InLife: a platform enabling the exploitation of IoT and gamification in healthcare

Nikos Koutsouris
Institute of Communication and Computer Systems
National Technical University of Athens
Zografou - Athens, Greece
nkoutsouris@telecom.ntua.gr

Pavlos Kosmides
Institute of Communication and Computer Systems
National Technical University of Athens
Zografou - Athens, Greece
pkosmidis@cn.ntua.gr

Konstantinos Demestichas
Institute of Communication and Computer Systems
National Technical University of Athens
Zografou - Athens, Greece
cdemest@cn.ntua.gr

Evgenia Adamopoulou
Institute of Communication and Computer Systems
National Technical University of Athens
Zografou - Athens, Greece
eadam@cn.ntua.gr

Katerina Giannakopoulou
Panhellenic Association of Adapted Activities 'ALMA'
Palaio Faliro - Athens, Greece
katerinagnk@yahoo.gr

Vanessa De Luca
University of Applied Sciences and Arts of Southern Switzerland
SUPSI
Canobbio, Switzerland
vanessa.deluca@supsi.ch

***Abstract*— The emerging era of cloud services has already started and the concepts of Internet of Things (IoT) are ready to be introduced in the modern everyday life through the deployment of a large scope of novel applications. In this paper we present the concepts and ideas of the INLIFE project. The software produced by using the INLIFE platform can be seen as a hybrid of a typical e-health application and a typical recreational electronic game and this is one important differentiation of the INLIFE games and apps. The users play an attractive game like e.g. a strategy campaign or an MMORPG (Massively Multiplayer Online Role Playing Game) but the only way to collect the points or the resources they need in order to play, is to do something in their real life, namely "inlife". These valuable actions, that credit points to the players, are detected in an automatic way by using IoT sensors and actuators or by retrieving information from other monitoring systems like ADL (Activities of Daily Living) data.**

Keywords—internet of things, gamification, serious games, incentives, daily living activities, cloud applications, development platform

I. INTRODUCTION

The emerging era of cloud services has already started and the concepts of Internet of Things (IoT) are ready to be introduced in the modern everyday life through the deployment of a large scope of novel applications ranging from smart city solutions, public safety and transportation, to home automation, wearables and of course personal health. During the last years there is a proliferation of available hardware and software solutions related to IoT, most of them allowing the wireless connection and interaction of components and thus enabling the creation of pervasive ecosystems that integrate seamlessly with the environment. Especially for the e-health sector this is a very significant advantage that facilitates the adoption of innovative applications in the daily life. But probably the most important factor that affects the penetration level of e-health solutions is giving to users the right incentives. This is one of the great benefits offered by the platform that is presented in this paper.

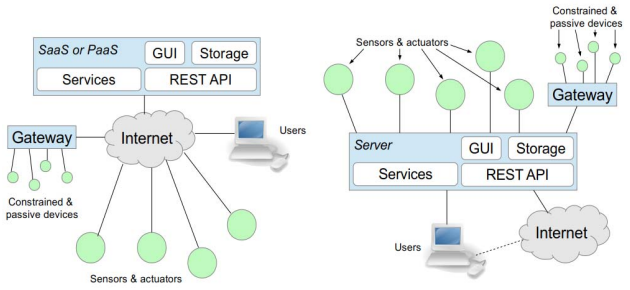
The INLIFE platform, which is built in the INLIFE project [1] and is funded by the H2020 EU programme, supports the development of novel e-health services and applications by combining three main technologies and concepts: Internet of Things, gamification and cloud based recreational games with 3D graphics. The main idea is to exploit the mild addiction of people to games in order to incentivize them to change their behaviour and act as desired. The software produced by using the INLIFE platform can be seen as a hybrid of a typical e-health application and a typical recreational electronic game and this is one important differentiation of the INLIFE games and apps. The users play an attractive game like e.g. a strategy campaign or an MMORPG (Massively Multiplayer Online Role Playing Game) but the only way to collect the points or the resources they need in order to play, is to do something in their real life, namely "inlife". These valuable actions, that credit points to the players, are detected in an automatic way by using IoT sensors and actuators or by retrieving information from other monitoring systems like ADL (Activities of Daily Living) data.

More details on the architecture and the role of its entities are provided in section III. Beforehand, section II outlines an overview of the several research areas and industrial sectors related to the INLIFE concepts. Section IV presents an INLIFE application developed to facilitate the carers of autistic children in their work and the paper is concluded in section V.

II. STATE OF THE ART

A. IoT Management & Control

When building an IoT architecture, one of the major design choices to be made that affects usability and control is whether the platform should be local or cloud-enabled. These two approaches are depicted in Fig. 1 [2]. In the INLIFE platform, wireless sensor networks provide a basis for the IoT layer. Because sensors are a major input to the overall system, it is highly important that versatile, proven and effective technologies are used for the communication of sensor measurements. Two of the most popular wireless connectivity protocols deployed in this context are Zigbee [3] and Bluetooth Low Energy [4].



(a) Cloud-based platform (b) Local platform

Fig. 1. Typical IoT platform architectures (Source: [2])

Sensors provide the required inputs to the system that can be used to detect events or confirm events registered into the system manually by the users, in order to ensure that users are fair. This concept suggests a tight integration of user-sourced information and sensor-based data. A simple example for this would be a kindergarten where the teacher asks the children not to make a lot of noise. Wireless sensors placed in the facility could monitor noise levels created by the children and objectively give feedback to them and the teacher in a game-like manner. This approach to enforcing the desired behaviour would be not only effective, but also entertaining for children, which would act collectively in order to achieve a certain group goal. IoT research and technology currently available present a solid basis for INLIFE to build upon, allowing us to create successful value-added services for IoT platforms.

B. Using serious game concepts to influence behaviour change

Gaming started out as a branch of children's play. Throughout history, children's games have brought up generations and have been widely recognized as a vital aspect of the development of one's personality, social skills, knowledge and other characteristics. However, playing games has not always been considered an educational activity and in the past was predominantly focused on young people as opposed to adults. This has changed in the recent past, where the concept of "serious games" was introduced. Serious games started out as a concept focused on [5] education through experimenting and investigation, having entertainment as a secondary purpose. Board and card games are two examples of serious games which have been around long before the introduction of electronic games.

One of the greatest challenges in the creation of serious games is to find the right proportions between efficacy and pleasure. A game of this kind should be effective in building skills, knowledge and competences for its players, while at the same time providing an acceptable but not excessive reward level. The effectiveness of such games has been proven [6] in the domain of industrial and military role-playing training games, and they have recently made their way into the educational domain. The success of serious games in education is based on some fundamental and inherent characteristics they possess; they are well-structured, highly motivational, they have a well-defined set of rules that are accepted by all participants etc. Of course, one of the most important aspects of serious games is the gameplay, which is what keeps the players interested in it. It should therefore be able to adapt to each participant's interest and time they spent playing the game, providing the necessary rewards, just as a traditional game would do. The importance of game design is further analyzed below.

Behaviour modification, also known as Applied Behaviour Analysis (ABA), refers to empirically derived techniques designed to influence the occurrence or frequency of certain behaviours. The research of behaviour modification dates back to 1911, when E. Thorndike frequently mentioned "modifying behaviour" in his article Provisional Laws of Acquired Behaviour. Since 1940s and 1950s, J. Wolpe [7] had adopted this term to describe psychotherapeutic techniques derived from empirical research. Common methods used in behaviour modification include increasing the adaptive behaviour through reinforcement, and decreasing the maladaptive one through techniques such as extinction, punishment or satiation, with emphasis on reinforcement measures.

In contrast to behaviour modification that imposes or removes stimuli to affect a behavioural change, gamification attempts to achieve the same result by creating an entertaining and engaging experience using the elements of a game or contest [8]. According to [9] gamification has four major elements that significantly increase its acceptance: increase of user satisfaction, conveyance of optimism, facilitation of social interaction and provision of meaning. In this way, compared to traditional behaviour modification methods (such as punishment), gamification relates behavioural or habit change to positive emotional feedback. INLIFE exploits gamification as a "technology" which aims to create entertaining experiences while accomplishing serious personal, social, or business goals. Gamification usually includes game elements such as leader board, rankings and points system, to create entertaining and engaging experiences. In addition, INLIFE uses advanced artificial intelligence algorithms based on ant-colony optimization in order to adjust the players' rewards based on their actions.

C. Social Media and Gamification in the context of INLIFE

Social Media and online Social Networks in particular, have a major impact in everyday life. Facebook [10] and Twitter [11] are the most popular ones, but other types of social media are growing, focusing on a variety of themes, including reviews and ratings, blogging and conversations, location, DIY, wikis and business networking. Social media have been used in (serious or not) gaming platforms, mainly as a means to report gameplay progress in order to increase motivation and competition among players. This enhances the playing experience of users and contributes to the overall success of a game.

An example of using social media in a serious game involves taking into account the level of participation of the player in a social network (such as counting shares, likes, friends, commits, etc.) and allowing progress only if a checkpoint has been reached. In an educational serious game for instance, it could be asked that the player completes a task and then uploads a corresponding video on YouTube, where it gathers views by other players. The game engine could check that the user has indeed uploaded a video on their account and it has enough views to consider the task as fulfilled, providing the relevant reward.

In the context of INLIFE, social media have a much more significant role. INLIFE allows the tighter integration of social media into the gameplay, considering them not just another means to disseminate the results of playing the game, but also a source of information and a major parameter that affects the progress of the game. This notion is based on the fact that social networks are inherently collective and can therefore play a quite supportive role in games which focus on collaboration between users. The INLIFE platform will facilitate the effortless development of games that are tightly linked to social media, allowing these concepts to be used in practice.

D. Gamification and digital healthcare

Gamification is to apply game design techniques and game mechanics to non-game applications or processes, aiming at solving problems, engaging audiences and making more attractive some tasks that otherwise are mundane. During the last few years it has actually become a trend and numerous health and wellness apps related to self-management, disease prevention, medication adherence, medical education, have appeared. One reason is the cost efficiency of technology-based training, but the most important factor is that the carers, physicians and other healthcare providers are interested in using gamification tools in order to assist their patients to do what they have to do, e.g. don't miss their medication schedule etc. Other approaches include story-telling games and 2D & 3D comics, describing in a graphical way the health literature related to diagnoses, medical procedures and patient behavior.

III. THE INLIFE PLATFORM ARCHITECTURE

INLIFE introduces a robust, integration and development platform providing the necessary ICT tools and services for building, simulating and validating interactive serious games and formal learning programs. INLIFE aims to implement an event-driven framework, where serious game evolution is tightly bound to real-life actions and conditions. To achieve this, it forces towards the following directions:

- Leverage on a reliable, modular and flexible IoT platform providing bi-directional interaction between gameplay activities and the surrounding real-space, taking advantage of IoT technology.
- Integrate data analytics, artificial intelligence and automation mechanisms, able to closely follow and analyse behavioural improvement and learning progress for each individual player and make decisions about triggering special learning actions when necessary.
- Realize a modular, flexible and open architecture that is able to i) integrate Serious Games in a wide range of educational learning and social inclusion contexts with zero or minimum external intervention and ii) operate under several different logics by adjusting critical serious game parameters, e.g. activate on demand audio/visual support, record and analyse players' information trails, formulate on the fly completion/cooperation clusters of players for certain purposes, etc.

The INLIFE architecture, depicted in Fig. 2, defines two major layers, namely the *IoT-based Data Adaptation Layer*, which establishes communication with smart devices and takes over data aggregation and adaptation, and the *Gamification Layer*, which coordinates INLIFE's services provision and gamification control. In INLIFE, trainees are able to access and play Serious Games through their portable smart devices, e.g. smartphones and tablets, after they have been registered by the IoT platform.

In the following two subsections, the two major layers of INLIFE's open framework are thoroughly described both in technological and operational aspects.

A. IoT-based and Data-Adaptation Layer

Data aggregation in InLife is built on top of an open and flexible IoT Platform, which facilitates registration, communication, data flow and smart device management providing the core IoT infrastructure and services. The IoT platform implements both vertical and horizontal functions to support Gamification Layer applications. The essence of INLIFE's IoT platform is to enable the secure connection of a multitude of heterogeneous sensing and actuating devices, having different constraints and capabilities. This includes the interaction with the hardware infrastructure, including the control of smart meters, smart plugs and sensors. Indicatively, collected information will track peoples' or objects' mobility, lighting, temperature, room occupancy, pressure forced on objects/surfaces, location/acceleration measurements, interaction with smart objects, etc. The IoT platform provides the required scalability through its distributed message queue-based architecture for interfacing and collecting metering data from a large number of deployed meters. Also, it employs cloudification, service discovery and sophisticated data chain technologies, in order to define credible data adaptation and flexible data management mechanisms able to enable powerful administrative tools exploited by subsystems of the Gamification Layer. INLIFE's architecture also inherently

supports different communications standards (mainly IEEE-based such as WiFi and ZigBee, etc.).

B. Gamification Layer

Gamification Layer is responsible to monitor and control Serious Game evolution and players' progress timeline integrating in a smooth and interoperable way the developed ICT-enabled automation and modelling components and services of the InLife open framework. It is built on a modular design, the main blocks of which and their corresponding responsibilities and functionalities are the following:

Context Information Modelling: The first step to demonstrate a successful Serious Game is to develop a comprehensive context design capturing all aspects of the (IoT-equipped) smart environment, within which the educational or social inclusion activity is unfold. Context information modelling (CIM) aims at identifying the firm and meaningful entities of the educational/social inclusion ecosystem and how each one supports the overall educational objectives. Further, it specifies what exact variations and degrees of freedom are available for each entity or part, as well as the relations between them both in a qualitative and quantitative aspect.

Game logic engine: In the context of Serious Games, this engine drives the development and integration of modules not traditionally associated with computer gaming but vital for non-leisure gaming contexts. Among others, this includes modules that provide support for bridging between the physical and digital world, interactive educational narratives, neurostimulation to promote learning and integration of haptic feedback into the learning experience, etc. The ultimate objective of the game logic engine is to define a number of alternative options for game structure and logic.

Serious Game Analytics integrates a number of artificial intelligence mechanisms and powerful analytics tools to understand in-game player behaviour and better measure

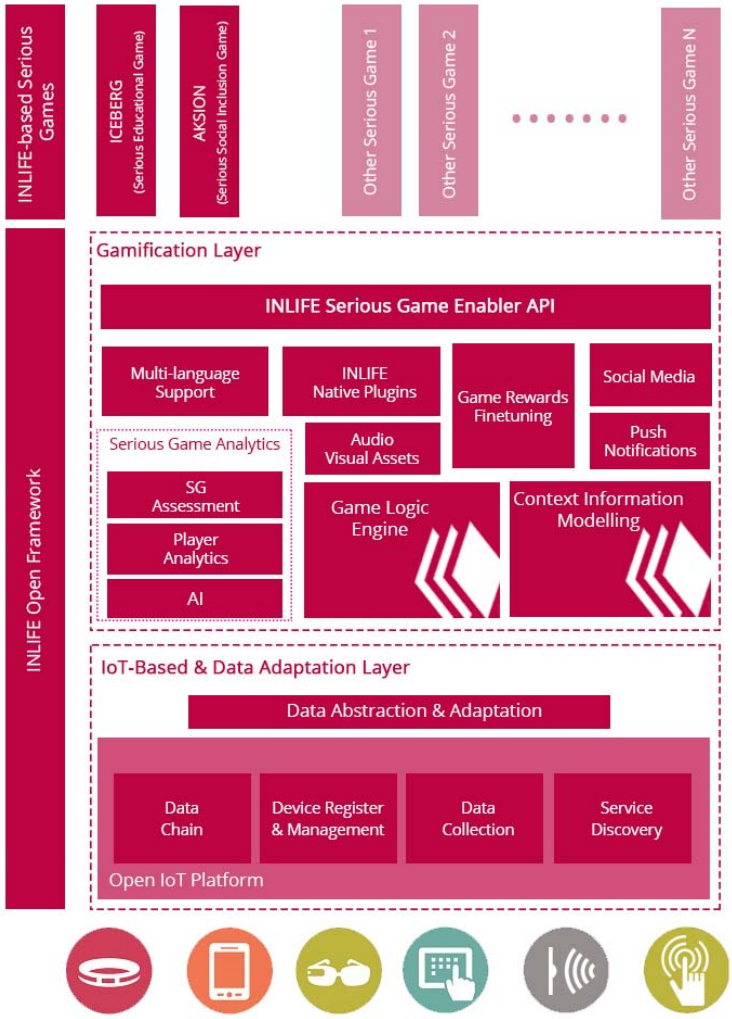


Fig. 2. INLIFE platform architecture

overall Serious Game business success. The main goal is to provide advanced game analytics, while assuring functional consistency, data transparency and hiding any heterogeneity issue. The framework is able to seamlessly define and integrate sophisticated behavioural models for (group of) trainees by employing effective classification, feature extraction, clustering and time-series analysis over the collected data and discovering hidden relationships and inherent interdependencies. Based on these models and on regression and extrapolation techniques, the aim is to provide a better and more effective gaming environment for (group of) players by recommending both in-game adjustments and real-life actions, according to player's skills, response level in set challenges/goals and style of learning process. Apart from player-centric analytics, Serious Games Analytics will provide (actionable) insights on critical KPIs and welldefined metrics that outline the success of Serious Games, as a valuable means for all stakeholders to drive specific strategies/policies that improve their effectiveness, and to (re)train or remediate play-learners for performance improvement.

Game Rewards Fine-tuning fulfils two central needs: firstly, the serious game's need for optimizing its reward scheme to increase its effectiveness, and, secondly, the player's need for information that helps him/her to orientate, achieve goals and solve problems. Feedback about player's progress evolution and state is individualized (per player) leveraging on *Serious Game Analytics* and on three different mechanisms of feedback provision. Through intermittent and immediate feedback during the learning progress, the trainee will get reflections on what has been reached so far during game play. It is a key aspect of interaction that influences player's motivation and provides guidance and assistance when necessary. Based on serious games' Graphical User Interfaces (GUIs), text and texture objects are simple mechanisms to provide this type of feedback. Another kind of feedback would be the assessment and measurement of overall progress, which informs players about their overall level of performance and possible correlate it with other (group of) players, e.g. by showing scores tables, leader-boards etc. Finally, the third mechanism will utilize competitions and rewards to increase trainees' motivation and replayability.

Multi-language support which allows the quickly and easily change of language, as well as adding new languages to the user interface, to broaden the spectrum of potential users from different countries (also especially useful when addressing children of small ages).

Push notifications module that is responsible for broadcasting push messages to trainees, asynchronously announcing that new milestones have emerged or that certain milestones have been achieved. It may also be possible to display the achievements of peers / competitors in the serious game.

Social Media module that is responsible to activate interaction between Serious Game world and the social media. Hence, this module establishes a link able to upload information from Serious Game to the social media (e.g. leader-boards reports or rewards), whereas in the future (after the project completion) this link can be made bidirectional and also transfer actions caught from players' profiles in social media, public profiles or local news aggregators into the serious game in a context-aware manner.

INLIFE Native Plugins module that defines code libraries executed by Unity during the development process of Serious Games and allow developers to integrate particular middleware libraries of the platform or have access in context-specific features and attributes.

It is worth mentioning that INLIFE, through its open APIs, enables third-party developers to create and/or configure their own 'in-life based' serious games, without having to start from scratch. Hence, it is envisaged that the INLIFE project will enable an ecosystem of INLIFE based serious games and e-health solutions multiplying the impact of the initial investment.

IV. USE CASE – APP FOR AUTISTIC CHILDREN CARE

Playing a game is one of the very first social activities of every human being. Games are changing the way children learn, helping them think differently and stimulating new ways people of all ages can use their minds. Serious games have been proven to be a solid method of changing a user's behaviour models in real life. Research is showing games are a more interactive and participatory way to help someone understand almost anything – from a history lesson to the dramatic change a flood can have on a specific community. A "virtual world" can be used as a safe environment to try out a certain behaviour and repeat that behaviour until the player has learned the best approach to reach a certain target. The INLIFE platform combines playing with the recent advances in the Internet of Things, the capabilities of modern handheld devices and the addictive 3D graphics technologies that are available in order to serve adapted and personalized learning and pedagogical needs i.e. for autistic children. The real life tasks that the players have to accomplish in this case are related to daily activities like using correctly the toilet (e.g. flush, soap, water, towel etc) or cooperate with other persons in simple actions as expected. If it is more suitable, the verification that an action has been done (correctly or not) can be also come with the intervention of a human supervisor (e.g. the carer, the educator etc).

Fig. 3. Sensor in the toilet flush to detect when it is used

Gamification can be part of the holistic approach in the education of persons with autism or disabilities in general.

Serious games can co-exist with several methodologies (ABA, TEACCH, PECS, sensory completion through the WILLBARGER protocol etc). The participation of the whole family is also desirable. The goal is to facilitate and support the social inclusion of persons with disabilities by means that do not differ from cases of other people of the same age, as well as to improve their social and communication skills. The participation of different parts of the society in the same INLIFE game and in the common efforts for a reaching a goal in the game through actions in the real life can generate the feeling of a "parallel family" which is present in all stages of growth.

In the context of the INLIFE project a game called AKSION has been deployed in the Panhellenic Association of Adapted Activities 'ALMA'. ALMA is a Service Provider for children, teenagers and adults with disability (autism and mental retardation), aiming at their psychosocial development and total integration in a society of equal opportunities. ALMA offers a system of integrated alternative therapeutic intervention, addressing not only people with disability, but also their families.

Fig. 4. Tagged toys and the RPI reader before its decoration as a

The main set of real life actions in this case is related to the teaching of speech comprehension and object recognition by young autistic children with ages between 4 and 7. For this reason, a set of RFID tags has been installed in various toys, shown in Fig. 4, in the classrooms of ALMA. A Raspberry PI (RPI) with an RFID reader and a WLAN connection module has been hidden in a box decorated in an attractive way as a robot. The autistic children are asked as usual to bring a specific toy to the educator, who writes down if the child brought the correct toy or not. Several repeats are done. This process has been automated with the use of the INLIFE platform and the IoT devices. The robot/RPI asks (through the attached loudspeakers) for a toy and when the child approaches the object to it a sound is played depending on if this object was the one requested or not. At the same time, some points are credited to the account of the child in the AKSION game based on the gameplay which is explained in the next paragraph. Later, during his/her break, the student will be able to use the collected points while playing AKSION in order to customize his/her avatar in the game, to travel to other planets etc.

The AKSION serious game tells the story of an astronaut who travels along unknown and unexplored planets and tries to learn about the inhabitants' traditions and behaviours. The astronaut commands a spaceship with the help of his/her loyal companion: a robot that supervises the operations and gives advice to the player during the whole adventure. The astronaut is not alone in the story: he/she is part of a Galactic Confederation with a common purpose: navigate through the universe and get in touch with the local culture. The players should feel that they are part of this alliance, made of all the children who play the AKSION game. That is the reason why the avatar's spaceship hosts a room for the Intergalactic Meetings, where every player can see the others characters' friends and the whole community. An indicative screenshot of the AKSION game is shown in Fig. 5.

Fig. 5. A screenshot of the AKSION game

The first feedback from the pedagogists and the children is very positive. As the whole application is cloud based, by ensuring a good WLAN coverage in the building and a robust internet connection there are no problems or any continuous need for technical support. The use of the system is actually easier than the current use of paper for writing down answers and remarks (in this trial phase the INLIFE application is used in parallel) and the children really like the game graphics and the use of the tablet. More quantitative results will be presented in the fourth trimester of 2018, after the consolidation and processing of the data that is being collected.

V. Conclusions

This paper has presented the concepts and ideas of the INLIFE project as well as the architecture and the features of the INLIFE platform. The key differentiating point, namely the connection of a recreational 3D game with actions in the real life and IoT, has been highlighted, while a specific e-health application has been presented as a use case for demonstration. The realization of the INLIFE vision will ultimately pave the way for the proliferation of new innovative IoT-based e-health applications and games, created mainly by third parties, featuring enhanced gameplays and educational efficacy. Existing games can be transformed into INLIFE games by using the APIs of the platform and by allowing the collection of points only through real life actions. The final version of the platform will be soon be available for testing and download, thus establishing new market opportunities for involved stakeholders.

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