D4.5

PERVASIVE GAMES PLATFORM FINAL PLATFORM

April 2015

ABSTRACT

This document describes the final “Pervasive Games Platform” available at the end of the project. The description includes the architecture of the platform and the supplied Specific Enablers. Moreover, a brief discussion outlines the deployment of Enablers and the technical infrastructure we employed during the two experimentation cycles at the experimentation sites.

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DISCLAIMER

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EXECUTIVE SUMMARY

The “Pervasive Games Platform” consists of a number of Specific Enablers that are relevant for games on mobile devices with a focus on Augmented Reality applications and social interaction. This document describes the finale release of the platform after two release, experimentation and feedback integration cycles.

With the goal to enhance development of such games we have a categorization of three tiers to reflect different technical challenges for a number of scenarios: Tier 1 is for small scale indoor settings including marker tracking and toy tracking applications. Tier 2 consists of location based games where the players will be able to play a game at certain prepared locations, usually adapted to the special setting of that location. With city-wide games, Tier 3 has the technically most challenging scenarios where tracking and localization need to work without control of the environment.

Improvements to existing Specific Enablers were made for the Tier 1 and Tier 2 scenarios, and specific enablers for Tier 3 scenarios were released.

We grouped our Specific Enablers according to the portfolio of a dedicated feature set. For instance, the SEs in the Reality Mixer group improve the augmentation of real content with virtual ones to achieve seamless integration and the Enablers in the Augmented Reality group focus on visual tracking algorithms.

The following Enablers were already provided in the previous releases of the platform:

- The **Reality Mixer - Reflection Mapping SE** takes environmental lighting into account.
- The **Reality Mixer - Camera Artifact Rendering SE** applies effects to computer generated content to mimic the behavior of the device’s camera and enhance the integration.
- With the **Leaderboard SE**, high scores can be submitted and retrieved.
- The **Augmented Reality - Fast Feature Tracking SE** provides efficient markerless 2D-feature tracking.
- The **Game Synchronization SE** provides a simplified way to ensure that all game objects and properties have the same state on all devices.
- The **Geospatial – POI Matchmaking SE** (formerly: Spatial Matchmaking SE) helps to find other players ready for a game in the vicinity.
- The **Geospatial – POI Interface SE** provides a set of commonly used functions to interface and access the POI data.
- The **3D-Map Tiles SE** is a tile server for 3D data in a map context.
- The **Social Network SE** provides an implementation of a social platform.
- The **Visual Agent Design SE** provides the bricks to visually design the behaviour of agents in Unity 3D

This releases adds the following enablers:

- The **Unusual Database-Event Detection SE** is a monitoring service of a database.
- The **Reality Mixer - Augmented Audio SE** improves immersion by adding correctly located sound effects.
- The **Flexible and Adaptive Text To Speech SE** is a Text To Speech server that enables simple and fast creation of synthetic speech starting from text.
- The **SLAMflex SE** provides detection and tracking of dominant planes on smartphones.
- The **ARTool SE** enables the creation and deployment of AR applications from a user-friendly design platform.

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ABBREVIATIONS

AR	Augmented Reality
CG	Computer Graphics
API	Application Programming Interface
SE	Specific Enabler
GE	Generic Enabler
FAQ	Frequently Answered Questions
XML3D	Three Dimensional Extensible Markup Language
POI	Point of Interest
GPU	Graphics Processing Unit
FI	Future Internet
FI-PPP	Future Internet – Public Private Partnership
GPS	Global Positioning System

1 - INTRODUCTION

1.1 - Overview

The Pervasive Games Platform is a collection of tools and techniques, designed to enable the creation of Augmented Reality video games and interactive experiences, on mobile devices and the web. This technical portfolio takes advantage of established game development tools, of specific technical contributions (FIcontent Specific Enablers), and generic Future Internet technology (FIWARE Generic Enablers). A set of assets like 3D characters are provided as well.

This deliverable is mainly an update to D4.4, now describing the final version of the software of the Pervasive Games Platform.

Please be aware that this document is generated from the FIcontent Wiki [1]. Thus, the document may sometimes still refer to the FIcontent Wiki. All information in this document is also available online. We suggest to use the online version [2] for an advanced reading experience.

1.2 - Terminology

The following table contains terms, which are used in multiple deliverables. Therefore, we provide their shared definitions to ensure consistency across several documents.

Term	Definition
Application or Application software	Software layered on top of one or several platforms for realizing various useful tasks for end-users
Architecture	A structure of functional elements organized in a given way and presenting well defined interfaces
Capability	The ability of a component to satisfy a requirement
Conceptual Model	A set of view with written description of the organization of the FIcontent infrastructure to offer services
Enabler Software	Module or web service providing well-specified functionality, accessible and usable by application developers through clearly-described APIs (Application Programming Interfaces)
Experiment or Experimentation	Concrete test with actual users of one scenario in one of the experimentation sites in a given time frame
FIWARE Tools	The tools put in place by FIWARE to send requests for Generic Enablers are based on a backlog list in the frame of an agile methodology
Functional requirement	Either calculations, technical details, data manipulation, processing or other specific functionality that define what a system is intended to accomplish
Generic Enabler	An enabler realized by the FIWARE project or its follow-up sustainability project
Platform	A comprehensive combination of technology infrastructure and Generic Enablers as well as Specific Enablers capable to host and to support development of application software
Point of Interest	A POI is a place, an area or a journey (short distance) which are geo-located. For example: a place (a restaurant, etc.), an area: a public garden, a journey (a hiking trail, etc.). A POI has possibly features such as : static features (opening hours, address, name description, etc.), dynamic features (price, menu, number of

	available places, the delay before the next bus, etc.), event features (a beginning and an end)
Scenario	Description of foreseeable interactions of users with one or several applications
Specific Enabler	An enabler realized by the FIcontent project. Specific Enablers may be layered on top of, or otherwise make use of, Generic Enablers. Please refer to the definition of a FIcontent Specific Enabler from deliverable D6.1 Architecture specification [3]
Interface	The connections between domains (or sub domain or functional elements) serving the actor's actions by exchanging information
Interoperability	The capability of two or more networks, devices, applications to exchange and use information
Technology	A standard or industry specification that has the capability of addressing requirements

2 - PERVASIVE GAMES PLATFORM ARCHITECTURE

The architecture of the Pervasive Games Platform is a set of integrated, modular Enablers designed to aid building Internet-based games connected with the real world. While moving from native to in-browser execution as browser technology develops, we target real-time, low latency, and high performance goals with the Pervasive Games Platform. Moreover, the platform supports new forms of interactive entertainment of three tiers:

- **Tier 1 -- Digital Consumer Products (Toys).** This tier targets augmented-reality games based on toys, fashion, and other physical products. Games will use the product as a known and structured environment/level and include a limited number of networked uses, for storage and toy-to-toy communication.
- **Tier 2 -- Location Based Games.** Here, we target games developed in an installation such as a museum in which connected, cooperative game experiences are used to make the visit more compelling. This tier builds upon the first tier with real-world locations and a greater number of users.
- **Tier 3 -- City Wide Games.** The third tier targets city-wide games in which larger numbers of players interact in unstructured environments. Testing has taken place in large-scale experimentation sites such as Zurich and Barcelona. This tier is the most challenging as it requires a high degree of mobile connectivity as well as game dynamics implemented in unstructured locations.

The Pervasive Games Platform is accessible for web developers and provides dedicated features to easily create web-based games with well-known and established technologies. In addition to that, the platform takes advantage of the Unity native engine plugin to support professional game developers by allowing them to work with their accustomed tools.

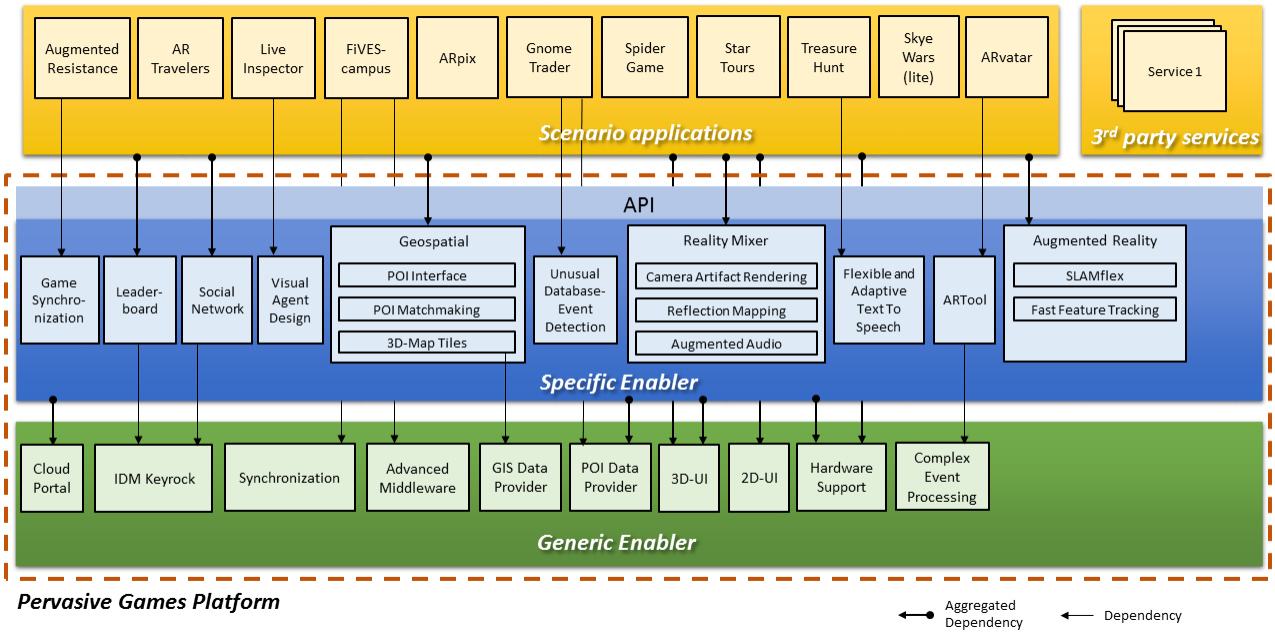

*Figure 1**Error! Bookmark not defined.** High-level architecture of the Pervasive Games Platform*

The Pervasive Games Platform acts as an intermediate layer between the Generic Enablers provided by FIWARE and the applications built on top of the platform. Further, it exposes the APIs of the Specific Enablers shipped with the platform to the application developers. A selection of applications showcase specific features or Enablers of the platform as illustrated in the figure above. Each application is dedicated to a scenario of the three tiers supported by the Pervasive Games Platform. The scenarios are described in detail in deliverables D4.1, D4.1.2 and D4.1.3. In addition, further applications, such as FiVES-campus were developed in collaboration with the WebUI chapter of FIWARE as joint demos mainly for exploitation on events and exhibitions.

2.1 - Architecture Description

The core components of the Pervasive Games Platform are shaped by the Specific Enablers dedicated to domain-specific gaming scenarios. Thereby, the platform takes advantage of Generic Enablers from FIWARE as well as common Specific Enablers developed in FIcontent. All of these Enablers may form groups, as shown in the figure below, and cover a range of features in game development, such as the group Augmented Reality SEs, which provides several tracking methods, or the group of Reality Mixer SEs, which focus on seamless augmented reality applications.

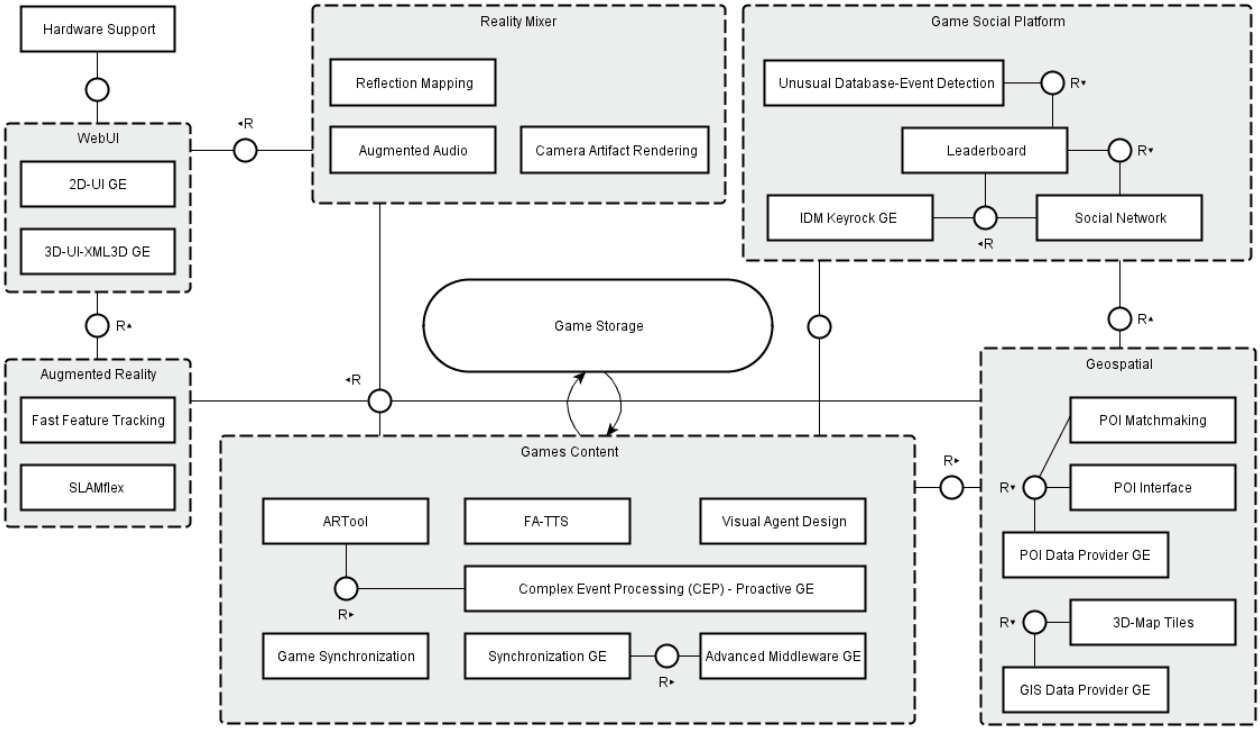

*Figure 2**Error! Bookmark not defined.** Architecture of the Pervasive Games Platform including the interaction of SEs with GEs from FIWARE*

The following sections describe the main functions provided by each component of the Pervasive Games Platform.

2.1.1 - Augmented Reality

Augmented Reality games break the line between reality and computer generated content by enhancing a real environment. The augmentation of a scene with additional computer generated content requires a very precise estimation of the camera pose. Therefore, we provide different tracking techniques based on the 3D-UI-XML3D GE [4] in order to achieve a fully immersive experience in real-time. In addition to that, we utilize usual positioning methods, such as GPS localization, and provide with the Fast Feature Tracking SE [5] a GPU-accelerated implementation to easily create applications with basic markerless Augmented Reality functionality on today's mobile devices. The SLAMflex SE [6] provides detection and tracking of dominant planes for smartphone devices, integrating with the phone's inertial measurement unit. This plane can then be used to show AR content relative to the plane orientation.

2.1.2 - Reality Mixer

A context aware connected interactive experience must focus on the development of methods to integrate and match real or filtered video footage with rendered virtual objects and characters seamlessly. In this way the mobile device acts not as a traditional electronic display, but as a lens onto the real world with transparently aligned augmented reality content.

Moreover, we render augmented reality Computer Graphics (CG) objects that match the artifacts of the device's camera by utilizing the Camera Artifact Rendering SE [7]. Adding synthesized computer images to live action footage, e.g. movie grain, noise, chromatic aberration and providing a reality slider that grades the disparity between video and CG footage achieves a seamless transition for mixed reality applications. In addition to that, stylization and beautification filters applied to both video stream and CG rendered content achieves an artistic goal avoiding the uncanny valley (as employed for example by PIXAR in traditional CG).

Augmented reality experiences further take place with virtual objects placed in the real world. Virtual objects under a physically accurate simulation thus far have no physical effect on real objects and conversely rigid and soft body dynamics captured from real objects have no physically simulated effect in virtual objects. The architecture of the platform envisions an enabler to achieve a physical Simulation Continuum between real and virtual objects. For time reasons and because the focused switched from development to support near the end of the project, this enabler was never finalized. Yet we believe that it is a conceptual contribution to the platform and kept it in the architecture diagram for that reason.

Sound is also common in augmented reality productions. However, sounds are often not located at the correct projected 3D location. Furthermore, these do not account for the environment's aural signature, binaural effects, the influence of the presence of virtual objects and materials as sound reflectors. For these purposes we provide the Augmented Audio SE [8].

2.1.3 - Geospatial

The Geospatial - POI Matchmaking SE [9] (formerly Spatial Matchmaking SE) is amended by a new set of Specific Enablers in this second release of the platform. The Geospatial - POI Interface SE [10] adds functionalities that are often needed to access and update POIs from a client side application. In addition to that, the 3D-Map Tiles SE [11] provides 3D representations of scene ground tiles (e.g. projected maps or satellite images). This geospatial SEs is a common Specific Enabler of FIcontent and demonstrate the integration and sharing of technologies between Smart City Services [12] and in the context of the city-wide gaming (Tier 3).

Moreover, this component incorporates the capabilities of the POI Data Provider GE [13] and GIS Data Provider GE [14] provided by FIWARE to attach our content to existing objects in real-world environments. This becomes in particular relevant for Tier 3 applications together with the Game Synchronization SE [15] and Synchronization GE [16].

2.1.4 - Game Social Platform

We utilize social platforms for the Pervasive Games Platform in two ways - one is intended for game developers and the other one for players.

The first is realized in FIC2Lab and github [17]. In FIC2Lab it provides a starting point to get in contact with the capabilities of the Pervasive Games Platform, and to thinker with web-based enablers without any software installation. On Github, it allows advanced developers to contribute to the enablers themselves and to report and track bugs.

The players part takes advantage of the Social Network SE [18] in combination with the Identity Management Keyrock GE [19] from FIWARE. This allows, for instance, to show overall high scores for individual games or levels through the Leaderboard SE [20]. Some games may require a group of players, like collaborative or competitive games. Therefore, the POI Matchmaking SE [9] connects to the social platform and helps to find nearby teammates.

Finally, to help administration, we use a simple monitoring of database availability and content checks with the Unusual Database-Event Detection SE [21]. It seamlessly integrates for instance with the Leaderboard SE [20] and is able to send out alerts via email to make the administrator aware of problems or cheating attempts.

2.1.5 - Games Content

This component of the platform is designed to provide services to manage the actual content of games. It allows the synchronization of UI and game states between players and devices and offers an efficient API for scene interactions and rendering. Therefore, we take advantage of several Generic Enablers alongside with Specific Enablers for game-domain specific purposes.

The Synchronization GE [16] can be used to create new types of multi-user applications shared between multiple devices and can be combined with the Game Synchronization SE [15] for taking charge of specific synchronization of game states. The first relies on the technologies of the Advanced Middleware GE [22] to update game settings and 3D-scenes in multiplayer scenarios across different platforms, while the second builds on top of the networked feature provided by Unity 3D.

We foster the creation of rich user-generated content by allowing any user to specify the behaviour of agents visually through the Visual Agent Design SE [23].

In case the game needs to communicate textual information via speech the Flexible and Adaptive Text to Speech SE [24] can be adopted to generate dynamic speech prompts. This can be used also to characterize a peculiar voice of a character using specific audio effects (e.g. child voice, monster voice).

The ARTool SE [25] aims to dramatically simplify the development and deployment of AR applications by utilising pre-defined templates, components and modules enabling the creation of cross-platform applications with minimal or no programming effort required.

2.2 - Specific Enablers

We provide the following Specific Enablers through the Pervasive Games Platform.

- Reality Mixer - Reflection Mapping SE [26]
- Reality Mixer - Camera Artifact Rendering SE [7]
- Reality Mixer - Augmented Audio SE [8]
- Augmented Reality - Fast Feature Tracking SE [5]
- Visual Agent Design SE [23]
- Leaderboard SE [20]
- Game Synchronization SE [15]
- Geospatial - POI Matchmaking SE [9]
- Geospatial - POI Interface SE [10]
- ARTool - ARTool SE [25]
- SLAMflex - SLAMflex SE [6]
- Unusual Database-Event Detection SE [21]
- Flexible and Adaptive Text to Speech SE [24]

We utilize the following list of common Specific Enablers for the Pervasive Games Platform.

- Social Network SE [18]
- 3D-Map Tiles SE [11]

2.3 - Generic Enablers

We take advantage of the following FIWARE Generic Enablers as part of the Pervasive Games Platform.

- Complex Event Processing (CEP) - Proactive GE [27]
- 2D-UI GE [28]
- 3D-UI-XML3D GE [4]
- Identity Management Keyrock GE [19]
- Advanced Middleware GE [22]
- Synchronization - FiVES GE [16]
- POI Data Provider GE [13]

- GIS Data Provider - Geoserver/3D GE [14]
- Self-Service Interfaces - Cloud Portal GE [29]

2.4 - External Game Development Tools

One goal of the Pervasive Games Platform is to connect to existing game development tools created by European companies that have been proven in the field and supported by large communities. In the final platform release, we provide connection to **Unity3D** from **Unity Technologies** (Denmark). Previous releases did also provide connection to **SmartFoxServer** from **gotoAndPlay()** (Italy), but we dropped that connection for reasons explained below.

2.4.1 - Unity3D

Unity3D [30] is a Game Development IDE that provides a feature-rich Game Engine as well as a production environment for the creation of game scenes and the management of game assets. Unity3D supports JavaScript and C# code. Code and content of the Pervasive Games Platform relevant to Unity3D is distributed in form of unity packages - containers that facilitate the import and export operation between unity users.

Unity offers a marketplace for unity packages. Some of our enablers have been uploaded as unity packages and are thus available to the whole Unity community. We think this is a powerful distribution mechanism with a large pool of potential users. The list of available enablers can be found at the Unity Asset Store [31].

2.4.2 - SmartFoxServer

SmartFoxServer [32] is a multi-platform server-client solution for multiplayer games and applications. It provides a rich set of features and extensive documentation, and comes with free and commercial licensing options. In particular, SFS provides functionality to create lobbies where players can chat, create instances of a game and start a playing session.

The initial and second platform releases did connect to SmartFoxServer as a provider of meta-server services (game discovery, etc.) for the Game Synchronization SE. However, as we strengthen the platform to answer the reviewers' concerns of the first review, we decided to also use Unity3D for the game discovery services of the Game Synchronization SE. Therefore, we dropped the SmartFoxServer dependency.

3 - PERVASIVE GAMES PLATFORM - RELEASE 04/15

The previous releases of the Pervasive Games Platform focused on Tiers 1 and 2 gaming scenarios, while this one focuses on Tier 3 and answer the requests of the reviewers from year 1 review. For AR tracking, mostly existing image-based or marker-based approaches are used. We concentrate in particular on mobile devices with portability in mind. For these requirements, two foundation technologies suit best: HTML5 and Unity.

Install-free HTML5 web applications. Nowadays, many mobile devices support WebGL which features hardware accelerated 2D and 3D graphics. For many users, a dedicated software installation can mean too much effort, but in our case it is enough to just go to a website.

Unity 3D based games for high performance and quick development. For gamers that are willing to install the Unity player software, games can be a bit more sophisticated. For game development and content creation a useful tool exists that is already used by many game developers. A game can be easily deployed to multiple operating systems.

This release is the final release. The following Specific Enablers are included in the April release of the Pervasive Games Platform and provide the technological foundation for our gaming scenarios.

3.1 - Unusual Database-Event Detection [NEW]

3.1.1 - What You Need

The main functionality that the Unusual Database-Event Detection SE provides is a monitoring service of a database. It regularly checks database values. If any value is out of an expected range, an email alert is sent.

3.1.2 - Why You Need It

This SE helps to maintain high quality service by early detection of something going wrong. If the database cannot be reached or if there was cheating, the supervisor will be alarmed by an email.

3.1.3 - Documentation

- Technical Documentation of the Unusual Database-Event Detection SE [21]
- Developer Guide of the Unusual Database-Event Detection SE [33]

3.2 - Geospatial - POI Interface

3.2.1 - What You Need

The POI Interface SE implements an interface to the POI Data Provider GE or POI Storage SE APIs for Unity3d. It provides access to all the POI Data Provider GE methods and wraps the POI data structures into C# objects.

3.2.2 - Why You Need It

This SE simplifies the development of city-wide games by giving a direct access to POI data through standard C# code without worrying about Http calls and POI specifications

3.2.3 - Documentation

- Technical Documentation of the Geospatial - POI Interface SE [10]
- Developer Guide of the Geospatial - POI Interface SE [34]

3.3 - Geospatial - POI Matchmaking

3.3.1 - What You Need

The POI Matchmaking SE is an extension of the functionality of the Spatial Matchmaking SE (this was originally in the 09/13 release but is now no longer available). This enabler allows any number of players to group together based on their latitude and longitude value, or their spatial proximity to a point of interest. These points of interest are taken from the POI-DP GE by FIWARE.

3.3.2 - Why You Need It

This SE provides a straightforward implementation to create networked sessions between groups of clients which are physically located near POI. The system is made for volatile sessions in mind, where clients may disconnect and new clients may join later.

3.3.3 - Documentation

- Technical Documentation of the Geospatial - POI Matchmaking SE [9]
- Developer Guide of the Geospatial - POI Matchmaking SE [35]

3.4 - Reality Mixer - Reflection Mapping

3.4.1 - What You Need

All visually-oriented SEs of the Reality Mixer group measure camera properties and adapt the virtual objects to fit to the camera image background visually. The Reflection Mapping SE utilizes a light probe to extract a sphere map from the camera image, which contains the environmental lighting conditions. This sphere map will be used to apply an appropriate lighting model to rendered virtual objects. Thus, the additional virtual objects are incorporated into the resulting image in a very seamless fashion leading to a more realistic experience of mixed reality applications.

3.4.2 - Why You Need It

This enables a new level of realism in augmented reality applications. It may be used directly with a diffuse light probe to match the appearance of matte surfaces on virtual characters and vehicles. Furthermore, developers may experiment with mapping different materials to application objects, such as marble or crystal.

3.4.3 - Documentation

- Technical Documentation of the Reality Mixer - Reflection Mapping SE [26]
- Developer Guide of the Reality Mixer - Reflection Mapping SE [36]

3.5 - Reality Mixer - Camera Artifact Rendering

3.5.1 - What You Need

All visually-oriented SEs of the Reality Mixer group measure camera properties and adapt the virtual objects to fit to the camera image background visually. This client-side code modifies the virtual rendered content to match the camera image more closely in an AR context to provide more realistic appearance.

3.5.2 - Why You Need It

This SE helps making the virtual objects more believable and fit seamlessly to the camera image in the background. When the camera imperfections such as color casts, motion blur or noise are not taken into account, the virtual objects will stand out and not look like belonging to the scene. This SE estimates such parameters from the life image and other sensors and applies a post processing step to the virtual objects.

3.5.3 - Documentation

- Technical Documentation of the Reality Mixer - Camera Artifact Rendering SE [7]
- Developer Guide of the Reality Mixer - Camera Artifact Rendering SE [37]

3.6 - Reality Mixer - Augmented Audio [NEW]

3.6.1 - What You Need

This aurally oriented enabler of the Reality Mixer group measure sensor location properties and adapt the virtual sound sources to the audio environment. The Augmented Audio enabler makes use of the POI interface enabler to provide correctly located spatial sounds. Thus, the addition of audio incorporated into the physical environment in a very seamless fashion leads to a more realistic sound experience for mixed reality applications.

3.6.2 - Why You Need It

With the Augmented Audio enabler you are able to make fast responsive interactive mobile applications with core augmented reality audio functionality. The enabler functions well on native mobile applications with the Unity3D game platform. Thus, you can create AR Audio application without being an expert in device sensor processing and without need for predefined locations.

3.6.3 - Documentation

- Technical Documentation of the Reality Mixer - Augmented Audio SE [8]
- Developer Guide of the Reality Mixer - Augmented Audio SE [38]

3.7 - Leaderboard

3.7.1 - What You Need

The main functionality that the Leaderboard SE provides, is the storage of high scores and the retrieval of a sorted list of high scores. In addition, it can connect to the Social Network Enabler and automatically post a message when a new player broke the high score.

3.7.2 - Why You Need It

This SE helps to easily integrate a high score list into a game and motivate players or participants. With its REST interface it can be easily integrated in your application.

3.7.3 - Documentation

- Technical Documentation of the Leaderboard SE [20]
- Developer Guide of the Leaderboard SE [39]

3.8 - Augmented Reality - Fast Feature Tracking

3.8.1 - What You Need

All specific enablers of the Augmented Reality (AR) group provide various tracking methods to enable AR applications. The Fast Feature Tracking SE learns targets by colour and then matches the centre of a colour area (for example a coloured football or road sign) in the camera image to retrieve the relative camera pose information. This extends an application with the capabilities to apply the matching transformation to 3D-scene content and render them onto respective targets.

3.8.2 - Why You Need It

With the Fast Feature Tracking enabler you will be able to fast responsive interactive web and mobile applications with core augmented reality tracking functionality. The enabler functions well in our target ecosystems both in browser with XML3D, NACL and Javascript and on native mobile applications with the Unity3D game platform. Thus, you can create AR applications without being an expert in computer vision and without the need for predefined QR-codes, fiducial or image markers, just pick a colour to track.

3.8.3 - Documentation

- Technical Documentation of the Augmented Reality - Fast Feature Tracking SE [5]
- Developer Guide of the Augmented Reality - Fast Feature Tracking SE [40]

3.9 - Game Synchronization

3.9.1 - What You Need

The Game Synchronization SE provides functionality to synchronise the game world using the RTS (Real-Time Strategy) Lockstep mechanism. Provides an efficient way to synchronize many objects by sending their actions instead of streaming their positions.

3.9.2 - Why You Need It

It simplifies the complex task of developing a network model for real-time strategy games by providing an implementation where the programmer needs only to specify packets and events.

3.9.3 - Documentation

- Technical Documentation of the Game Synchronization SE [15]
- Developer Guide of the Game Synchronization SE [41]

3.10 - Visual Agent Design

3.10.1 - What You Need

This SE provides the building blocks to visually design the behaviour of agents in Unity 3D. These agents will typically be physical robots. This SE also allows to inspect their behaviour in real time through augmented reality.

3.10.2 - Why You Need It

This enabler allows a new level of interaction in framing the behaviour of autonomous agents. By doing so, it brings user-created content to a new dimension!

3.10.3 - Documentation

- Technical Documentation of the Visual Agent Design SE [23]
- Developer Guide of the Visual Agent Design SE [42]

3.11 - Flexible and Adaptive Text To Speech [NEW]

3.11.1 - What You Need

The Flexible and Adaptive Text To Speech (FA-TTS) SE is a Text To Speech server that enables simple and fast creation of synthetic speech starting from text. The technology used allows the manipulation of some acoustic and linguistic parameters in order to obtain the synthetic voice that is most suitable for a specific situation: pitch/rhythm modifications or a vocal tract scaler can be used to generate more expressive speech.

3.11.2 - Why You Need It

The SE can be used to generate speech from text in an expressive and creative way. A typical use in the context of electronic games is to give voice to the characters of games.

3.11.3 - Documentation

- Technical Documentation of the Flexible and Adaptive Text To Speech SE [24]
- Developer Guide of the Flexible and Adaptive Text To Speech SE [43]

3.12 - SLAMflex [NEW]

3.12.1 - What You Need

SLAMflex provides detection and tracking of dominant planes for smartphone devices. This plane can then be used to show AR content relative to the plane orientation. The detection of plane is performed in the field of view of the smartphone camera. In subsequent frames it is tracked. The interface returns the plane position and orientation.

3.12.2 - Why You Need It

This SE enables markerless AR utilizing a dominant plane detected in the filed of view. If you would like to have AR content placed on the dominant plane without markers required then this enabler will help you to achieve this.

3.12.3 - Documentation

- Technical Documentation of the SLAMflex SE [6]
- Developer Guide of the SLAMflex SE [44]

3.13 - ARTool [NEW]

3.13.1 - What You Need

The ARTool platform is designed to enable an easy creation of AR applications using a user friendly design platform (ARTool Creator) as well as the deployment of these applications through the deployment platform (ARTool Deploy).

3.13.2 - Why You Need It

This SE enables quick creation of AR applications without programming utilising a simple drag and drop interface. It can be used for quick prototyping or more complex application development for the cross-platform deployment.

3.13.3 - Documentation

- Technical Documentation of the ARTool SE [25]
- Developer Guide of the ARTool SE [45]

3.14 - 3D-Map Tiles

3.14.1 - What You Need

The 3D-Map Tiles SE supplies map tiles of the ground in an OpenStreetMap-like manner. These tiles are a 3D representation of the scene geometry in contrast to usual image tiles of OSM. Moreover, the 3D-Map Tiles SE supports different backend data providers to offer different kinds of tiles, such as projected OSM-tiles and laser-scanned elevation data with textures. Therefore, the 3D-Map Tiles SE incorporates the GIS-DP GE from FIWARE.

3.14.2 - Why You Need It

When moving from traditional 2D-map applications towards geo-referenced interactive 3D-applications, a representation of the environmental ground (i.e. terrain) is needed. The 3D-Map Tiles SE addresses this requirement in a flexible approach and an easy-to-use way for web-based applications. It seamlessly incorporates with the 3D-UI GE from FIWARE and thereby preserves full control over rendering in the client application.

3.14.3 - Documentation

- Technical Documentation of the 3D-Map Tiles SE [11]
- Developer Guide of the 3D-Map Tiles SE [46]

3.15 - Social Network

3.15.1 - What You Need

The Social Network SE Core (or SNE) is a REST Service with a Web interface that gives end users the opportunity to communicate with each other. Unlike monolithic infrastructures (like Facebook) the SNE provides not only full autonomy of the user data but also gives the opportunity to run it as a federated service.

3.15.2 - Why You Need It

This enables a social network of your own design with absolute data sovereignty. You own your own data and have total control over the design and functionality.

3.15.3 - Documentation

- Technical Documentation of the Social Network SE [18]
- Developer Guide of the Social Network SE [47]

4 - PERVASIVE GAMES PLATFORM APPLICATION PROTOTYPES

A number of example applications were developed using the Pervasive Games Platform. They are described in more detail in D7.1.2, D4.1.3 and D7.6.2. Since the targeted use cases of the Pervasive Games Platform are very broad, there is no single application incorporating all SEs. Instead, these following applications showcase the usage of all 3 tiers of the Pervasive Games Platform.

4.1 - Augmented Resistance

The Augmented Resistance application is an augmented-reality tower defence game, in which a physical tower on the center of a board must be defended against hordes of virtual characters. This application explores the augmentation of traditional board games with the help of mobile devices. AR Tracking is used to situate the device with respect to the board. Real objects are mixed with virtual ones. A light-probe system is used to capture the light of the environment, and uses it to illuminate the virtual content, obtaining a better matching of the virtual elements to the real ones. The application uses the Reflection Mapping SE.

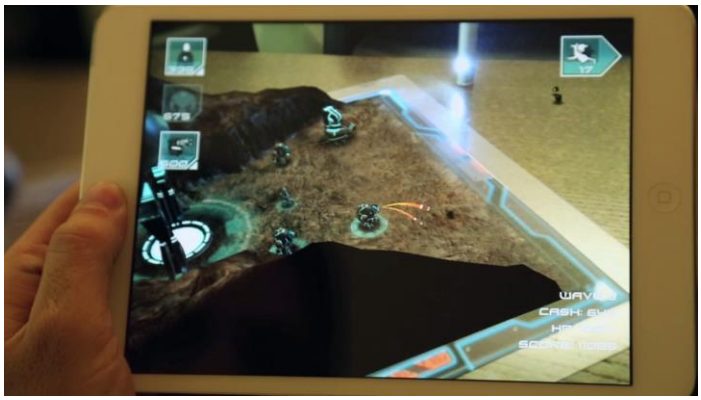

*Figure 3**Error! Bookmark not defined.** Augmented Resistance*

4.2 - Skye Wars (lite)

Skye Wars merges an advanced tracking system with augmented reality launched to enhance the SKYE experience at Siggraph 2013 Computer Animation Festival. The internal LEDs of the flying robot are used for the creation of aerial visual effects and provided also a color target for the Augmented Reality - Fast Feature Tracking SE.

Many conference attendees downloaded the Skye Wars app, which was the first FI-PPP app released on iTunes. Thereby, it has become really popular and reached 2000 downloads. As follow-up, a web implementation of the Fast Feature Tracking SE was presented at Web3D 2014, which seamlessly integrates with the 3D-UI-XML3D GE of FIWARE and demo "Skye Wars lite" showcasing this SE at ECFI2 in Munich.

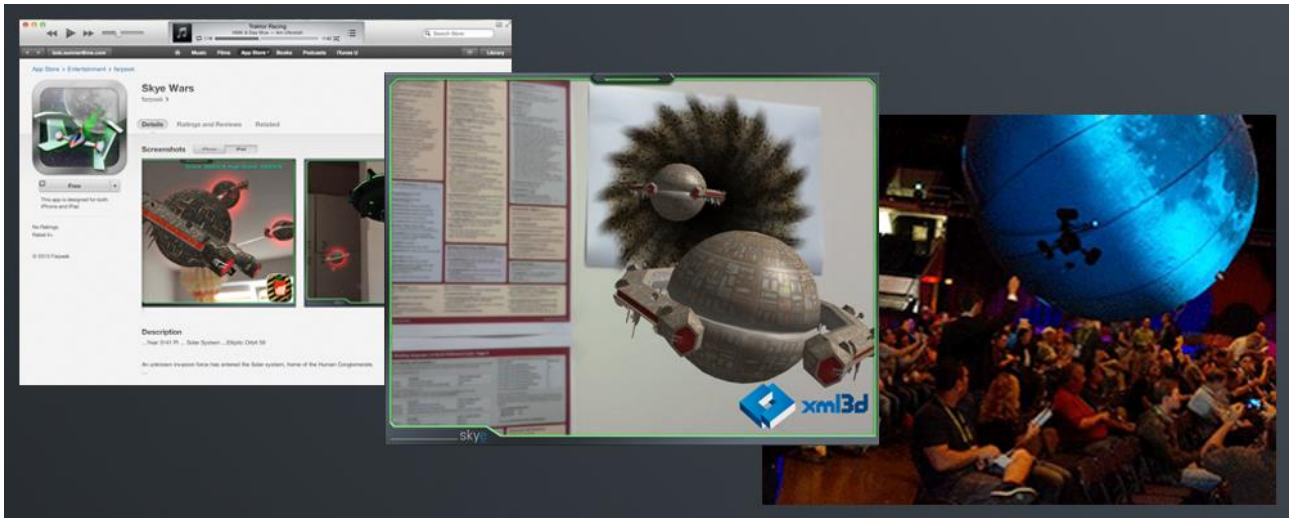

*Figure 4**Error! Bookmark not defined.** Skye Wars Lite*

4.3 - ARPix

ARPix is an application that lets a person take a picture of another person posing with an augmented virtual character. The goal of ARPix is to blend a virtual character into the camera image with a high degree of realism. To achieve this goal, two effects are integrated using the Camera Artifact Rendering SE: A diffuse sphere and a specular sphere mounted at each side of the image marker reflect the lighting condition of the current real scene. ARPix, knowing the positions of the spheres, calculates the lighting condition and applies it to the virtual scene.

*Figure 5**Error! Bookmark not defined.** ARPix*

4.4 - Spider Game Demo

The Spider Game Demo is a physical simulation of the movement of a virtual spider character crawling over some surface. We used a marker image on a table to augment several players around the table with the synchronized motion of the spider. Thereby, the simulation runs on a server and broadcasts the motion to the clients. Those clients were either Unity3D-based with the augmentation part or realized on the 3D-UI-XML3D GE to visualize the same scene on the web. Finally, this demo built the foundation for the Dragon Flight application.

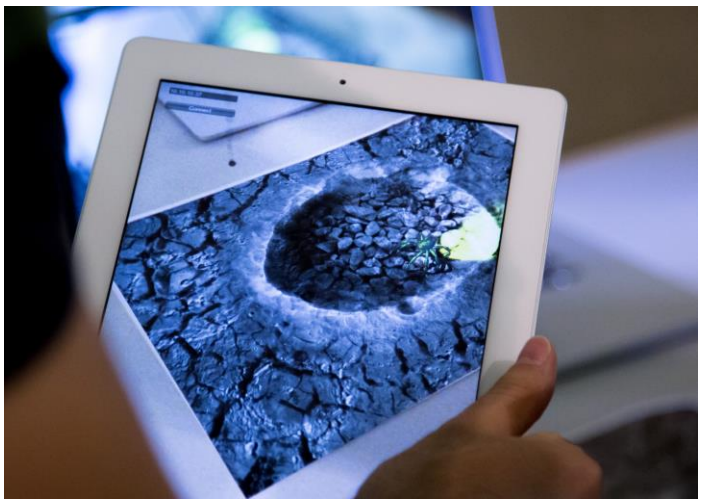

*Figure 6**Error! Bookmark not defined.** Spider Game Demo running on iPad*

4.5 - Star Tours

Star Tours is an augmented reality space opera application. It showcases the Reality Mixer - Reflection Mapping SE. Spheres placed at a certain position on top of the image marker are used as lighting probes to integrate realistic lighting effects for virtual objects in a very efficient way.

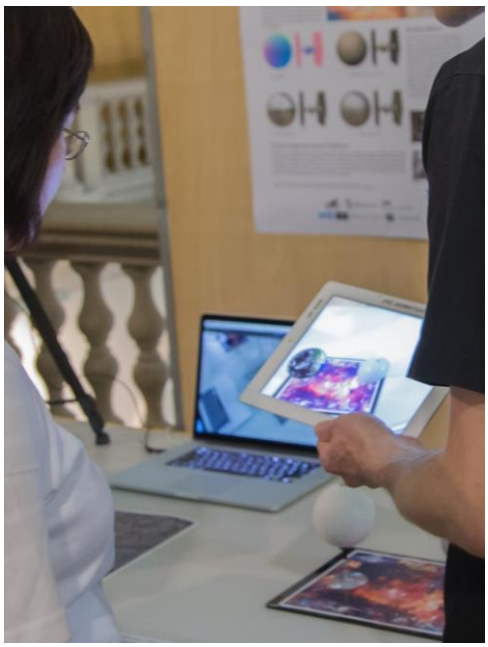

*Figure 7**Error! Bookmark not defined.** Star Tours*

4.6 - Dragon Flight

Based on the experience from the Spider Game Demo about synchronizing motion of virtual characters on multiple clients, a more advanced Tier-2 showcase "Dragon Flight" was realized. In this showcase, the motion input is captured from the player flying a virtual dragon using Kinect rather than from a physical simulation. Both motion inputs have in common to be unpredictable and thus the animations are not pre-computable.

Therefore, the Synchronization GE was amended with the Networked Virtual Character SE to take care of exactly these use cases, which are beyond keyframe animations and require the synchronization of individual bones of the virtual characters. Finally, the resulting SE gathered interest from FIWARE in the way that it is going to be integrated into the core of the Synchronization - FiVES GE.

*Figure 8**Error! Bookmark not defined.** Dragon Flight*

4.7 - FiVES-campus

FiVES-campus is a joint-demo between FIcontent WP4 and the FIWARE WebUI chapter showcasing several common SEs of FIcontent and GEs of the respective WebUI chapter. It was developed in particular to manage the integration of a larger set of Enablers and to strengthen the collaboration between partners of FIWARE and FIcontent. It was used for project exploitation at dedicated events, such as ECFI and Open Days on FIWARE technology, and improved the visibility of FIcontent and its FIWARE Enablers for Media & Content towards 3rd-parties in particular Phase-III applicants.

*Figure 9**Error! Bookmark not defined.** Screenshot of FiVES-campus Demo*

4.8 - AR Travelers

AR Travelers is a multi-player augmented reality location-based game. In this game, several players have to shoot aliens invading earth through a portal. The portal is a physical cube, which is tracked by AR and augmented with CG content and virtual characters. AR Travelers uses the Camera Artifact Rendering SE to seamlessly blend CG content with the real video feed.

*Figure 10**Error! Bookmark not defined.** AR Travelers*

4.9 - Treasure Hunt

Treasure Hunt Zurich is a city-wide Augmented Reality scavenger hunt game that is played in the city of Zurich, Switzerland. The player is sent on a quest that leads through the city to find a hidden treasure. The locations are found with the help of text descriptions and clues. At several locations throughout the quest Augmented Reality puzzles have to be solved in order to continue.

Treasure Hunt exploits the Leaderboard SE to show high scores and the FA-TTS SE to provide reading of location descriptions and hints.

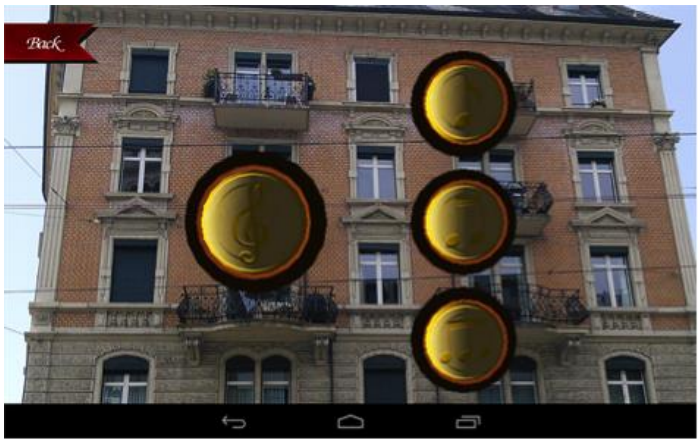

*Figure 11**Error! Bookmark not defined.** Treasure Hunt*

4.10 - Gnome Trader

Gnome Trader is a city-wide location aware Augmented Reality resource trading game. Resources can be bought from and sold to Gnomes hidden in newspaper boxes all around cities. Gardener gnomes produce food and sell it to the player at a dynamic price. Gnome families are waiting for the player to bring them food. The resource's price base is tightly coupled to the Swiss Market Index. Additionally, the Gnomes change their resource prices according to the amount of resources in their storage.

Gnome Trader uses the POI Data Provider GE and the POI Interface SE to access POI location. It uses the Augmented Audio SE for improved immersion, and the Leaderboard SE to store and display high scores.

*Figure 12**Error! Bookmark not defined.** Gnome Trader*

4.11 - POI Matchmaking Unity Demo

This application is a technical demonstration for the POI Matchmaking SE.

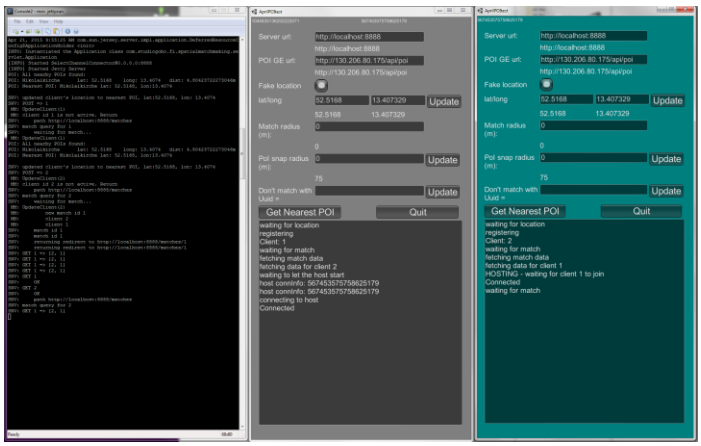

*Figure 13**Error! Bookmark not defined.** POI Matchmaking Unity Demo*

4.12 - Live Inspector

The Live Inspector application showcases the Visual Agent Design SE. This application allows to inspect live a behaviour executed on the Thymio II mobile robot. While the robot moves in the world, the part of the visual program executed is shown on a tablet at the location this part was executed. This allows to better understand which part of the program is executed where, therefore improving the learning of programming for beginners.

*Figure 14**Error! Bookmark not defined.** Live Inspector*

4.13 - ARvatar

The ARvatar game demonstrates how the web tool ARTool SE can be used to create engaging AR applications. The ARTool SE aims to dramatically simplify the development and deployment of AR applications by utilising pre-defined templates, components and modules enabling the creation of cross-platform applications with minimal or no programming effort required.

The ARvatar game is based on marker-less or marker-based AR tracking where the AR content is superimposed on a global plane detected (e.g. on a street pavement or on a table top) or 2D image marker respectively. Each user chooses its own ARvatar from a set of available 3D models. The ARvatar's appearance can be influenced by many factors but initially it is dependent on the meteorological and air quality parameters determined by the ekoNET service (for now only air temperature and concentration of CO2). This is an IoT device connected to the ARTool platform providing real-time measurements on different meteorological parameters such as temperature, air pressure, humidity and air quality. Depending on the temperature and air quality, the ARvatar's appearance will be modified accordingly. The users can view the ARvatar and share the view with other users via Facebook. The aim of the game is to score as many points as possible by trying to guess the true values of measured temperature and concentration of CO2 based on the appearance of the ARvatar. The score of the user is logged on the server where the leader board is kept. The measured values of temperature and CO2 are obtained from the device selected from the list enabling users to become aware of the meteorological and air quality parameters at different locations.

*Figure 15**Error! Bookmark not defined.** ARVatar*

5 - INTERACTION AND COOPERATION WITH OTHERS FICONTENT PLATFORMS

With regard to the effort in platform development, there is an overlap between the Social Connected TV (WP2), Smart City (WP3) and Pervasive Games (WP4) Platform. In particular relevant for city-wide games, for instance, might be the cooperation with work package 3. We address these synergies in various fashions:

Common Specific Enablers. First of all, we promoted certain Specific Enablers, such as the Social Network SE [18], as Common Specific Enabler of FIcontent due to the fact, that multiple platforms take advantage of them. For example, the social platform module of the Pervasive Games Platform utilizes the Social Network SE as well as the Smart City Platform (WP3) as described in D3.2. Thereby, both platforms benefit from the user interaction abilities of the Social Network SE including sharing of contents such as media, status, and comments. For instance, the Leaderboard SE uses the Social Network SE to automatically post any new top score.

Technology Transfer. Moreover, we developed groups of Specific Enablers within WP4, such as the Augmented Reality SEs and Reality Mixer SEs, dedicated for gaming in the first place, but probably useful as well for advanced interaction techniques in the context of Smart City Services. Hence, we pushed selected pieces of technology from WP4 either directly to WP3 or even promote certain SEs as Common Specific Enablers, too. Our Augmented Reality group of SEs contains promising candidates for the latter approach. Therefore, we cooperate with WP3 on the requirements for these SEs and aligned the development of features with gaming scenarios in mind as well as POI use cases, for instance.

FI-PPP Architecture Board. In addition, we maintain a strong connection between the technical work package WP6 and partners of the Pervasive Games Platform to strengthen in particular the link between the technology providers and game-domain related parties, and through WP6 to the whole FI-PPP in general due to the active engagement of WP6 in the FI-PPP Architecture Board.

Finally, few partners, which are driving the technological platform development and being involved in multiple work packages, act as bridge with regard to common requirements and sharing efforts between those work packages.

6 - DEPLOYMENT OF THE PERVASIVE GAMES PLATFORM

The figure below illustrates where the Enablers are located, i.e. where they are installed and running. On the left side the cloud services are listed that mostly have a RESTful API to be used by clients or other services. The right side shows Enablers that are running purely on the client side. The center contains Enablers that simplify the interface and need to run code both on the client and server side.

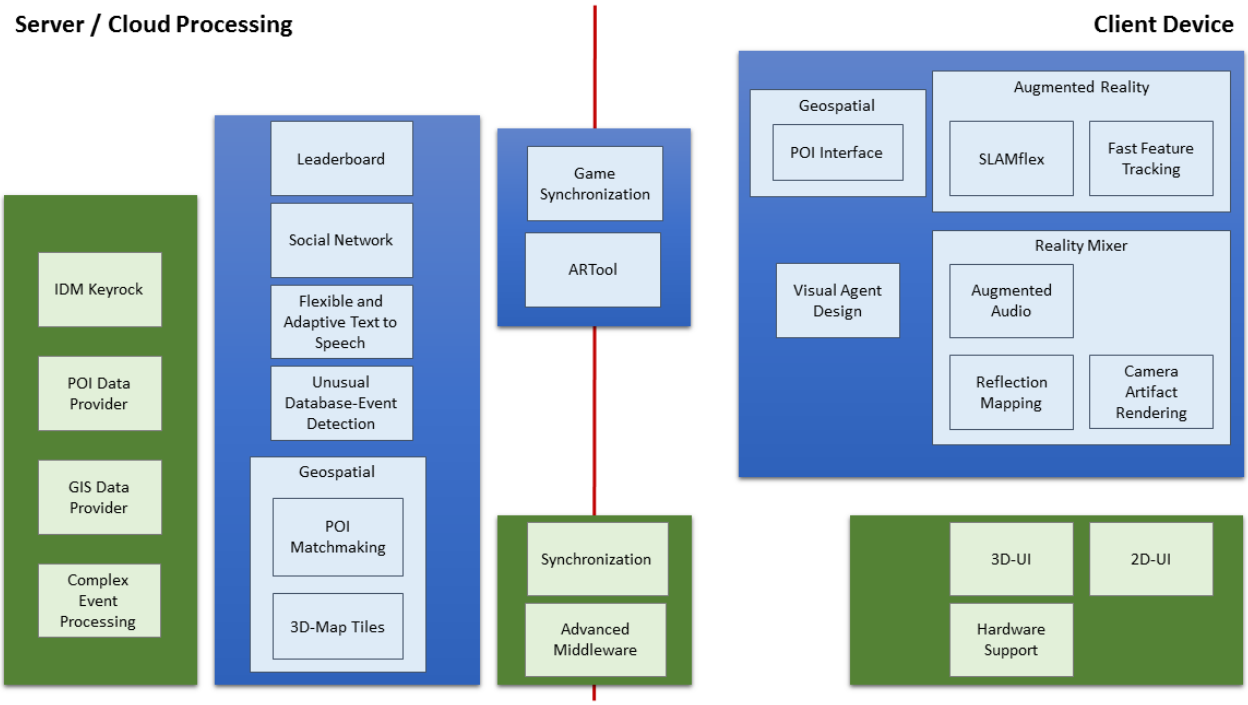

*Figure 16**Error! Bookmark not defined.** Deployment sites of Enablers of the Pervasive Games Platform*

6.1 - Client Side Enablers

Some Specific Enablers of the Game Platform are purely located on the client side. They consist of libraries, installation packages or standalone applications. Download links are provided via the FIcontent catalogue ('where to get') but the files are hosted on github [17] or by each responsible partner to allow for easy updates. Such Enablers are:

- Reality Mixer - Reflection Mapping SE (see Section 3.4)
- Reality Mixer - Augmented Audio SE (see Section 3.6)
- Reality Mixer - Camera Artifact Rendering SE (see Section 3.5)
- Augmented Reality - Fast Feature Tracking SE (see Section 3.8)
- Geospatial - POI Interface SE (see Section 3.2)
- SLAMflex SE (see Section 3.12)
- Visual Agent Design SE (see Section 3.10)
- 2D-UI GE [28]
- 3D-UI-XML3D GE [4]

6.2 - Server Side Enablers with a Shared Instance

Some Specific Enablers and Generic Enablers that have either little performance requirements and are used by several games or SEs and GEs, which are intended to share data among several games, will use single instances. They will be deployed once and used by a number of games. These Enablers are:

- Geospatial - POI Matchmaking SE (see Section 3.3)
- Leaderboard SE (see Section 3.7)

- Flexible and Adaptive Text to Speech SE (see Section 3.11)
- Social Network SE [48]
- 3D-Map Tiles SE [49]
- Identity Management Keyrock GE [19]
- Complex Event Processing (CEP) - Proactive GE [27]

6.3 - Server Side Enablers with one Instance per Game

Some Specific Enablers are cloud services and have to be deployed per game by the game developer (e.g. in FIWARE Lab facilities). Usually, such instances also require database access. These Enablers are:

- Geospatial - POI Matchmaking SE (see Section 3.3)
- Unusual Database-Event Detection SE (see Section 3.1)
- POI Data Provider GE [13]
- GIS Data Provider - Geoserver/3D GE [14]

Most cloud-based (server side) Enablers are utilized either on the Xifi FIWARE testbed infrastructure or the FIWARE Lab. Three notable exceptions exist where dedicated servers might be used at the respective test sites:

- latency-critical message handling for multi user games such as racing or first person shooter type games
- ethical requirements to store private data within the same country as the test site
- GPU computing power for high performance physical simulations if not available on cloud servers

For these cases, the experimentation sites provided a server infrastructure, supporting local experiments during the two experimentation cycles.

6.4 - Enablers on Both Client and Server Side

Some Enablers are located at the interface between client and server and, therefore, consist of both a server side cloud service as well as a library part which is used on the client. The enablers are:

- Game Synchronization SE (see Section 3.9) (uses Unity 3-D meta server for game discovery)
- ARTool SE (see Section 3.13)
- Advanced Middleware GE [22]
- Synchronization - FiVES GE [16]

6.5 - Deployment on FIC2Lab

To facilitate the test, tweak, experimentation, and use of all enablers, a dedicated Lab has been launched in April 2015. This requirement was identified by the reviewers after the first year review, as a milestone critical in order to help developers to bootstrap their use of all the Social Connected TV, Smart City Services, and Pervasive Games platform technologies.

The FIC2Lab:

- Centralizes all enabler documentation / deployment recipes / docker instances.
- References the demo instances of all enablers.
- Allows to tweak all Javascript-based client-side enablers directly in the browser.
- Allows to instantly deploy server-side enablers on both public and private clouds, via the use of Docker Images and Chef Recipes.

To start discovering, hacking and using the enablers, go to FIC2Lab [50].

6.6 - Deployment on Unity Store

Several of the Unity-based enablers are also provided on the Unity store, for easy deployment within the existing Unity ecosystem. The list of these enablers is available at Unity Asset Store [31].

6.7 - An example of deploying a client-side application

While server-side enablers can be tested on FIC2Lab, deploying client-side applications demand local operations. To help beginners deploying Unity-based enablers, we have created a starting guide within the context of Treasure Hunt. The starting guide's source code is available in the "StartingGuide/" subdirectory in the git repository of Treasure Hunt [51]. A starting pack containing the compiled guide and sample Unity project is available as well [52].

6.8 - Infrastructure used in the 1st and 2nd Experimentation Cycles

The Pervasive Games Platform is deployed on two of FIcontent's six experimentation sites: Barcelona and Zurich. The following sections briefly describe the available infrastructure at both experimentation sites, which are described in more detail in deliverables of WP7 (see D7.1.2, D7.5.1, D7.5.2, D7.6.1, and D7.6.2).

6.8.1 - Technical Infrastructure in Barcelona

Regarding the technical infrastructure used in the Barcelona Experimentation site, i2Cat has connected different venues to run the FIcontent experiments: PMT in Castelldefels [53], Citilab in Cornellà [54], Neapolis in Vilanova [55] and Fabra & Coats in Barcelona [56] as main hub of activities.

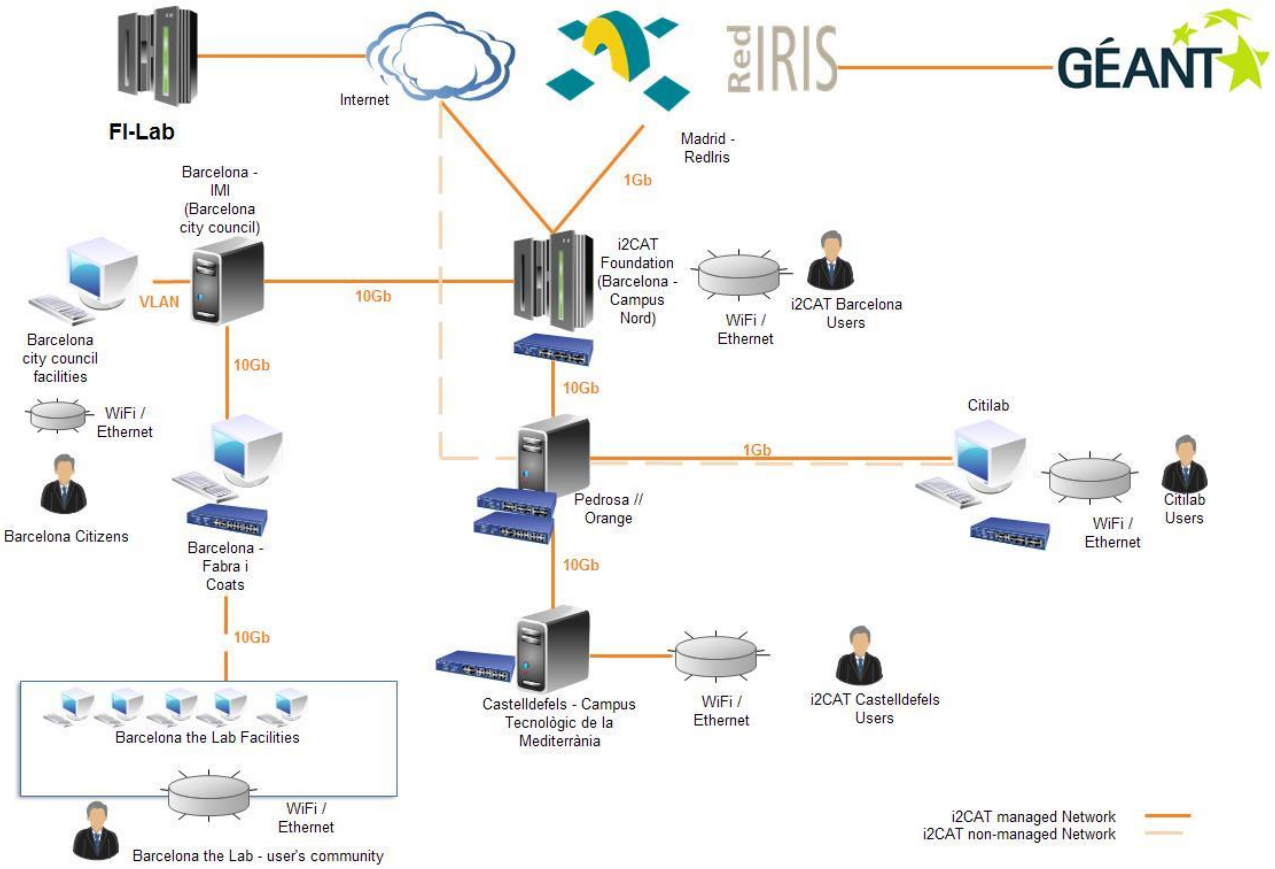

*Figure 17**Error! Bookmark not defined.** Barcelona: Technical Infrastructure*

The connectivity of the Barcelona site to the external world, and to FI-Lab in particular, is provided by a 10GE link to FIRE facilities through I2CAT and Barcelona Municipality fiber optic network.

The Barcelona experimentation site can also count on an extensive hosting and networking infrastructure through MediaCAT's hardware facilities, fully owned and operated by I2CAT. Located in the C4 building of the Mediterranean Technology Park (Castelldefels, Barcelona), the MediaCAT CPD has 10 racks with 9 power lines (three triphasic lines) fully dedicated to hosting:

- 3 lines connected to the university's uninterruptible power system (backup electric generator).
- 3 lines per equipment distributed in the communication and services racks
- 3 lines dedicated to cluster servers and storage racks

MediaCAT's hosting capabilities are currently supported by:

- 90 hardware servers that host both services and virtual servers based on VMware or Xen.
- 14 Switches 10/1Gbps dedicated network
- 7 storage boxes.
- Different network testbeds including a Juniper MX480 router.
- Other equipment such as video conference, DWDM ...

6.8.2 - Technical Infrastructure in Zurich

The current technical infrastructure consists of a dozen of mobile devices, i.e. tablets and phones, as well as the infrastructure offered by ETH Zurich (Wi-Fi, rooms, open areas where to run experiments). Zurich is both using the cloud hosting provided by FIWARE Lab and our own hosting services, as unfortunately FIWARE Lab hosting has proven not reliable enough for the current needs of the Pervasive Games Platform. Our own hosting services are done through virtual servers rented from ETH on demand.

7 - CONCLUSION

In this document, we have presented a technical description of the final Pervasive Games Platform. First, we have presented the overall architecture of the platform, listing the groups of Specific Enablers and Generic Enablers that are involved, as well as how they interact with each other. In addition, we have indicated the external development tools that are currently integrated in the platform and how this integration works.

Second, we have presented the enablers themselves, with a high-level description of the Specific Enablers provided by the partners behind the Pervasive Games Platform. For a detailed description of Specific Enablers, please refer to FIcontent Wiki. Description of FIWARE GEs is available in the FIWARE catalogue [57].

Finally, we have discussed the deployment of the platform and pointed out the diversity of environments hosting the utilized enablers between client devices and server instances together with technical infrastructure used for the second experimentation cycle in Barcelona and Zurich.

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