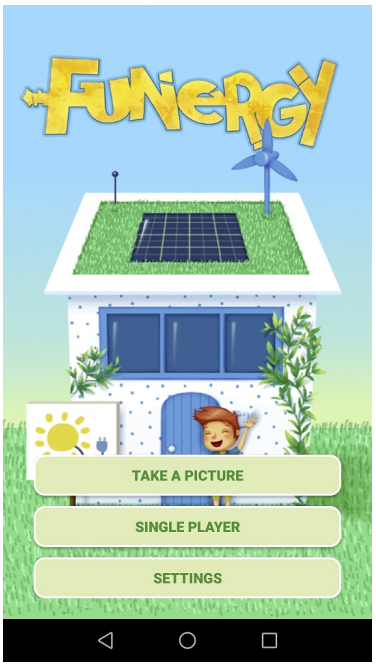
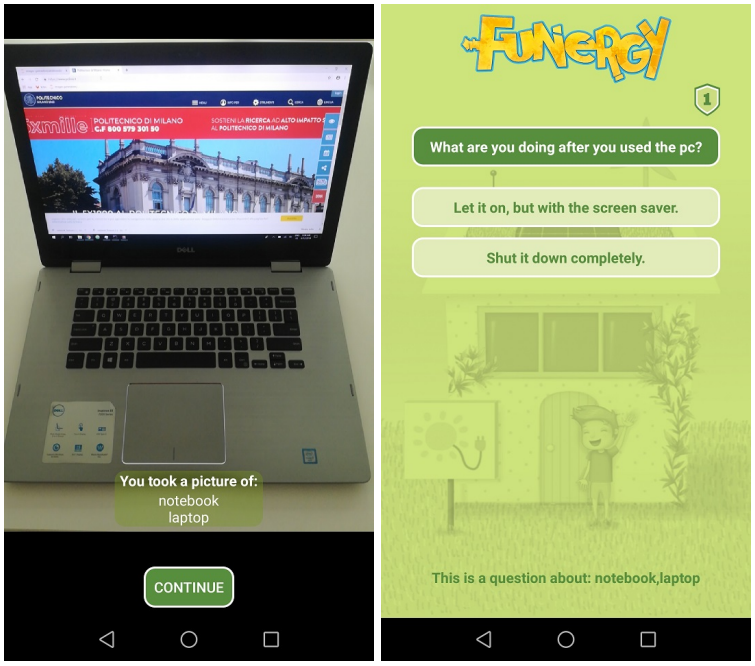


Fig. 1: The home page shows the two game modes of the game: take a picture and single player

Selecting the *Take a picture* option opens the Augmented Reality interface, shown in Figure 2(a). The player frames the environment around him in the camera view and the Computer Vision module of the game detects objects and displays their class at the bottom of the screen; when some energy quiz is associated to a detected object, a *Continue* button appears, whereby the user can obtain an energy quiz related to the framed object type. Quizzes are binary (Yes/No, true/false) questions, delivered with an increasing level of complexity along the game play session (Figure 2(b)). After responding to the quiz, the

game displays the outcome of the response (see Figure 3(a)) and the user can ask for an explanation, which is a short text with information on the topic of the question (Figure 3(b)).



(a) (b)

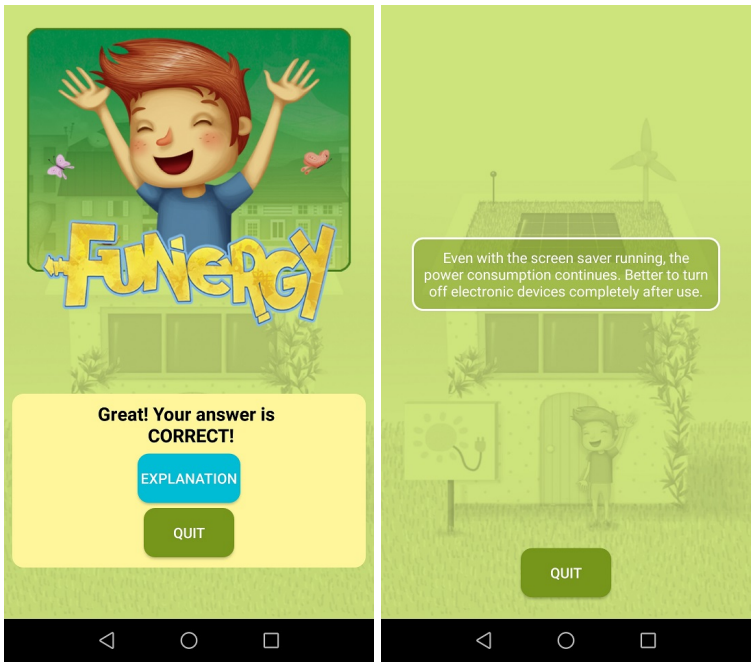
Fig. 2: FunergyAR recognizes objects and asks energy questions about them

3.2 Game Implementation

FunergyAR is implemented as a client side app for Android devices, interacting with a server-side backed that exposed REST services for content retrieval. The game is coupled to a gamified web application, whereby schools can cooperate and compete in the creation of content for the game. Figure 4 shows the overall architecture of FunergyAR and of the companion Content Management System.

The Android client application uses the Camera 2 framework to handle the camera sensor. Images are captured continuously at a 640x480 resolution to reduce the processing time. When a frame is delivered from the camera to the application, it is rotated depending on the device and camera orientation, because the object detection model performs better on vertical images. Each frame is processed with the TensorFlow* Image Classifier Framework. The model used

* https://www.tensorflow.org/



(a) (b)

Fig. 3: Funergy whether the answer was right or wrong, and a concise explanation about the topic.

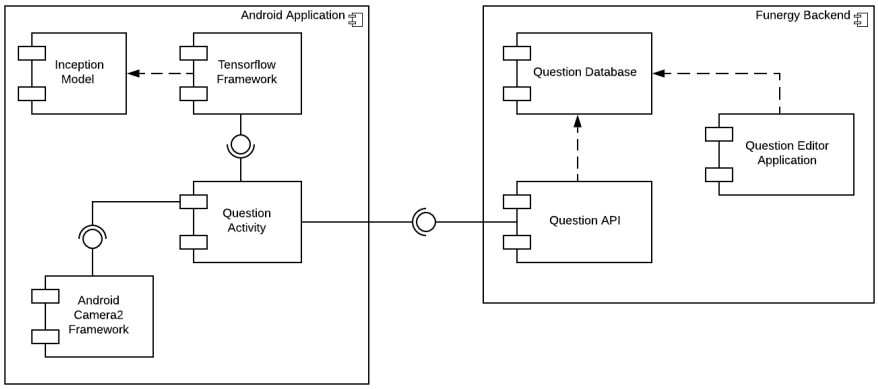


Fig. 4: The architecture of FunergyAR

for object detection is the Inception model [17]** version 3, trained with 1000+ classes. The classifier returns the classes with the highest confidence and the application discards the classes with confidence under a threshold and retains the top 3 classes. Then, the application queries the back-end for a question related to the identified classes. The question retrieval API is a server-side component that exposes a set of REST services to retrieve questions based on parameters, such as the level of difficulty, the language, the related classes, etc. The last component is the Funergy content management system, a gamified web application that enables the users to create, edit and translate questions to be used in the game. The users climb positions on a leader board depending on the question that they have created and translated. The registration to the system is done on a group basis, to encourage collaboration among the member of a school class and convey the message that energy saving is a collective effort.

3.3 Coupling FunergyAR with a traditional card game

FunergyAR can be used in conjunction with the Funergy card game, to attain a hybrid game play that mixes the paradigms of card games and of digital games. Funergy (shown in Figure 5) is a card game aimed at explaining the value of the European Energy efficiency scale. The game is divided into seven rounds, one for every Energy Scale Level. The game begins with the G level (the lowest one) and finishes when players reach the A level (the highest one). At the beginning of the game each player receives seven cards and the rest of the cards form the drawing deck. The objective is to form a combination of cards numbered from 1 to 7 by drawing from the deck and by exchanging cards with other players. The first player completing the right sequence is the winner of the round. For

** https://github.com/tensorflow/models/tree/master/research/inception/inception

every round, there is a small pack of 5 cards showing a piggy-bank with an increasing value. The winner of the round takes the highest card and distributes the remaining ones to the other players. The values of the piggy-bank increase level by level, so winning the last one can be crucial for determining the final winner. The game contains bad card, showing old appliances, which must be discarded for closing the hand; it also exploits wild cards, which can replace any number and help completing the sequence. At the end of the rounds, all players sum up the points of their Energy Scale Cards and add 3 points for every wild card. The winner is the player with the highest score.

FunergyAR is used to "unlock" the value of a wild card. For the player to retain her wild card, she must locate an object of the type chosen by the other players, scan it, and respond correctly to the question attached to it. If a wrong response is given, the wild card and its associated points must be "donated" to a competitor player.

Fig. 5: The Funergy card game: box, Energy Scale score cards (the piggy-bank is on the reverse side of the card) and game play cards

The interplay between the non-digital and the digital part of the game is designed carefully. The use of the FunergyAR app is non-intrusive with respect to the flow of the card game, but at the same time increases the fun of the play by exploiting a treasure hunt like search and a trivia quiz game mechanics.

4 Experience, discussion and conclusions

FunergyAR has been developed in collaboration with several schools in Italy and Switzerland, where requirement elicitation has been conducted to understand from teachers the best approach to integrate the game in the education programs and to engage pupils and their families.

A key design choice to better integrate the game within the educational programs of schools about sustainability is to open the content of the game to the classes, who can submit their own questions, associate them with the object classes recognized by FunergyAR, and thus compete to become "top contributors" of the game. To support this feature, a Web application has been developed, whereby classes can register and input their questions and explanations ***. The application records the number of quizzes that have been accepted by the editorial board of the game and assign scores to the contributing classes, who can check their status in a leader board.

The evaluation of the impact of Funergy and FunergyAR will be assessed by a structured activity with schools. The idea is to verify if and how playing the energy game changes kids' (and family's) energy saving knowledge and attitude. The intervention in schools is structured in a sequence of activities: 1) an initial questionnaire is distributed for determining knowledge and attitude before the experiment; 2) an activity involving the game is performed; 3) a final questionnaire is gathered, for determining if and how knowledge and attitude have changed after the experiment. To better understand the role of the game play and of the collateral education activities performed in the school, the treatment consists of alternative activities, performed in distinct classes:

- None: only the initial and final questionnaires are filled in; this "no activity" helps us understanding the difference made by the game.
- Playing: the activity consists of a visit to the school by researchers, an explanation of energy sustainability issues and a round of the game play (2 hours). Pupils are then assigned a homework, consisting in playing the game with their relatives and friends.
- Creating content: the activity consists of a visit to the school and homework assignment (as in the "Playing" case), followed by a period in which the class creates energy quizzes for the game and inserts them into the web application, before and after the treatment.

The experiment will permit us to assess the impact of gaming, and specifically of hybrid game schemes, on the change of attitude and behavior (at least at the intentional level) towards sustainable energy use. In the future, we plan to partner with a utility company, to integrate the experiment with the analysis of smart meter energy consumption data, so to understand the impact of the proposed game not only on the intention to save, but also on the actual consumption by households.

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*** The application is published at: http://funergy.ifmledit.org/funergy

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