Using choreographies to support the design process on the development of serious games to reduce electricity costs

Fernando Cassola[1,2], José Iria[1,3], Hugo Paredes[1,2], Leonel Morgado[1,4]
António Coelho[1,3], Filipe Soares[1]

[1] INESC TEC - INESC Technology and Science, Porto, Portugal,
[2] UTAD – Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal,
[3] FEUP – Faculdade de Engenharia da Universidade do Porto, Porto, Portugal
[4] Universidade Aberta, Lisboa, Portugal,
{fernando.c.marques, jpiria, antonio.n.coelho, filipe.j.soares}@inesctec.pt,
leonel.morgado@uab.pt, hparedes@utad.pt

Abstract. Building automation systems can contribute to reduce electricity costs, by managing distributed energy resources. But human behaviours impact a large range of energy consumption that cannot be optimized by automation alone. So we propose to use gamification techniques merged with building automation solutions to enable behavioural demand response. However, there is a lack of knowledge of the real actions of building users. We propose storing human actions data as choreographies, to enable the study of users' behaviours and then support a gamified solution in order to reduce electricity costs by behavioural change combined with building automation.

1 Introduction

In general, building automation systems contribute to reduce electricity costs by managing distributed energy resources in an efficiency way. However, a large share of consumption cannot be optimized through automation alone, since it mainly depends of human interactions. Gamification can be used as one form of changing users' behaviours [1, 2], but its implementation does require assumptions on the behaviour patterns that need to be identified, encouraged, or discouraged. To tackle this problem, we propose a framework that joins building automation solutions with gamification techniques to enable behavioural demand response (DR). Other approaches have been developed [3, 4], however without employing gamification techniques powered by automation solutions to reduce electricity costs.

Several authors [5–7] tell us that the "knowledge acquired in an action-based and meaningful context promotes behavioural change" [8]. So we propose identifying users' behaviours that can be potentially relevant in a three phase process. In the first phase we will be using the building automation systems to monitor electric consumption of all actions produced by the building equipment (elevators, air conditioning, etc.) and inhabitants. Next we intend to extract users' behavioural patterns as choreographies related with energy consumption. After that, analysing the energy consumption of choreographies, we will promote the most effective ones employing gamification techniques (or even promote novel choreographies), with the goal of achieving electricity savings.

Employing platform-independent choreographies is a way to guarantee the interoperability and integration with other systems and approaches. First of all, because we have multiple input datasets from which to create the choreographies of the building devices and their occupants. Namely we are going to use the data given by the building automation electricity meters and also use smartphone and desktop applications to collect indoor users' locations and behaviours. Platform independence will enable the future association/adaptation of choreographies to different inputs. The other reason why we need the platform independent choreographies is because we must be able to render them in various output systems. We need to employ a graphical interface, showing the collected behaviours associated energy consumption data, so human users can identify choreographies on that historical data registry. But we also may need to provide access to machine learning systems. Even graphical interfaces may require multiple implementations, depending on the intended analysis approaches. Choreographies will also be used on the gamified application in order to encourage users to adopt specific behaviours. And communication of results may require a demonstrator to show and validate the new changed behaviours and the main gains obtained with the proposed solution. Platform independence enables choreographies to be treated as core data for this software solution, rather than a mere visual gimmick. For this purpose, we will follow the Ontology-based transformation approach for choreographies proposed by Silva et al. [9].

2 Background

Regarding the previous chapter we divide this in main topics, which represents the theoretical challenges that allow us to develop the solution.

2.1 Building Automation Systems and Demand Response

Building automation is a system designed to monitor and control distributed resources, such as lighting, smart appliances, heating, ventilation and air conditioning [10]. The objectives of building automation are to improve occupants' comfort, increase the efficient of buildings' operation, reduce energy consumption and operating costs and improve the life cycle of devices. Direct load control is a core functionality of building automation that enables owners to participate in DR programs with the objective of reducing electricity costs [4, 11].

The DR programs can be categorized into two groups [12]:

1. Incentive-based – reward users with direct payments to change their consumption upon request. These programs can be divided in two groups: retail and electricity market services. The electricity market services refer to demand that competes directly with generation in the ancillary and energy markets. On the other hand, retail programs consist on the provision of peak reduction services;

2. Price-based – refer to consumers choosing to be exposed to time-varying electricity prices or time-varying network tariffs (or both) that partly reflect the cost of electricity and/or transmission/distribution in different time periods and react to those price differences depending on their own possibilities.

Building automation shows to be an effective solution to reduce electricity costs. However, a large share of consumption cannot be controlled though automation, since it mainly depends of human interactions. Therefore, new DR solutions focused on behavioural change must be investigated, in order to optimize demand that cannot be controlled through automation.

2.2 Human Behaviour Detection

Collecting human mobility patterns and actions is one task that we need to realize in order to obtain data that will allow us to create the choreographies. To correlate the electricity building consumption meters with their occupants we need to know users' indoor location.

Since the wireless networks access is now widespread, we can use them to develop the recently wireless indoor location techniques, providing new tracking object location detection. These techniques may be classified based on two different methods, the location positioning algorithm and the physical layer or location sensor infrastructure [13]. The first approach can determinate the location using the measurement of the signal (Time of Flight, angle, signal strength). The other uses the wireless technology to measure the broadcast (transmission and reception) of signals between hardware components of the system.

Some dedicated indoor positioning systems have a high precision, but an expensive infrastructure is needed. Another class is using the existing infrastructure such as Wi-Fi (IEEE 802.1) [13], RFID [16], Bluetooth [17] or ultrasound [18].

Additionally to the previous mobile location systems we can also use computer based applications to evaluate and log whenever the user is using the computer [14] and even calculate the energy that is being consumed [15].

2.3 Choreographies and Platform Independency

Transforming human actions data storage into choreographies will allow us to study the users' behaviours and then propose the gamified solution in order to reduce electricity costs. Choreography is a set of interactions and events that take place in a given time and space, with a well-defined objectives and rules, performed by human and / or virtual actors [19]. There are several contexts that need to use virtual systems based on multi-user behaviours incorporating choreographed scenarios [20–22], where the user interacts with the environment collaboratively, namely for better training and understanding [23] (e.g., mechanical maintenance of F-16 [24], factory assembly simulation [25], disaster training [26], medical education [27]).

In addition to these multiuser online training systems choreographies are also used in very specific scientific areas (e.g., psychology, sociology, history), where multiuser activities or interaction with choreographies of agents and objects play a relevant role.

These representations allow us to test hypotheses that would otherwise be difficult to verify and validate empirically, significantly improving the predictive capacity of phenomena [28, 29].

The application of the choreographies must be platform independent to allow an automatic data adaption between the knowledge domain and the technological platform [30]. But there are some difficulties to develop choreographies to different platforms [31]: the variety of virtual platforms with several differences contributes to the implementation of a choreography in a particular environment; the dependency necessity prejudice the evolution of the choreography (changing a choreography or some part of it compels to change the implementation); also the involved experts (domain specialists and researchers, choreographers) have several terminological differences, which represents an independent approach, mainly on the data representation. So as Silva [31] systematize "the problems that arise from the application of choreography to multiple platforms can be systematized in three dimensions: Semantic gap, heterogeneous platforms and evolution of systems and choreographies".

Furthermore if we look to the representation of the choreographies there are several models, which supports quite a few scopes (multi-user, multi-domain, multiplatform) [32–34]. However, the ontology based approach proposed by Silva et al. [9] allows the simultaneously blending of these three scopes, facilitating the development, adaptation and sharing of the choreographies. Based on the concept of Model Driven Architecture (MDA) this method can capture not only the physical virtual environment but also the users' (real and virtual actors) actions and conditions performed on the scenarios. The solution proposes an ontology to capture the semantics of a generic application domain choreography, which is integrated with an ontology representing the specific area (functionalities, terminology). If we use this schema with a set of alignments we can obtain a complete sequence of processes and reduce the resources and time spent on the implementation process. We also can guarantee the independency of any platform (although we use domain choreographies) as a way of staging choreographies in a certain environment.

2.4 Gamification Techniques

Although there is no standard definition, ultimately various authors converge to define gamification as "the use of game design elements in non-game contexts" [35]. So we use game elements and mechanics to engage and motivate end-users on an interactive platform [36]. To persuade this approach we will follow the Six Steps Gamification framework [37], commonly identified as 6D. Initially this framework requests that we define the business objectives and to target the expected behaviours. Then proceeds to describe the players finding the ways to engage them, devises the activity cycles (frequency and order of engagement loops such as motivation action-feedback) and forces to don't forget the fun / pleasure. Finally deploys the gamification system with the appropriate tools.

Additionally to the 6D framework, we can employ another gamification design framework, which places more emphasis on human motivation: Octalysis [38], proposed by Yu-kay Chou. It is centred on a Human-Focused Design and based on an octagonal instrument with eight vectors, called core drives, that represent: epic meaning and calling, development and accomplishment, creativity and feedback, ownership and possession, social influence and relatedness, scarcity and impatience, unpredictability and curiosity, and loss and avoidance.

3 Approach

In Fig. 1 we present our approach to develop a framework that joins building automation solutions with gamification techniques to enable behavioural demand response actions.

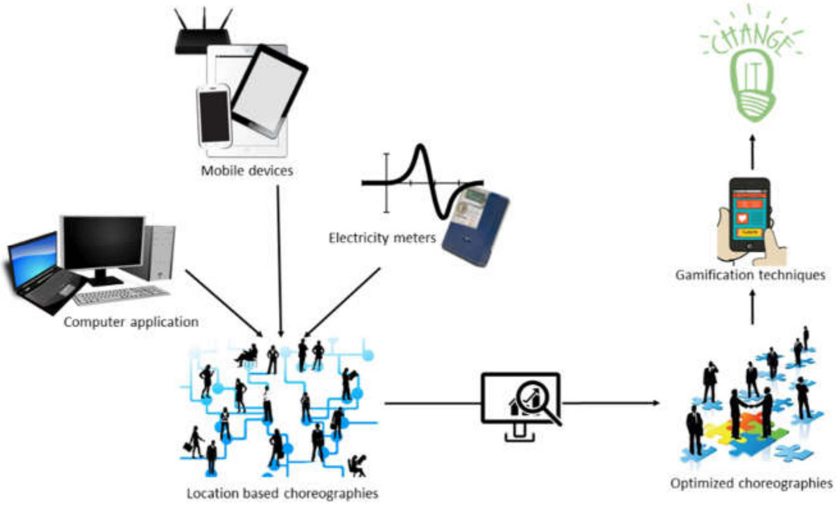


Fig. 1. Main Idea Schema

In order to better understand the users' buildings actions we are going to develop two types of applications that were previously presented on the background chapter. One is going to be installed on each working computer and will generate a log file (Table 1), that give us the moments when the worker his using the computer.

Table 1. Computer Application Log File Header.

DateTime	UserID	Action	Physical Address	IPv4 Address

The other application must be one that follows the users' movements, so we are going to implement a mobile application. Using indoor location techniques on the mobile app we are able to obtain a log file (Table 2) with everywhere the user walked inside the building.

Table 2. Mobile Application Log File Header.

DateTime	UserID	Action	Building location	Physical Address

So collecting different data obtained from various sources (computer application, mobile application and digital electricity meters that where installed all over the building) we are able to identify individual / group actions and behaviours patterns of the building occupants and their devices, which we can co-relate with the electricity consumption.

Based on the approach presented by Silva et al. [9] and bearing in mind that the choreographies must be platform independent, we propose a high-level generic ontology, which represents the conceptual behaviours on an abstract manner. So with the collected data we need create ontologies that integrate the models of the different choreography abstractions.

First we implement an independent ontology, which represents the main concepts of a choreography independently of the implementation technology, also described as "the foundational ontology" [39]. At this level there is a representation of the concepts, their properties and also the relations between those concepts. Then we develop a platform-dependent ontology which contains the core concepts of a choreography for a concrete platform. So it's natural that each platform needs to have an ontology of this kind and even can integrate specific characteristics and terminology of the platform. After that an authorship ontology must be implanted, which captures the representation of a complete choreography for a concrete application domain, not taking into account any platform specification. Last a platform and domain dependent ontology has to be developed. This is the approach that serve as a guide for the implementation on each platform.

After the ontology representations we are able to implement a visual interface that demonstrates the location based choreographies previous captured. Besides this, the demonstration tool should allow the user to:

a) Correlate the electricity values with the concrete choreographies;

b) Define what where the parts of the presented choreographies which interest to observe;

This platform shows us the users' building actions that will lead us to analyse the specific users' mechanisms interaction and the events dynamics. With those observation data we can propose, in another tool, what where the optimized choreographies and even predict what were the costs benefits that those new behaviours should bring.

At this point following the 6D design gamification framework with the Octalysis framework we must propose concrete gamification approaches in order to engage the users' building occupants. We will be using a mobile and computer application because we think that the concrete gamification techniques should act on opportunities and group dynamics with context awareness. The optimized choreographies should be take into account when we calculate the electricity costs and benefits.

Now we present some pre-identified choreographies with our approach that demonstrates what we are going to implement.

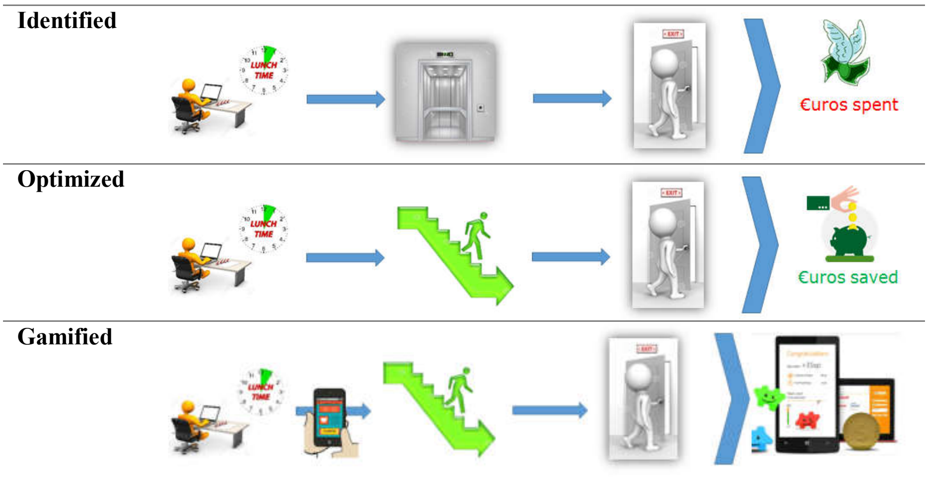


Fig. 2. Elevator Choreography process

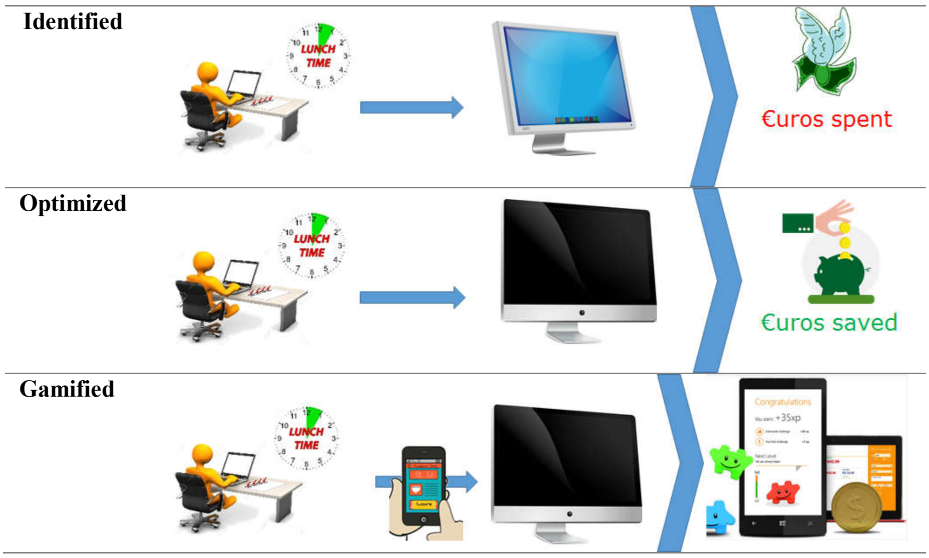
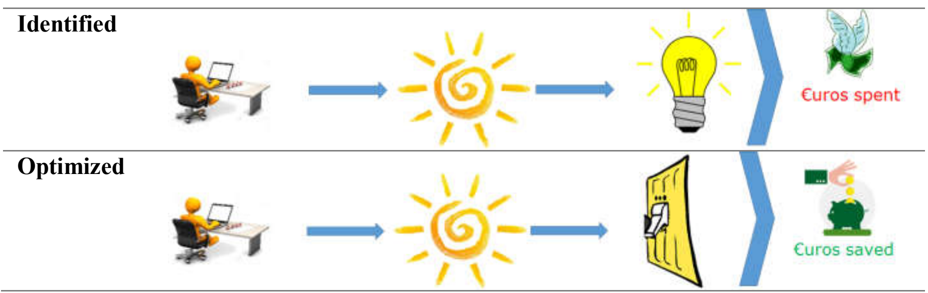


Fig. 3. Monitor Choreography process



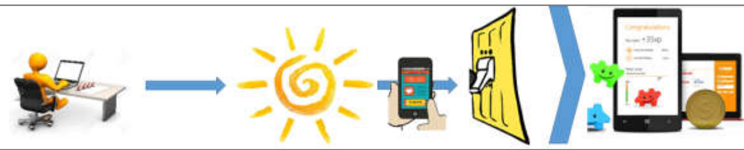
Gamified	

Fig. 4. Lightning Choreography process

On the example presented on table 3 we identify that the user usually goes to lunch at the same time and uses the elevator to go down the building. With this identified behaviour and joining the electricity meters we can estimate that with this action some euros was spent. After analysing this we can define an optimized choreography that will save money. But one question arises: how can we promote this behaviour change? To realize that modification we are going to use gamification techniques. So minutes before lunch time the application suggests the use of the stairs instead of the elevator. If the user accepts that suggestion, the application can recognize it and automatically increment the user global score and show how much euros were saved.

The same approach can be made with the example on the table 4. But instead of saving money not using the elevator we can do it by not leaving the monitor turned on. We can identify the right behaviour by consulting the electricity meter and then give the rewards.

The last illustration (table 5) uses another predictive approach. Because we have a pervasive application we know exactly what the natural light is in each day. So if the user occupies an office that has a lot of windows and if the electricity meters told us that the lights are turned on, we can send a message and suggest to turn them off.

With these pre-identified examples we can understand the actual usefulness of our approach in order to reduce electricity costs. We predict that there'll be many more behaviours that can be modified, so using our pervasive applications and then converting them to choreographies we think that we will more easily impart behaviour changes.

3 Conclusions

This article presents an approach of using choreographies to support the design process on the development of serious games to reduce electricity costs. The primary obstacle to this field is to identify main behaviours and join them with the electricity meters. Another technical challenge is to draw alternative behaviours to reduce electricity costs. Rather the technical barriers we need to obtain a large spectrum of related behaviours and engage the building occupants to participate on this project.

Using the gamification techniques presented merged with the independent choreographies method we can expect to present a new way to engage people to reduce energy costs.

Last but not the least, with the platform independent choreographies supported with the ontologies representation we expect to promote a new kind of method to capture, store and represent users' behaviours on different platforms.

Acknowledgments. This work is financed by the FCT – Fundação para a Ciência e a Tecnologia (Portuguese Foundation for Science and Technology) within project SmartGP/0003/2015 under the framework of ERA-Net Smart Grids Plus.

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