The interplay between IoT and serious games towards personalised healthcare

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***Abstract*— Given the beneficial role of the serious games (SGs), which has been evaluated and found effective over the last years through large scale pilots, SGs are gradually being considered as new and effective tools in the healthcare domain. Following this evolution, this paper presents the potential value of the interplay between the Internet of Things and the SGs in a twofold approach: SGs consuming heterogeneous information coming from the user's environment (through IoT) as well as SGs as virtual devices providing meaningful information pertaining to the user's progress and physical and cognitive health status. The insights provided in this paper support the augmented personalization and consequently effectiveness of the SGs as part of the users' lifestyle. The paper concludes with the big challenge of the next years which will remain the deep understanding of the SGs information, as well as the semantic representation of it.**

Keywords—serious games; internet of things; exergames

I. Introduction

The increase of population's age across developed countries is followed by the increasingly important social issue for independent and healthy lifestyle of elderly populations. The beneficial role of the SGs (either cognitive or exergames) for elderly people, gradually being accepted as tools for new treatment options and therapies [1], has been evaluated and found effective over the last years through large scale pilots, in terms of participants and duration [2]. Improvements in spatial executive processing, spatial, verbal and visual working memory, visual attention, speeded processing as well as verbal and non-verbal reasoning and problem solving have already been reported [3]. When SGs promote physical activity and exercise (exergames), apart from physical fitness improvements, positive mood changes, improved confidence with everyday functional activities and overall quality of life improvement have also been documented [4][5][6].

The majority of the aforementioned studies take place in controlled environments or even lab settings due to the gap between technology and elderly population, the special requirements for carrying out pilot trials with special infrastructure and the intrinsic need of the studies for observation and documentation of the participants' behavior. Such settings are far away from real life settings [7] which remain the challenge for the future of SGs. Besides this, the challenge for monitoring people in real life, in a more holistic manner, has been on the foreground for many years in a variety of research fields.

Continuous monitoring of behavioural trends and physiological parameters has been feasible due to the avalanche of low cost, off-the self devices and sensors that support ubiquitous connectivity. Unobtrusiveness is key to their wide acceptance by senior people, especially when it comes to installation within the home environment or being worn throughout the day [8]. Indicative examples of the sensors used in the literature, include but are not limited, to ON/OFF motion sensors, wearables, such as activity trackers, visual and audio sensors.

However, Internet of Things (IoT) connectivity is not yet among the standard approaches in the domain of SGs and only recently a couple of articles with insights on how IoT can advance exergames and SGs have been published [9]. This paper attempts to shed light on the potential twofold role of the IoT advances to the future of SGs: a) how IoT devices can enhance the personalisation engines of SGs and b) how SGs can feedback to the environment (consumed by IoT analytic engines) information relevant to the user's progress and physical and cognitive health status. This paper puts the threads together and summarises the insights highlighting the novelty, strengths and limitations of the interplay between IoT and serious games.

II. The Concept

This paper aims to provide an argument on how SGs for active and healthy ageing and IoT technological advances could be combined enhancing the role of SGs in healthcare ecosystems. Although this combination and more specifically the interconnection of technologies towards pervasive serious games has already been discussed [10], this paper presents indicative approaches of what could be investigated in the near future with respect to exergames and cognitive games for elderly people. A twofold approach will be presented: SGs consuming heterogeneous information coming from the user's environment (through IoT) as well as SGs as virtual devices and source of meaningful information pertaining to the user's progress and physical and cognitive health status.

The most common example of IoT connectivity in SGs is the adoption of publish/subscribe architecture for gaming controllers facilitating the cross device - cross platform approaches [11]. Such approaches enable gaming controllers to be exploited by SGs regardless of the hardware system or the operating system while at the same time allow gaming controllers to be consumed by more than one system at a time. However, there are plenty of IoT enabled sensors that have

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started being considered as complementary inputs for the SGs, such as activity trackers, health measurement devices, indoor location monitoring, etc.. One could see the larger picture where all these diverse information sources, properly described by well-defined ontologies [12], could develop a new context for SGs in the future.

Robert et al. [1], recognising the capacity of SGs to assess the user's in-game progress and performance, referred to Plato's statement "...you can discover more about a person in an hour of play than in a year of conversation...". Many recent studies have concluded that SGs can provide reliable information in terms of physical and cognitive status assessment through unobtrusive/stealth monitoring [13][14]. The fact that SGs are intended and designed to be part of the user's lifestyle, make their monitoring capacity more significant, even for early signs (disease onset) detection [15]. Therefore, it's needless to say that if the in-game performance and in-game metrics could be translated to understandable and meaningful information, they could feed IoT analytic engines with rich information concerning the user's physical and cognitive status.

Fig. 1. Fig. 1 Serious games in the IoT domain

III. SGs CONSUMING IoT INFORMATION

This section presents some of the IoT technologies that could be consumed by the SGs. Indicative examples are the gaming controllers, health measurement devices, activity trackers and indoor monitoring systems.

A. Gaming controllers and IoT

The emergence of powerful and futuristic gaming controllers (Microsoft Kinect) or monitoring devices that could be used as gaming controllers (i.e. wireless EEG devices: Emotiv Epoc or Mindwave Neurosky) [16], attracted increased attention of the gaming and mobile development community. Cross device frameworks have been built [11] that allow publish/subscribe architectures following the IoT paradigm. Although the real controllers' revolution will probably come with the native IoT support, such frameworks allow the controllers to be utilised by SGs regardless of hardware and software whilst serving other purposes too. For instance, a Microsoft Kinect connected to such a framework could be used by an exergaming platform whilst another application could subscribe to the silhouette skeleton information in order to measure gait speed or balance [17].

B. Health measurement devices

A continuously increasing number of healthcare monitoring devices are capable of being transform to IoT devices [18] and even EU funded research projects, such as UNCAP [19] and i-Prognosis [20], work towards this direction. Apparently, information coming from healthcare monitoring devices (blood pressure meter, oximeter, etc.) the users use in their daily life independently of the gaming sessions, could significantly enhance the personalisation engines of the SGs. Thus SGs could potentially justify the in-game performance or even to take decisions before a gaming session (i.e. high blood pressure within the last hour).

C. Activity Trackers

Ambient motion sensors, that support presence detection of a person, activity trackers monitoring the amount of activity a person has throughout the day, and visual sensors providing qualitative assessment of movement, has been being investigated by the research community over the last decade. Most commercially available activity trackers enable the monitoring of activity amount and intensity, e.g. number of steps and categorisation such as light/moderate/strenuous activity [21]. They also provide sleep tracking capabilities, e.g. sleep onset time, duration, restlessness events, and physiological signals monitoring, such as heart rate and skin conductance [22]. Data transfer to the cloud is a common feature for most fitness trackers, facilitated by an intermediate layer usually. In most of the cases, this main hub for the interconnected devices is the smartphone or a local PC.

D. Indoor monitoring

Following the notion of continuous monitoring the user's real environment, a large number of studies have focused their research on technologies of indoor monitoring [23][24] as well as approaches on extracting useful information for the user's behavior [17]. Gait analysis, including velocity, balance, heel raise, stride length, etc., as well as in-home walking routes and places the user stays more are only some of the information produced by indoor monitoring systems. The value and type of information made the researchers adopting IoT approaches to publishing these features [17].

IV. SGs AS VIRTUAL DEVICES

This section focuses on the information that can be produced by the SGs and could be of added value to IoT systems in the user's environment. Indicative examples include the in-game metrics, clinical assessment tests delivered as games, engagement levels and other emerging sensors and services.

A. In-game metrics

Cognitive SGs, as well as exergames in the most recent years, have been considered as potential assessment tools for the user's cognitive and physical status. A cohort of studies investigated the correlation of cognitive and physical assessment clinical test with the in-game performance. Staiano et al. [15] exhibited aerobic exergames as a promising tool for measuring physical health through unobtrusive data gathering

tools. Perceived exertion during gameplay, communicated through the Borg scale [25], could be an indicator of the user's effort. Additional in-game metrics such as movement time, response time and successful completion of activity, collected in a stealth way, have been found to correlate moderate to strong with clinical cognitive and physical assessment tests [13] as well as with EEG findings [26]. On top of this, exergames have been proven to have the capacity to estimate the users balance, fall risk or even gait performance.

B. *Clinical assessment tests delivered as games*

Beyond correlating in-game performance with clinical assessment test, SGs can be also used as gamified computerised forms of these tests, which are more acceptable from elders than the paper and pencil versions [27]. Both cognitive [28][29] and physical assessment test can be transferred to SGs. In the latter case, only exergames can be used prompting the user to perform specific movements as part of the game. For instance, the chair stand and sit (part of the Fullerton, measuring how many times the users stands in a time period, interpreted to lower body strength) could be easily delivered as a game (i.e. seesaw). However, in this special case of computerising clinical assessment test, although the user follows similar procedures, the assessment tool is totally different and needs to be validated.

C. *Engagement levels*

An additional domain which remains under investigation in the SGs research community is the adherence and the engagement levels of the participants. The researchers pursuit to extract useful insights about the user's behavior and attitude based on the aforementioned levels in order to improve personalisation. It is obvious however that such information, originated from the games, could be used by other behavior analytics engines that aim at delivering habitual information about the optimisation of routine tasks delivery to elderly

D. *Emerging sensors and services*

The recent years, emerging sensors which have been developed for purposes other than gaming have been turned into SGs controllers. Emotiv Epoc and Neurosky Mindwave, revolutionary wireless EEG devices, are two of the most representative cases. Both sensors have been initially introduced to facilitate designed for contextualised research and advanced brain computer interface applications. The SGs community, recognising the opportunities of utilising such controllers, has adopted relevant devices [16]. In a typical scenario, users would control the serious game's evolution according to their brain activity or even higher level information: focus, engagement, interest, excitement, affinity, relaxation and stress levels. Beyond the modern hardware controllers, recent software services have also been in the eye of the SGs research community. For instance, the Microsoft Cognitive Services, cloud based software as a service, enable natural and contextual interaction with SGs, augmenting users' experiences and gameplay. Capturing photos of the user's face during gameplay and applying emotion recognition algorithms [30] could influence the gameplay as well as the providing useful information for the user's emotional status over time.

V. Discussion

This paper presents a different view of the role of IoT devices and technologies in the SGs for healthcare domain. Different categories of IoT enabled technologies that can either feed the SGs or be extracted by the SGs in the IoT context are summarised to give the big picture of this combination. As it is highlighted in this paper, IoT enabled gaming controllers or even controllers that could be used during games, break the walls between SGs and hardware/software compatibility. Although software frameworks have been used so far, the native support of the controllers will facilitate further the cross platform communication. Following the same notion, health monitoring devices could be easily utilised by SGs, if they were IoT enabled. Physical exercise suggestions and recommendations could be then flawlessly applied in exergames in such cases. In the opposite case, SGs could promote the regular use of health devices by rewarding their usage with gaming points during gameplay [31]. Activity trackers tend to provide enriched information about the users physical status, as well as extracted features pertaining to sleep quality, activity levels and physiological parameters. Finally, indoor monitoring, focusing mainly but not limited to gait and posture analysis, complements a cohort of monitoring sources that hardly have been investigated so far, as far as their role in the SGs is concerned. It is obvious that all these sources could augment the personalisation engines of the SGs and consequently their efficacy. Providing summaries of these data extracted from the daily life of seniors, can provide beneficial information to the way the SGs are being delivered to the elderly people. Detailed information about the physical activity, and implications on the cognitive activity, could help personalise the intervention scheduling, e.g. change the intensity of exercises, based on the user's lifestyle.

On the other hand, SGs as "virtual sensors" have started to be considered among the most valuable sensors for cognitive and physical monitoring of healthy or non-hospitalised patients. Apart from the detailed, in-game performance, SGs can also deliver computerised forms of clinical assessment tests. In the same context, recent studies have also introduced SGs as screening tests [32]. Finally, the game engagement and schedule adherence levels, could be indicators of the user's behavior. The engagement levels of a senior during game play, if combined to routine extraction (identification of the time and the day that each person would be more available to perform a task) of activity levels stemming from IoT data, can allow for the maximum utilisation of SGs, based on the selection of the most convenient time point for the elderly to exercise ("just-in-time intervention"). As it is aforementioned, emerging sensors and services used with SGs, could provide rich information about the users status. A typical example is the wireless EEG devices, that could be utilised during the game, to measure excitement, while at the same time, a low-quality EEG could be collected. Similarly, the user's emotion during gameplay could be added to the list of the SGs' monitoring sources. Apparently, in the case that IoT enabled SGs provide such information in real time, available IoT analytic engines could extract more accurate and holistic findings.

This paper summarizes some of the most common, IoT devices of significant added value, in terms of exploitation by the SGs, based on the authors' previous experience in large scale pilots with serious games. Apparently, the set of the IoT devices that is provided cannot be considered as exhaustive. Besides this, the big challenges for the following years, given that the IoT architectures will be well-defined and easily adopted by any hardware/software, will be the deep understanding of the SGs information as well as the semantic representation of it [12]. Only then, IoT analytic engines will be able to exploit the real value of the SGs.

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