Title:
Applications Virtually Augmenting Real Experiences for Behavioral Change

Authors:
Marina Carulli, marina.carulli@polimi.it, Politecnico di Milano
Monica Bordegoni, monica.bordegoni@polimi.it, Politecnico di Milano
Elena Spadoni, elena.spadoni@polimi.it, Politecnico di Milano

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Introduction
The increasing concerns for issues related to sustainability rise new research questions in the design domain aiming to limit the negative impact of human actions on the environment and on society. In particular, Design for Sustainability is a research area based on a multidisciplinary approach, which has become increasingly important in recent years. The main goal is to design and develop more eco-sustainable products and services as regards to production, reuse and recycling processes. Among the several strategies and approaches used to meet this important topic, the design discipline has been engaged with different aspects of sustainability subject and practice. More specifically, according to [2], several approaches to Design for Sustainability have emerged in the past decades. Among them, they highlighted the "Design for sustainable behaviour" approach, which is based on the fact that the users' behaviours produce important environmental impacts [6].

The idea that a particular design affects the users' behaviour is not new: Norman already discussed how products invite us to perform certain actions on and through them, guiding and potentially changing our behaviour [3]. However, more recently we started reasoning about the rebound effects that the users' behaviour has on the main challenges we are facing on the global and local scales, including resources consumption, environmental damage, health and social issues. For this reason, designing products to support users' behavioural change is becoming one of the most popular trends in the current design research [5]. Provided that, several design experiences based on the use of advanced technologies, e.g. Internet of Things (IoT), Augmented Reality (AR) and Virtual Reality (VR), have been proposed and experimented. In fact, through the use of those technologies, applications and smart systems are able to "dialogue" with the users, support them in the identification and understanding of any misbehaviour and suggest more sustainable ones. Indeed, the behavioral change of a huge number of people is of fundamental importance, since only a collective change will bring to effective results.

The paper presents two case studies about the design and development of Augmented Applications and IoT products to be used for behavioural change. Specifically, the literature review in the reference research areas, and the research objectives will be presented. In addition, the paper discusses two case studies of AR applications developed for supporting users towards more conscious food consumption in their daily life, in order to reduce food waste.

Related works
One of the key features of AR and VR Applications is "Interactivity", which is the possibility for the user to actively interact with all the digital elements present in a virtual environment. In addition, interactivity is an important aspect in the domain of Design for Sustainable Behaviour, because it

allows us to “create a dialogue” with users, engaging them in the experience and eliciting pro-environmental and pro-social behaviours. This is demonstrated by the literature review. In the Bhamra et al. [1] Design for Sustainable Behaviour model, it has been proposed a set of “design intervention strategies”. Those strategies can be applied within design to inform, empower, provide feedback, and reward users, also by using advanced technology to persuade or control the users’ behaviors.

Furthermore, a well-designed interaction can be particularly effective for two reasons. First, it engages the users’ body, an aspect that is considered fundamental for improving our understanding and learning process according to the well-known psychological theory of embodied cognition [4]. Second, being actively engaged in the interactive process, instead of being the passive recipients of inputs and notions, it allows the users to catch the deep meaning of the subject-to-be-learnt, to develop logical and semantic links with related topics, and to elaborate a personal and critic vision.

The state-of-the-art technology in the ICT domain can provide a huge boost to this process, enabling the users to interact with several kinds of digital contents in a stimulating experience. Furthermore, the possibility to use interactive technologies to monitor the users’ behavior and push them to start new actions, can be particularly effective in fostering durable behavioral changes and generate new habits.

For all these reasons, AR and VR interactive Applications are becoming more and more appreciated and effective, involving people through different senses and calling them to action.

In the context of this research, several applications and smart objects have been developed with the aim of making people think about the impact of humans on Earth. For instance, the “After Ice” (https://secondverse.org/#/after-ice/) mobile application uses AR to simulate the effects of climate change around the world. Also, on the basis of the “Human Footprint” exhibition (https://www.wikitude.com/wikitude-eovision-bring-augmented-reality-frankfurt-book-fair/), the eoVision company developed a book named “OneEarth”, consisting of a collection of 119 satellite images used to show the status of the Earth’s environment though an AR application. Similarly, NASA created different applications based on pictures from its satellites and missions. Among them, a virtual gallery named “Images of Change” (https://climate.nasa.gov/images-of-change) features images of different locations on planet Earth, showing changes over time periods.

Main idea

This section presents the design and development process of two AR interactive applications aiming to generate awareness about the impact of humans on Earth and induce their behavioral change. The applications are meant to engage users in an active process of exploring and discovering informative contents and to foster them to elaborate a personal and critic vision and change their bad habits.

In particular, the two case studies address the “food waste” phenomenon that is one important erroneous behaviour related to environmental sustainability and to users' daily actions. According to the FAO (Food and Agriculture Organization of the United Nations), about one third of the food produced each year is lost during production and distribution or is thrown away by consumers. Specifically, in Europe, the amount of food wasted by consumers is noticeably higher than the food loss during the production and distribution phases. The effects of this phenomenon consist of waste of resources like water, land, energy, labour and money, and also of the production of gas emissions, contributing to the global warming and climate change. Organizations and countries have implemented instruments to face this problem. Examples are the awareness campaigns, such as the "International Day of Awareness of Food Loss and Waste" (http://www.fao.org/international-day-awareness-food-loss-waste/en/), and the SAVE FOOD project (https://www.save-food.org/). In spite of these and many other attempts, the amount of consumer food waste is constantly increasing.

The first case study consists of a physical object connected to an interactive AR application, named “EGGup” which aims to raise people, including children, awareness about the impact of food waste on the environment and to make them reason about how they can personally contribute to limit the expansion of this problem. The application uses chicken eggs as main communication element. Chicken egg has been selected because it is one of the main wasted food, and because it has a very important symbolic meaning, since it is used in several cultures as symbol of life, of birth and regeneration, and even of wholeness. Given that, the design solution aims at informing the user about the eggs expiration date and at inducing him/her to consume the eggs before they expire.

EGGup consists of an eggs tray, integrating sensors and actuators, which is linked to an interactive application for monitoring eggs consumption, and for communicating eggs usage and waste statistics. The egg tray is designed to be placed in the middle shelf of the fridge. The tray includes a set of egg holes, each having touch sensors and LED lights in order to enhance the value of the eggs and give immediate feedback and information about the egg expiration date and quality. The tray is also equipped with a Bluetooth module to connect and send information to the EGGup app.

The EGGup app consists of two modules. The first one has been designed for adults / parents of children, and manages and controls the whole system: it is connected to the Smart Egg Tray and to the children's application. From this application the users can check remotely the quantity of eggs in the fridge and their quality, and also check statistics about the eggs' consumption and waste. The application also allows parents to verify the children's progresses in learning.

The second module has been designed for children, who are aimed to improve their awareness about food waste and the impact on their food habits through an "edutainment" approach, which combines entertainment and educational contents. The entertainment part consists of an AR Easter Egg search. When the Easter Egg is found, educational contents about the food waste problem in form of videos with fairy tales and legends can be enjoyed.

Unity3D (https://unity.com/) and Vuforia (https://developer.vuforia.com/) software tools have been used to develop the two AR applications. Specifically, the virtual representations of the Easter Eggs have been developed in Unity3D, and the Vuforia software has been used for the development of the AR visualization of the contents. The application features two different kinds of markers that allow users to visualize in AR two different types of eggs. Indeed, the children can find seven normal eggs (light-blue marker) and just one gold egg (orange marker) inside the environment. In Unity, several scenes, animations controlled by an event system and scripts have been created and used to display different digital contents.

For what concerns the User Experience, the application presents different interfaces. Before starting the game, an Instructions page gives information on the tasks that the children have to accomplish during the treasure hunt, and on the points related to the different eggs he/she can find. In particular the normal egg score is about 50 points while the gold egg can duplicate the total points value. When the child starts the Finding egg treasure hunt, a Unity script starts updating a timer, located on the application interface. He/she has 30 minutes to find the markers hidden around the house. Whenever he/she finds a marker, he/she can scan it using the camera of his/her device. Thus, the 3D model of the relative egg appears rotating on itself. When the child clicks on it, some animations of the egg decoration cage are visualized and the egg is opened, revealing some coins hidden inside it. The gained points and the counter, showing the number of eggs that the child has already found, are displayed on the top of the app interface (See Fig. 1). At the end of the game the child visualizes a final scene, corresponding to a summary page that shows the gained points.

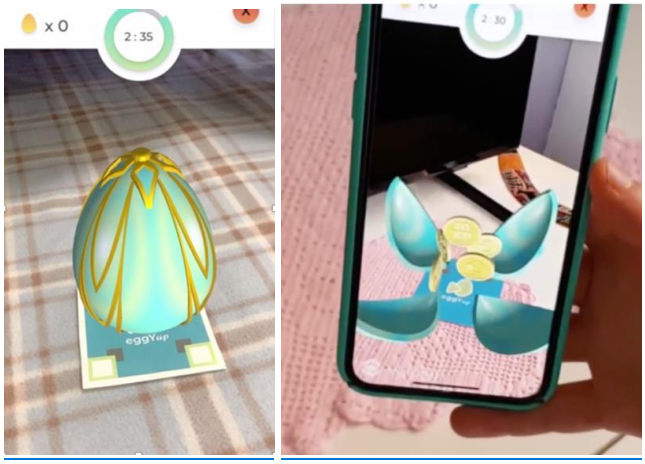

Fig. 1: Two Screenshots of the Augmented Reality Finding Eggs game.

The second case study is focused on improving the users' awareness about the effects on the environment that their food consumption habits produce on the environment. The proposal consists of an AR interactive application, named "FOODDY", that provides truthful information and data about the environmental impact of food, with the aim to provide an educational mean to arouse consciousness and persuade people to the correct environmental behaviors. The application is meant to be used during the grocery shopping at the supermarket. Here, the customers can better understand their level of sustainability, avoid overbuying goods that are not necessary and be more aware of their purchasing choices. During shopping, the user can scan the product label and visualize information about the product sustainability characteristics, related to the carbon footprint, land use, water consumption, packaging and distribution. These items of information are not always easily accessible. However, they are of great importance to identify the most sustainable products, for example by comparing the total greenhouse gas emission and water consumption over the entire life cycle of the product.

When the customer fames a product, contents about it are presented through 3D elements and animations in AR (see Fig. 2). The AR application also shows the customer's current level of sustainability, given by his/her purchasing choices and. The customer's actions are represented by means of a virtual plant, which grows when he/she behaves correctly, and withers in the opposite case. The FOODDY application also allows the customer to record the purchased products, providing information about their quantity and alerting him/her about their expiration dates.

Furthermore, a dedicated area of the application presents educational contents and tips that the users can adopt in their everyday life, learning, for instance, new methods of food preservation and storage.

In addition, the application uses colors that change according to the user behavior: bright green represents a correct trend concerning sustainability, and orange the opposite.

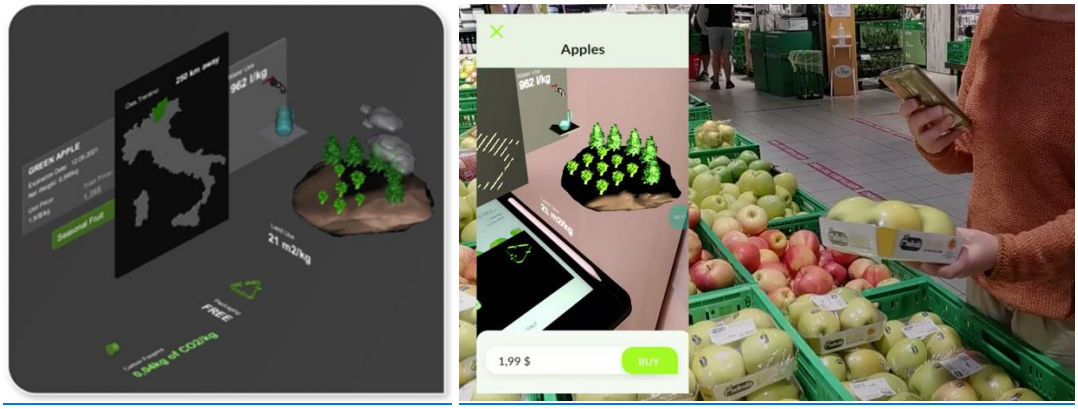

Fig. 2: Augmented Reality contents, related to green apple and a screenshot of the FOODDY AR application.

Also in this case, Unity 3D and the Vuforia package have been used for the development of the FOODY AR application. More specifically, several scenes were created within Unity, each corresponding to a screen of the interface of the application. Three labels, related to three different products (apples, meat and eggs) were used as markers for the development of the AR application. Regarding the User Experience, the application presents two main sections. In the MyShopping section, the user can click on the User Interface button at the top right of the screen, to scan the label of the product he/she wants to buy. When the user clicks on this button, the AR scene is loaded, and the camera of his/her device is automatically activated. By scanning one of the markers, the digital contents appear. Each marker is connected to various three-dimensional panels and interface elements that indicate the name of the product and the expiration date, its carbon footprint and land use, water consumption, packaging of the product and its origin and distribution. Some information is also represented thanks to the use of 3D models. For instance, a 3D model of Italy shows the geographical origin of the food,

while a loading bar shows the relative amount of CO2. Moreover, the color of these 3D models varies according to the information shown, allowing the user to view the sustainability level of the product easily. In addition, depending on the scanned label, the 3D model of a land appears, indicating the land use, showing the cultivation or animal husbandry density, for apples, meat and eggs respectively. Furthermore, when the user scans the product label, its price also appears automatically. By clicking on the price, the product is added to the MyShopping section, displaying a list of all scanned products. When the user purchases the products on the list, they are automatically moved to the Cupboard section, in which the user can reopen all the products details and access all the information displayed in Augmented Reality. The products on the Cupboard section have an influence also on the MyTree section, where the user views his level of sustainability, that increases or decreases accordingly to the products purchased.

Conclusions and future developments

The paper has described two Interactive AR Applications developed to support users towards a more conscious food consumption in their daily life, as well as to generate awareness about the food waste problem. Specifically, the EGGup Interactive AR Application has been developed with the aim of improving the users' engagement and understanding the ecological problem and how they can act to reduce food waste at home. Particular attention has been paid to the design of the application for children with the aim to transmit educational content through an entertainment game.

Moreover, the FOODDY Interactive AR Application has been designed and developed with a similar aim. However, in this second case study, the application has been designed to be used during the grocery shopping at the supermarket, to visualize information and data on the environmental impact of food and to support users in adopting correct behaviors.

Proper tests on the educational value of the applications as well as on users' evaluation of their use and pleasantness have not been performed yet. Nonetheless, the authors have collected some preliminary comments and opinions from some users (mainly students) that have tried the applications. They reported a very high level of appreciation of the applications and a high level of pleasantness in their use. In particular, they found the AR contents of great entertainment and stimulating to continue using the applications. Moreover, some suggestions about the graphical elements of the interfaces have been collected and used to improve the first versions of the applications. It is worth mentioning that these initial evaluations will certainly need to be properly addressed in the near future.

Regarding the benefits of the presented work, in an envisaged scenario, it can be used as example to design and develop Interactive AR Applications for a wide range of educational purposes concerning ecological, scientific and technological topics, and can be used to support users towards more sustainable behaviors.

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