# FreeGaming: Mobile, Collaborative, Adaptive and Augmented ExerGaming

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## ABSTRACT

Addressing the obesity epidemic that plagues many societies remains an outstanding public health issue. One innovative approach to addressing this problem is Exergaming. A combination of "Exercise" and "Gaming", the objective is to motivate people participate in exercise regimes, usually in their home environment. In this paper a more holistic interpretation of this exercise paradigm is proposed. Freegaming augments Exergaming in a number of key dimensions but especially through the promotion of games in outdoor mobile contexts and within a social environment. The design and implementation of a platform for Freegaming is described and illustrated through the description of a sample game.

## Categories and Subject Descriptors

H.5.1 [**Multimedia Information Systems**]: Artificial, augmented, and virtual realities; J.3 [**Life and Medical Sciences**]: Health; I.2.11 [**Distributed Artificial Intelligence**]: Intelligent agents, Multiagent systems

## General Terms

Design

## Keywords

multiagent systems, mobile computing, exergaming, pervasive health, augmented reality

## 1. INTRODUCTION

In recent years, childhood obesity has become a major problem in many countries. According to several studies [1] [22] obese people have an increased risk for many health conditions, like coronary heart disease, type 2 diabetes, different types of cancer, certain musculoskeletal disorders, such as knee osteoarthritis and also for many chronic conditions such as hypertension and elevated cholesterol. At the same time, overweight children can more easily become overweight adults [1] [26]. There are approximately 17.6 million children worldwide aged less than five which are estimated to be overweight [7]. Most of the research about the treatment of obesity recommends an increase in physical activity combined with a controlled low calorie diet [22] [2] [8] [1]. Nutrition researchers at UNC-Chapel Hill surprisingly demonstrated that the lack of physical activity, but not increased energy intake, is also responsible for obesity among youths aged 12-19 [29]. Video games are considered the main reason for physical inactivity [30]. Such games do not need any serious physical effort and they consume time from the young population that could be spent in physical activities like playing out-doors. Also, many of these games do not need any collaboration, and the players generally prefer to play them alone, which contributes to antisocial children [23].

The exergaming concept searches for ways to combine exercising and gaming [10] by disguising the tiresome side of working out with the uplifting side of playing to make the exercise process more attractive, not only for the younger population but also for anybody suffering from physical ex-

ercise deprivation [25]. Thus, mobile collaborative exergaming forces players to collaborate and communicate with each other, while implicitly encouraging them to increase their physical activity levels while playing but without inducing boredom. Optimistic results about increased physical activity levels have been demonstrated from playing games [15], but all these systems are console dependent. On the other hand, studies [17] [31] show that the mobile game market is estimated to reach $18 billion in 2014 and the mobile collaborative gaming industry is seen as an area with great potential.

## 2. FREEGAMING CONCEPT

The Wit Fit from Nintendo [5] is probably the most well known commercial example of exergaming platform providing a series of games, such as golf, dance and football. Dance Dance Revolution from Konami [6], and Guitar Hero from Activision [3] are other examples of games that can be classified as indoor exergames. Indoor exergaming applications rely on virtual environments as the main game environment. The players in these types of exergames are represented in the game environment by a virtual representative (avatar). In such settings, the exergaming designer has several ways to integrate player's exercise with the game. In a living room it is relatively easy to capture the player's motion, for example through cameras [4] and other sensors, and use this data to manipulate the avatar to mirror the players movements. Also, the feedback can be delivered through haptic interfaces, and screen facilities, while, being based on virtual artifacts, game's scenarios and objects/virtual characters surrounding the user's avatar can be easily modified and driven.

The aim of Freegaming is to extend this exergaming concept to the outdoors. It aims to use its player's own body as an interaction interface for the game instead of a virtual avatar. This can allow fitting the exercise in more natural way to the player's other daily activities which can consequently improve the associated health benefits. Freegaming concept offers generating a play anywhere, anytime and collaborative exergaming environment.

- **mobile** - FreeGaming allows outdoor and ubiquitous exergaming. While indoor exergaming creates natural limits on what exercises can be performed, adding *mobility* to the exergames can open up the opportunity for encouraging many type of different exercises.

- **augmented** - Freegaming gives the ability to the developers to utilize *augmented reality* (AR) when developing, to break away from the traditional avatar paradigm. This allows the player to feel an immersive experience where it is their own physical body which interacts with the game instead of mediated experience through a virtual avatar.

- **collaborative** - Freegaming architecture is designed to allow multiplayer gaming. It offers a suitable system to combine the socialisation feature of *mobile collaboration games* with the positive effects of exergames on physical health.

- **adaptive** - Freegaming targets allowing outdoor exergaming. The objective of the Freegaming architecture is to **adapt** to this constantly changing outdoor environment by using intelligent agents technology.

### 2.1 Related Research

Two major related areas for outdoor exergaming are AR outdoor gaming and location-aware mobile gaming. We identify the following gaming systems as exergaming systems mainly because running is always the essential factor in their gaming design.

AR Quake [11] is such a game that uses GPS and a digital compass with mobile phone and users engage battle through SMS messages. Real tournament [32] is another application that equips every player with PDA which has an electronic compass and GPS. It enables shooting between players through wireless card incased in a water pistol shell. Human Pacman [12] is an applications where players wear HMD in outdoor gaming. However, the player will have to carry the notebook, with heavy batteries, in their backpacks.

There are various types of applications addressing location-aware mobile gaming. Pirates! [27] is an early application whose players use PDA to play through WiFi networks in a few connected rooms. Players will need to travel (sail) to the rooms (islands) and explore for virtual resources. CatchBob! [20] is a collaborative mobile game designed for a campus area, where players carry a TabletPC with Stylus Pen. They share a map of game zone while being able to synchronized tagging/writing on the map, GPS is used to determine the distance of players and virtual treasure. "Can you see me now?" [28] is a collaborative mobile game which provides a mixed real and virtual gaming experience. The online players can see their characters on a map and they can control the character with arrow keys to avoid being caught by fellow players, while the fellow players are actors that carrying GPS and PDA showing the game map. However, they are running in a real city.

As AR outdoor and location-aware games, none of these games promise to supply the full potential of exergaming and to achieve any health benefits.

### 2.2 Challenges

The exercise part of any exergames must satisfy certain requirements for realizing full potential. This can be supplying personalized "warm up" and "cool down" phases [25] [10] [24]. As an exergame, Freegaming should be able to supply games that can be personalized to the requirements of its players.

For outdoor exergaming, matters are definitely more complicated as it is a unstructured environment. An outdoor exergame will be played in a real world instead of a virtual world that can easily controlled and designed by the game and game designer. An outdoor exergaming system must operate robustly in complex and dynamic environments. The game designer will need to know a lot of context information about the environment and the status of the player in this environment. In such a situation, the player's context can only be captured via sensing the player's real surroundings. Sensors data should supply two main types of information for the game. They need to provide information about the players' body which includes physiological data. At the same

time, they should provide information about environment and players' status in it.

## 2.3 Agent-based Adaptivity

Using sensors to collect information is not enough by itself. In addition to this, an outdoor exergame should be able to adapt itself according to the information coming from sensors. To realise this, it is necessary that the architecture can achieve *adaptive and intelligent* behavior. Intelligent agents can be used easily to integrate multiple sensors for this aim as they can form context model, and reason about them to take decisions that will affect the game. They have been successfully deployed in many mobile computing domains including tourism [21], mobile commerce [16] and in outdoor exergaming environments [14].

## 3. FREEGAMING SYSTEM DESIGN AND ARCHITECTURE

Freegaming platform includes two main components. The first one is Freegaming Server and the other one is Freegaming Mobile Application (FMA) which runs on the mobile devices as a client application. Freegaming Server consists of two separate servers which are Freegaming Game Server (FGS) and the Machine Vision Server (MVS). A high level system architecture diagram for Freegaming Platform can be seen in Figure 1.
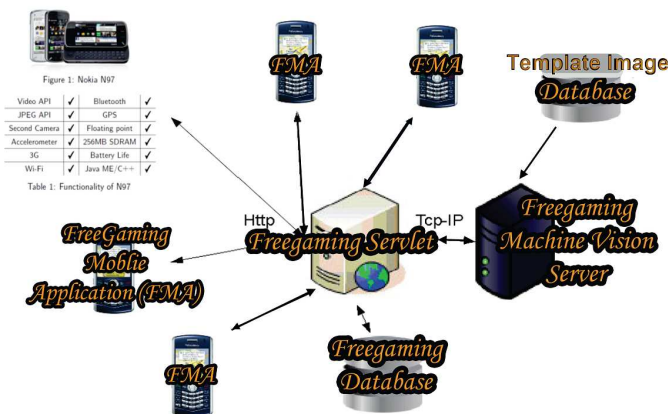


**Figure 1: Architecture of Freegaming.**

## 3.1 Freegaming Game Server

FGS includes the Freegaming Database (FDB) which maintains the game status and holds all the necessary information for each players during the game, like points collected, distance traveled, location, etc. FGS also consists the Freegaming Servlets (FSERV) which allows the FMA to access and modify the game databases.

## 3.2 Freegaming Machine Vision Server

Freegaming ambition to promote fitness requires that it creates incentives for a player or players to complete their goals within the game. To achieve this the Freegaming architecture allows the developers to augment on planar surfaces in the photos taken by the mobile phone camera. This creates an Augmented Reality [18] environment which allows the

further integration of the players physical body instead of an avatar unlike other approaches to exergaming. The players are able to use their mobile as a window into a world where the virtual objects are coexisting with their physical counterparts. To generate the augmented photos, the Speeded Up Robust Features (SURF) [9] algorithm is utilised, features can be tracked from a template image onto an image taken by the phone. As the phone uses is not computational sufficient to achieve this goal within a usable time frame, MVS on Freegaming Server is utilised to achieve this goal.

## 3.3 Freegaming Mobile Application

FMA also has two main parts, first one is the J2ME application and the other one is Game Agent (GA). J2ME application is mainly responsible from the GUI and augmentation over captured images on the mobile device screen. It includes the necessary screens for the game like, map view, objectives menu and augmented image screen.

The GA makes decisions over the game status and scenario which directly effects the J2ME application. In the current version, an agent in the GA continuously reads the Global Positioning System (GPS) data during the runtime and updates its belief set concerning the state of the player and the game itself. It uses this belief set to make logical commitments for the game play; for example, identifying those zones into which the player should move. In this case, the J2ME application would generate an audio alert and show the new objective to the player.

## 3.4 Implementation

During the game, locations of all players are obtained from built-in GPS receivers on the mobile devices. GA in FMA uses these data to continuously update the game scenario. FMA communicates with FGS via FSERV and accesses to FDB or makes updates on it if it is necessary. Also, the images captured by mobile phone during the game are sent to the FGS and it delivers these images to MVS for necessary SURF calculations on the images. The response coming from MVS then reflected to the FMA via FSERV. J2ME application in FMA uses these data to augment the virtual objects on the planar surfaces over the photo taken by the player.

All communications between the Freegaming components are done over web connections. Communication between the FMA and the FGS can occur over either wireless internet connection or 3G connection where it is possible. A dataflow diagram between components of the Freegaming Platform can be seen in Figure 2.

Freegaming platform is using the intelligent agent paradigm and implemented by using Agent Factory Mobile Edition (AFME) [19]. Agent Factory [13] is being harnessed for the fixed networked components. It is envisaged that the availability of sophisticated reasoning engines on both elements will maximise the opportunities for delivering adaptive, personalised games. Specifically, the FMA has been coded using AFME's (Belief, Desire, Intention) BDI-style agents which allow FMA to use any sensor data to adopt itself both to players' body information and also information coming about environmental context.
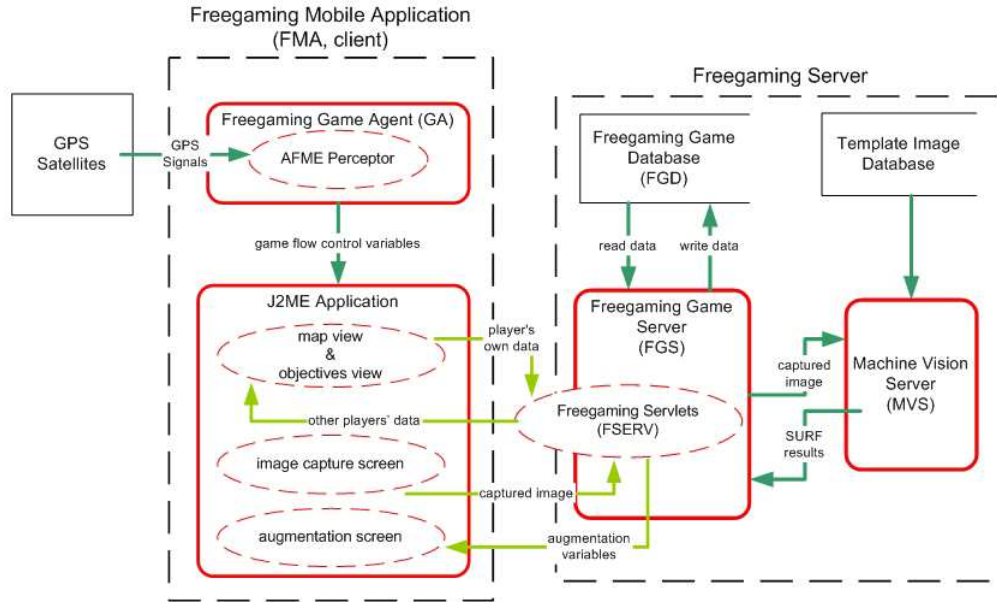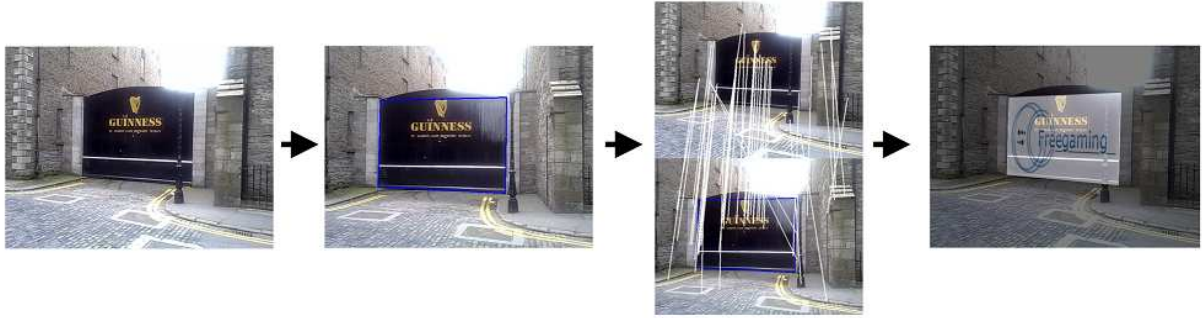
**Figure 2: Freegaming Dataflow Diagram**



**Figure 3: Augmented Reality, Freegaming Machine Vision Server and SURF calculations.**

## 4. GAME CREATION

Freegaming platform is designed to allow game designers to generate location sensitive exergames. It allows designers to create location based objectives for the game. Because of this nature of the system, game developers need to define special regions in a pre-defined gaming area. These special regions form the objective list for GA and the players in the game. All special regions will have their related GPS coordinates defined in the GA which will control the game flow during runtime. In the current version the GPS sensor data is used for couple of different adaptations during the game play. The simplest one is the adaption of the graphical user interface on the phone screen. For example, players need to arrive in specific GPS locations to take snapshots of the scene. The game will not show the button for taking snapshots until the players physically reaches to the target GPS location. After reaching to the target location, GA will update the necessary information for FMA and players will see their new objective on their phone screen and the map view will be updated according to these changes in the game scenario.

At the same time, game designer needs to generate a tem-

plate images database for each special region. These template images will be used in the MVS for SURF calculations to decide where to make the suitable augmentation on the captured image (Figure 3). To generate these image databases, game developers need to take pictures of predefined planar surfaces in the special regions. Then, these surfaces should be tagged in the taken pictures by the game developers. Freegaming platform has a separate simple tagging program (coded by Qt programming language) which allows the programmer to tag planar surfaces taken from photo within the game area. During the game, when a player reaches a target location the next objective is generally taking a photo of a certain object inside this location. After capturing, player will wait for a response from the server. During this time the captured photo is sent to MVS and it uses the template image databases to analyse the newly captured image and decide on where to augment the virtual objects.

Freegaming platform shows the potential of Agent-based and AR-based design to increase the flexibility while generating a game. Agent-based design eases the implementation of different games based on the same platform. In Freegaming

platform, agents are used to integrate and manage different resources, for example different sensors, and interact with services provided by the extended infrastructure, for example localization services. Changing the initial belief set, the goals of the agent and/or its commitment rules and also changing the virtual AR content will result with a totally different game.

## 4.1 Game Implementation

To implement the Freegaming Platform's capabilities a prototype game is generated. This is a proof of concept game and the full promise of the platform can only be obtained by integrating specific content. This demo is not using the multiplayer functionality and can only be played as a single player game. The screenshots in Figure 4 and 5 display this game as it is implemented on a Nokia N97. There are two special regions in this game and four objectives.

At the beginning of the game, player enters his/her age. After this, player sees a start menu for the game where they can select to see instructions about how to play or start a new round for the game. When the game begins, players can see the map view on the mobile phone screen which shows the player icon overlaid on the map of gaming area. For the first objective, player needs to go into the first special region which is the starting point for the game. When player reaches to this point, GA detects this achievement automatically by reading the GPS signal and automatically changes the player's state in the game. At that point player is prompted by J2ME application with a sound and a visual alert on mobile screen about a new objective. This second objective in the game is to take a picture of the scene, especially the walls or windows. When player captures a proper picture of the scene by mobile phone, MVS detects the windows inside this photo and augments virtual arrows on them that shows the direction of the next target location. After this achievement of the second objective the map view of the game is also updated by the GA and player can see where to go for the next target location on the map as well (Figure 4). When the player reaches to the second target zone game again gives an alert about the new image capturing objective. This time, game asks for a picture of the gate in the target area. When player takes the picture, GA decides on which message to augment on the gate based on the personalization information given by the player at the beginning of the game. It augments the direction for the nearest pub if the player is over 18 or the direction for the storehouse if the player is under 18 years old (Figure 5). After that, the game informs the player that the game is finished.

## 5. ONGOING RESEARCH

Current Freegaming system implements a basic exergaming platform and can be improved. The current architecture of Freegaming allows us to give the full control of the game to the GA running on the phone and it is based on the data coming from the GPS sensors. This makes the future planned integration of the Heart Rate (HR) sensor and accelerometer significantly less challenging to implement with this abstraction. Agents can use personal info like age, height, etc. that players gave before starting to the game and the data coming from all the sensors to generate fully personalized objectives and even user interfaces to its players. A simple example can be increasing the target HR for



**Figure 5: Agent controlled augmentation. The Game Agent augments different visual objects based on personalization data.**

a player by defining an uphill GPS position as a target location. At the same time, agents can be used to deal with disconnections during the game. Weak GPS signals can be covered by agents. The GPS reader agent will know when the game lost the GPS signal. It can use the last estimate and increase the range of the space over time which the game considers while looking for a match to the image captured by the user. Agents can increase the range for the players which are in a location with lower GPS signals and decrease the range for the players with the opposite. Also, an agent can be implemented that will periodically ping the Machine Vision server. If this server is unavailable, the GA can easily change the objectives for the game in order to hide this from the user. For example, instead of asking the user to capture a picture, which GA knows that cannot be submitted, the game can ask to cancel the current objective and reach another location, which will also increase the probability that the connection will work again. A good improvement can be creating an agent to deal with the changes in the weather and environment by adding proper sensor capabilities or virtual perceptors connected to online weather reports.

Another ongoing research goal within the Freegaming project is to create a more engaging scenario for the players, the hope is to expand the initial augmented reality interface from augmenting still camera frames into augmenting live video taken by the camera. To achieve this goal, it is intended to utilise the accelerometer within the phone to compliment the external machine vision server. Using an external server to process the camera data requires the use existing cellular networks which use 3G. 3G protocol poses a significant challenge to the programmer as it has unpredictable data rates. An Agent-based approach could help alleviate some of these problems. Each phone within Freegaming can have a dedicated agent assigned the task of deducing the current orientation in relation to the previous snapshot taken. This would of course only give an approximation for the placement of the augmented realty object but would elevate
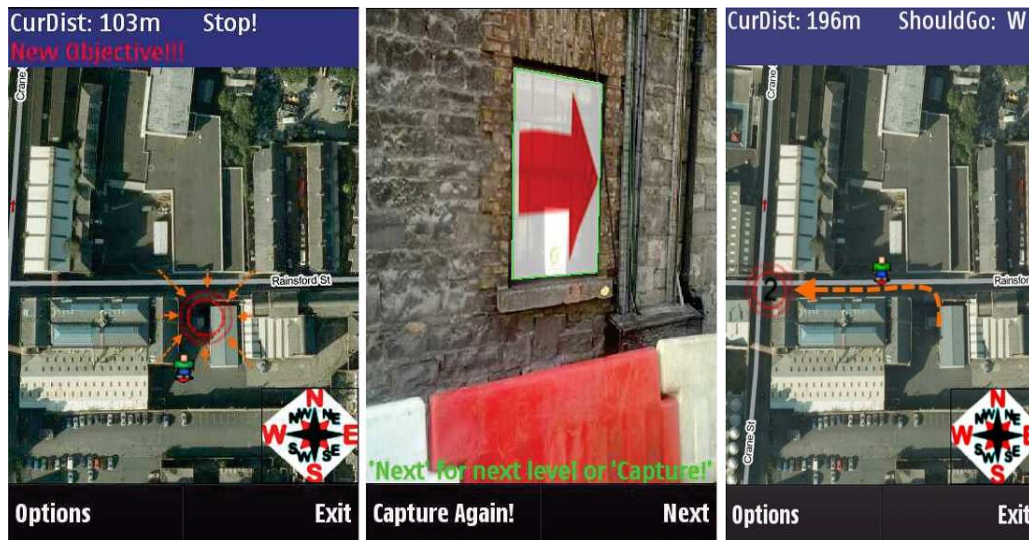
**Figure 4: Sample screen shots from Map View and Augmentation screens.**

the current disruption of waiting for the image server to process the latest camera snapshot.

## 6. CONCLUSIONS

In this paper, Freegaming, an agent-based mobile collaborative exergaming platform was introduced. The design of the Freegaming platform upon which multiple FreeGaming applications can be deployed is described with the implementation of a proof of concept game. Exergaming has the potential to help fight against obesity in the future. Although its primary audience would be young people who are part of a generation brought up in an electronic age, the exergaming idea can also be applicable for adults who have a sedentary lifestyle. The Freegaming platform architecture is discussed as along with a promotion of the use of agent technology to meet these principle while addressing outdoor, collaborative settings. Future work will incorporate health-related features in the application such as the estimation of energy expenditure and heart rate monitoring, before carrying out user-trials to study their impact on the player. The concept of utilising augmented reality within exergaming allows the player a more immersive experience with the virtual world and an honest feeling of achievement for their actions instead of living vicariously through an avatar. Mobile exergaming provides us with an opportunity that makes computer games more fun, more engaging and crucially live up to their potential as medium that can enrich both mind and body. In that way players enjoy the rich medium of computer games for health benefits instead of robbing them of future health.

## 7. ACKNOWLEDGMENTS

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