Game and Multisensory Driven Ecosystem to an Active Lifestyle

Aristodemos Pnevmatikakis[1], Harm op den Akker[2,3], Sofoklis Kyriazakos[4], Andrew Pomazanskyi[5], and Albena Mihovska[4(✉)]

[1] Multimodal Signal Analytics Group, Athens Information Technology, Athens, Greece
apne@ait.gr
[2] eHealth Group, Roessingh Research and Development, Enschede, The Netherlands
H.opdenAkker@rrd.nl
[3] Biomedical Signals and Systems Group, University of Twente, Enschede, The Netherlands
[4] BTECH, Aarhus University, Herning, Denmark
{sofoklis,amihovska}@btech.au.dk
[5] Nuromedia GmbH, Cologne, Germany
andrew.pomazanskyi@mgt.nuromedia.com

Abstract. The trends in healthcare are continuously evolving towards a virtually rich personalized experience that involves human-to-human (H2H), human-to-machine (H2M) and machine-to-machine (M2M) interactions. This article proposes a platform that fosters an ecosystem of games and applies them to real-life situations to motivate an active lifestyle in elderly and health-impacted adults. The platform facilitates behavioral change through numerous games and applications that contribute to active living by introducing awards that can be earned upon reaching goals and can be redeemed in other applications of the GOAL ecosystem. The platform consists of core functionalities (account management, virtual reward system and activity recognition); tools for social inclusion (the social marketplace) and tools for healthy behavior (the goal setting service and the motivational agent). Multisensory technology has been proposed as means to enhance the evaluation on the achieved degree of user motivation. The platform applications are interactive games functioning as GOAL Coin Generators and/or Spenders.

Keywords: Interactive games · Health and social inequities · Active lifestyle

1 Introduction

Failing health due to cognitive impairments, chronical diseases or simply advanced age, can seriously impact the lifestyle of the patients towards physically inactive one and social isolation. Gamification has been gaining momentum as a technology-based healthcare and training tool with the potential to motivate healthy and unhealthy individuals and reduce hospitalization and caregiving costs [1]. Existing virtual reality

V. Poulkov (Ed.): FABULOUS 2019, LNICST 283, pp. 49–58, 2019.
https://doi.org/10.1007/978-3-030-23976-3_5

(VR) games (e.g., Oculus Rift, HTC Vive, and PlayStation VR) already provide quite an immersive user experience, which is also a main user requirement when selecting a gaming application. Intelligent computer vision techniques have also been gaining strong research focus because of their potential to realize personalized applications based on human activity, object or scene recognition, of particular interest to the area of assisted living and eHealth, and even business modeling [2–5]. Such emerging technologies and platforms, are capable of sensing, digitization, transmission and replication of human-related information and can be seen as a first step towards a multisensory human-bond data communication (HBC) framework.

The field of promoting healthy lifestyles has exploded in recent years, with countless of tools and interventions generated in research labs and by commercial vendors alike. A key issue in each lifestyle- or behavior change tool is to enable motivation [6]. The user himself has to be motivated to change behavior – i.e. walk more, do physical or cognitive exercise, get out and socialize. There are many strategies towards increasing the user's motivation to comply with behavior change tools. These can be broadly categorized in those that aim to increase intrinsic motivation (using e.g., Social Cognitive Theory [7] or the Transtheoretical Model [8]) and those that provide extrinsic motivation. The GOAL platform focuses specifically on extrinsic motivation, by rewarding the user's good behavior with virtual (or real) rewards that are unrelated to the positive effects of the behavior itself. GOAL, thus, targets the less explored path of stimulating extrinsic motivation, by providing health benefits to the group most difficult to target and by using common health-behavior change tools.

In this context, enhancing the GOAL concept with advanced tools for capturing the multisensory information related to the user behavior and good feeling after getting a reward can increase the motivational impact with huge benefits for the individual's well-being.

The GOAL platform provides a set of services to integrated games and health apps. At the core of these are the physical measurements of activities of the individuals, which are enabled by smartphone or ambient sensors. Any physical activity application collaborating with the GOAL platform would obtain measurements from the sensors, would process them for the extraction of useful metadata and would report them to the GOAL platform. Optionally, the collected data can be visualized. Subsequent paragraphs, however, are indented.

Enriching the GOAL platform with multisensory communication via the Information and Communication Technology (ICT) infrastructure introduces new requirements to the provision of services in terms of delay, packet loss, computing, and cloud, encoding and other. Challenges are to establish the spatial-temporal constraints that determine the quality of the multisensory experience, and to develop coding, compression and transmission techniques that preserve the perceptual integrity of the multisensory signal thereby yielding a "natural" multisensory experience.

This paper is further organized to describe the main functionalities and implementation of the GOAL architecture, the physical activity measurements and the integration of multisensory features, and will focus on the expected impact, and possible integration with third-party applications.

2 Goal Architecture and Main Functionalities

The GOAL platform is an open middleware that can be integrated into apps and games. The platform has a server-based architecture and is inherently agnostic to device or platform of the applications or games that it integrates. The overall architecture is shown in Fig. 1. The platform supports a complete virtual reward system, in which applications function as coin generators, coin spenders or both. The platform provides generic, adaptive personalized goal-setting that apps and games can leverage to automatically provide the most relevant challenge to their users. An integrated motivational agent helps users to achieve their health-, or in-game goals. Finally, the platform includes a social marketplace that fosters social interactions among the GOAL community.

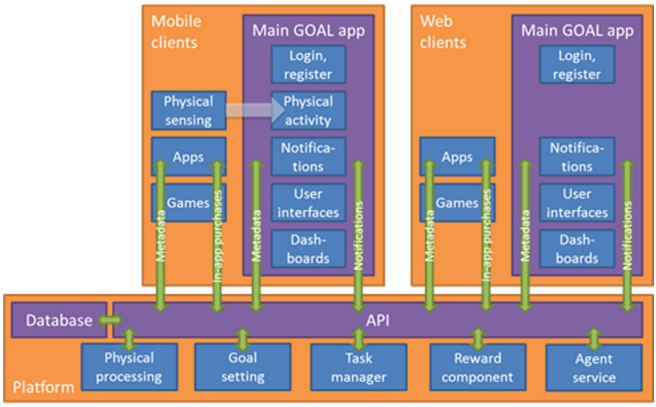


Fig. 1. High-level GOAL modular platform architecture.

2.1 Service Components

The platform has a server-based architecture and is inherently agnostic to the device or platform of the applications or games being integrated. The platform provides the following four major service components (see Fig. 1).

First of all, the platform provides account management and storage, as well as access to the user's virtual GOAL coin wallet. Integrated applications are categorized as coin generators or coin spenders, or can fulfill both of these roles simultaneously. Coin generators are those apps that stimulate healthy behavior and are allowed to award GOAL coins to the user, while coin spenders are games that allow spending coins.

Second, the platform provides a virtual market that stimulates social interaction among the users by allowing them to trade their earned coins for virtual goods or actions, but also for real-world gains. The platform provides the virtual marketplace, while users, developers, local business, or governmental organizations can provide the content. Third, the platform provides a generic goal-setting service to its connected apps, allowing, both, health applications and games to automatically set goals that are relevant for the individual users. The goal-setting component automatically learns to

adjust to its users by observing their lifestyle or game-play behavior and fine-tuning daily, weekly, or long-term goals accordingly. Finally, a motivational agent, which is an artificially intelligent companion guides the users through their game-play and motivates healthy lifestyle behaviors. The companion is tightly integrated with the goal-setting services of the GOAL platform, ensuring that the lifestyle motivations are appropriate to the context of the user's real behavior.

2.2 Other Components

The main GOAL app component allows for the creation and management of the user profiles and acts as the main interaction point for the user to check the status of the earned and spent GOAL coins on, both, the web and mobile. While using the web, access to all the other components (other web apps) making up the platform would be readily provided, this is not the case for the mobile version. All GOAL apps need to be installed individually, and in the mobile version the main GOAL app also acts as the only GOAL software a new user interacts with. Hence, it has to offer the complete GOAL experience of the physical activity measurement, gaming and the social marketplace, by integrating at least cut-down versions of these applications. The interested users can then download more apps, enriching their version of the platform.

The automatic goal-setting component is a service component that automatically calculates personalized goals based on measured activities within the GOAL platform. These goals form the basis for providing rewards (upon achieving them), and form the target for provisioning of motivational advice through the GOAL motivational agent. The goal-setting component provides added functionality on top of all measured data in the GOAL platform, to which some form of progress can be attributed. Examples of data types, on which the goal-setting component operate, are the physical activity (including various different forms, such as number of steps, calories burned and distance), and the cognitive behavior (e.g., amount of time spent in cognitive games, or cognitive game scores). The goal-setting component is a key element for providing relevant and personalized rewards. Earlier work on goal setting in the daily physical activity was reported in [9].

The motivational agent is a personal assistant that provides motivational feedback, advice and a friendly listening ear to the users of the GOAL platform. From a technical point of view, the motivational agent is a loosely connected GOAL platform component, built "on-top-of" the basic GOAL services and grounded on user tailored persuasive-technology principles. The design of the motivational agent has been tailored to provide additional levels of adherence, motivation, and fun to the platform. Regarding the interaction, the motivational agent has two modes of operation with the end user, namely, the following:

- User Initiated (UI) Actions – The user, through a UI action, requests to start a dialogue with the agent. At this point, the motivational agent component compiles the user profile with a request of all latest data from the GOAL Platform. Then, based on integrated persuasive and behavioral change methodologies, it would reply back to the user's UI with a list of possible topics, indicating possible subjects for interaction.

- System Initiated Actions – The motivational agent component will periodically reconfigure and update the User Profile with the user's accumulative behavioral data (physical-, and cognitive activity). If the user is deviating too much from a predetermined goal, the agent will initiate an action – a motivational message (see, [10]) – that will be pushed to the most appropriate UI device available.

The social marketplace exposes the social aspects of the GOAL platform, where players can interact by asking for favors (e.g. "I would like my grandsons to visit me!") or challenging each other with tasks (e.g., "Which of my friends can walk the most steps in the coming week?"). The component includes a back-end component that collects and stores task data, allowing it to process the full lifetime of a task from the generation to the awarding of a winner. This is of particular interest for the tasks, where the winner is detected automatically. The front-end application exposes the functionality to create a task, views tasks, selects tasks to participate to and views the ongoing task statistics (e.g., current or final rankings).

The physical activity is measured and presented to the GOAL players by the health apps. The physical activity measurement is by nature split into two parts: the front-end (i.e. sensor connection) and the back-end (processing). The signal sensing is carried out on the mobile device, and involves (i) atmospheric pressure; (ii) acceleration (3 axes); (iii) step counter, the latter, when present is asynchronously firing step count integer, whenever there is a new step or group of steps; and (iv) GPS data (latitude, longitude, elevation). The processing performed on the captured signal at the mobile device involves the following:

- Activity intensity estimation and step counting from acceleration;
- Altitude change estimation from atmospheric pressure and step activity;
- Distance, speed and altitude change estimation from GPS data;
- Activity intensity estimation in terms of Metabolic Equivalent of Task (MET) and its characterization based upon the step rate, speed and elevation change, together with the GOAL player profile.

The MET is a measure of energy cost of different physical activities normalized by the duration of the activity and the weight of the person exercising it. It is defined as the ratio of metabolic rate (and therefore the rate of energy consumption) during a specific physical activity to the reference metabolic rate of resting. The GOAL platform utilizes gender and age related thresholds on MET to quantify the intensity of the exercise, as shown in Fig. 2 [11].

The GOAL platform estimates the energy expenditure as active MET-minutes (enumerating the energy expenditure of some activity over the resting energy expenditure). Active MET-minutes along with the more widespread number of steps are used by the platform to define the personalized goals for the different users. The physical activity measurement system of the platform produces the regular meta-data records every few seconds. This level of processing is not prohibitive for the mobile device, and allows a significant reduction of the volume of transferred data. The server physical activity component utilizes the regular meta-data for activity classification and then computes meta-data aggregations to be used for visualizations and long-term storage.

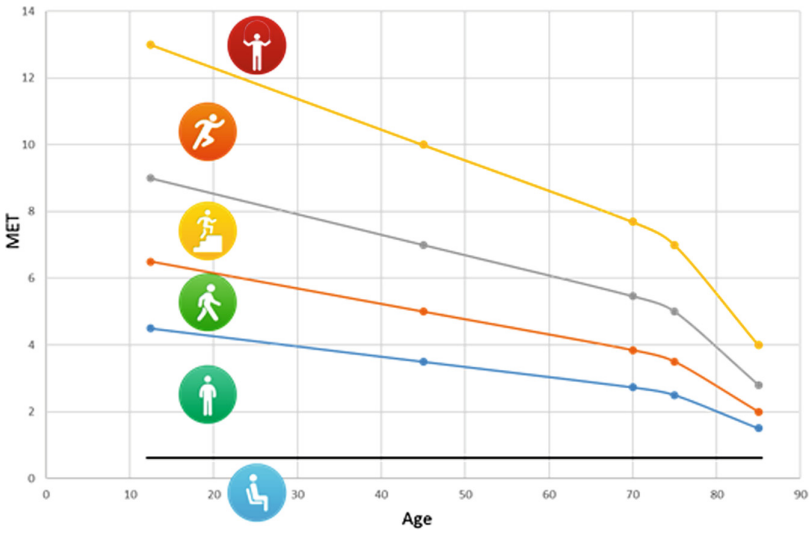


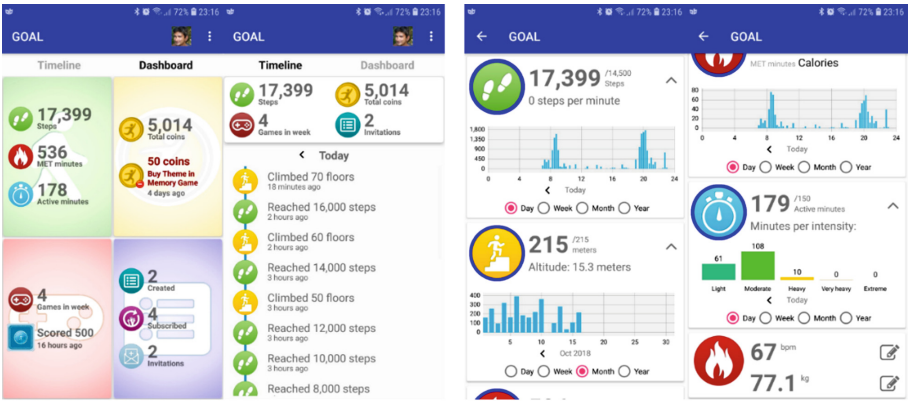
Fig. 2. MET-based intensity classification as a function of the age into idle, light, moderate, heavy, very heavy and extreme (that should not be maintained). Note, that for men the limits should be increased by roughly 15%, while for women they should be decreased by 15%.

3 Physical Activity Measurements

The physical activity measurements are an integral part of the platform, and it comes along with its own, feature-rich physical activity application, integrated within the mobile version of the GOAL main application. Although always there, the use of this integrated application is not mandatory. GOAL players can use other physical activity applications that communicate with the GOAL platform.

3.1 Physical Activity Measured from a Smartphone

The GOAL Physical Activity Application that comes with the GOAL Main Application utilizes the sensors of the smartphone to extract metadata, such as steps walked and stepping speed, floors climbed, distance, speed, elevation, energy consumed, active minutes. The Physical Activity Application can be accessed by clicking on the physical activity overview card of the main interface of the Main GOAL application as shown in Fig. 1. These metadata can be enriched with data registered by intelligent vision techniques and smart sensors, able to detect mood, degree of sweating and similar additional data that would provide vital information about the degree of user experience, which could be then rewarded by a higher value award in the GOAL platform. Such an approach would be vital to keeping high user motivation and determination to follow the activities. When the detected experience is below positive, it could be timely proposed to change the activity with a more rewarding one. An example of the metadata visualization on the mobile device is shown in Fig. 3. The physical activity tracking options can be reached as a category of the main GOAL application options.



(a) (b)

Fig. 3. GOAL metadata visualization. (a) Overview (dashboard and timeline views) and (b) physical activity details.

3.2 Physical Activity Measured from Smart Sensors

GOAL supports the integration from "3rd party" health applications. From the product perspective, commercial health apps could integrate their applications with the GOAL platform and report user's health and wellbeing data to the platform. In this way, users can continue using their preferred fitness tracker, food logging app, weight manager, relaxation app, etc. while benefitting from the additional motivation to use those apps through the GOAL platform. The GOAL Physical Activity Application utilizes the following sensors:

- Accelerometer: The average magnitude of acceleration is calculated in every reporting window.
- Android step counter: The steps accumulated in the reporting period are calculated, and from those the step rate, distance travelled and speed. In the absence of an Android step counter, the proprietary GOAL one is used. This utilizes directly the accelerometer samples.
- Barometer: The difference of elevation in the reporting period is estimated from the barometer reading. The barometer reading is only considered if the change is moderate and the current step rate is not zero, to filter out variations to the atmospheric pressure due to the changing weather.
- GPS: When outdoors, this yields a better estimation of the distance, speed and elevation.

Other physical activity applications can utilize sensors from the phone or from some third party hardware activity tracker. Here, an approach to capture multisensory information will allow for extracting novel contextual information in combination with information about the location, time, date, network, analytics and user settings. This would enable to customize an activity program to each user and increasing the rewarding experience on a personalized basis, and would enhance the functionality of

the activity type classification with personalized features, which aims at identifying what the GOAL user is doing when physically active.

Physical activity is reported to the GOAL platform via the GOAL API through a JSON POST call. The call accepts a list of JSON objects representing the different types of measurements.

4 Social and Business Impact

4.1 Integrating External Applications

Games. The first game integrated with GOAL is a cognitive card-based memory game. The player seeks card pairs and needs to remember cards already seen. The maximum score depends on the difficulty of the game (grid size and complexity of the deck, i.e. the images depicted) as well as the number of mistakes the user does. The score is reported to GOAL, and the platform translates it to GOAL coins based on the goals being set for the particular user.

There are also game spending mechanisms integrated in the game: The user can chose to cheat (peak at the cards on the grid) for a number of GOAL coins. The user can also buy more decks with GOAL coins. This offers variety in the three levels of deck difficulty.

Physical Activity Apps. Two physical activity apps currently have been integrated with the platform. One implements the platform's physical sensing and displays the information to the user as shown in Fig. 2. As already explained, the user profile plays an important role on how the different physical measurements are processed into an understanding of the user's physical behavior.

The second physical activity application, the Activity Coach, reports daily physical activity as it is captured by a third-party system, (e.g., Fitbit). The current design of the Activity Coach app is able to show the user's current number of steps and allows for switching to detailed- or weekly overviews. The integration of the app with the GOAL platform will be executed in the way it is envisioned for third-party app developers to perform the integration. This means that the app will include the option for the user to link his "Activity Coach" account with a "GOAL Account", after which, data will be shared between the application and the GOAL API.

User Impact. The GOAL platform has two clearly distinct target users - those that play games, and those that develop them. The primary target population are the players, and the GOAL project focuses specifically on the subsection of players that is most at risk of adverse health effects – older adults. Lack of physical activity, decline in cognitive skills, and social isolation are all commonplace issues in the older adult population – issues that are targeted by the GOAL platform.

Impact on the Game Industry. The GOAL platform has the potential to provide benefits to the gaming industry in two different ways. On one hand, it is opening up new markets, in which health behavior of the end user plays a central role, therefore introducing leisure games to a number of new target groups by pro-viding new

emerging experiences. On the other hand, the ability opens up to exploit the GOAL platform functionalities enhanced with multisensory context and introduce completely new business and revenue stream models. Over the past few years the market for mobile applications and games has shown a strong growth – at the same time oversaturating the market and creating a fierce competition. In order to stand out, developers seek for possibilities to provide some added value to their games in addition to unique art design and game-play. This is the gap that the GOAL platform can fill and address the demand. In fact, several developers already use different types of the reward systems, e.g. earning coins by playing partner games that the user can later spend on the gift cards, real products or paid apps. Nevertheless it is the first time that a platform connects to distinct areas – health applications and games (either physical or cognitive) with leisure gaming therefore having the potential of reaching a much larger user base.

5 Conclusion

A game-based multisensory approach carries an immense innovation potential to the traditional practices of support of active living of elderly and chronically ill patients. Besides the added value of a novel type of context that can be utilized to personalized applications and custom-tailored therapies, the proposed platform is a strong enabler of user motivation, which is still a crucial barrier to the successful deployment of eHeatlh therapies. Many research challenges lie ahead, requiring solutions allowing for the detection, sensory analysis and evaluation methodology, coding/decoding, synchronization, transmission, and reconstruction over the ICT infrastructure of complex data associated with the olfactory, gustatory and tactile experiences of a user. The authors believe that exploration of the integration of multisensory context with eHealth platforms will boost the user acceptance and speed up actual deployment.

References

1. Lee, C., Lee, K., Lee, D.: Mobile healthcare applications and gamification for sustained health maintenance. J. Sustain. **9**(772) (2017). https://doi.org/10.3390/su9050772
2. Li, K., Sun, Sh., Wu, J., Zhao, X., Tan, M.: Real-time human-robot interaction for a service robot based on 3D human activity recognition and human-like decision mechanism. arXiv: 1802.00272 [cs.HC], Cornell University Library, February 2018
3. Manolova, A., Panev, S., Tonchev, K.: Human gaze tracking with an active multi-camera system. In: Cantoni, V., Dimov, D., Tistarelli, M. (eds.) BIOMET 2014. LNCS, vol. 8897, pp. 176–188. Springer, Cham (2014). https://doi.org/10.1007/978-3-319-13386-7_14
4. Tonchev, K., Lindgren, P., Manolova, A., Neshov, N., Poulkov, V.: Digitizing human behavior in business model innovation. Presented at GWS, May 2017. https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8300484
5. Kyriazakos, S., et al.: eWALL: an open-source cloud-based eHealth platform for creating home caring environments for older adults living with chronic diseases or frailty. Wirel. Pers. Commun. **97**, 1835 (2017). https://doi.org/10.1007/s11277-017-4656-7
6. Pollak, K.I., et al.: Physician communication techniques and weight loss in adults: project CHAT. Am. J. Prev. Med. **39**(4), 321–328 (2010)

7. Bandura, A.: Self-efficacy: toward a unifying theory of behavioral change. Psychol. Rev. **84** (2), 191–215 (1977). https://doi.org/10.1037/0033-295X.84.2.191
8. Prochaska, J.O., DiClemente, C.C.: Stages and processes of self-change of smoking toward an integrative model of change. J. Am. Psych. Assoc. **51**(3), 390–395 (1983)
9. Cabrita, M., op den Akker, H., Achterkamp, R., Hermens, H.J., Vollenbroek-Hutten, M.M. R.: Automated personalized goal-setting in an activity coaching application. Presented at 3rd International Conference on Sensor Networks (SensorNets2014). Lisbon, Portugal, pp. 389–396 (2014)
10. op den Akker, H., Cabrita, M., op den Akker, R., Jones, V.M., Hermens, H.J.: Tailored motivational message generation: a model and practical framework for real-time physical activity coaching. J. Biomed. Inform. **55**, 104–115 (2015)
11. McArdle, W.D., Katch, F.I., Katch, V.L.: Human energy expenditure during rest and physical activity. In: Exercise Physiology: Nutrition, Energy, and Human Performance, 7th edn., pp. 192–205. Lippincott Williams & Wilkins, Baltimore (2010)