

VirtualLife

D1.4 Project Final report - publishable version

AUTHOR	Maria Vittoria Crispino - Nergal
MAIN CONTRIBUTORS	all partners
CATEGORY	Public
STATUS	Final
DOCUMENT NAME	VirtualLife_D1.4_ProjectFinalReport

TABLE OF CONTENTS

<u>SECTION 1: FINAL PUBLISHABLE SUMMARY REPORT</u>	<u>3</u>
<u>1. EXECUTIVE SUMMARY</u>	<u>3</u>
<u>2. PROJECT CONTEXT AND OBJECTIVES</u>	<u>4</u>
<u>3. MAIN S&T RESULTS/FOREGROUNDS</u>	<u>8</u>
3.1. SCALABLE, RELIABLE P2P ARCHITECTURE FOR A 3D ENVIRONMENT	10
3.2. CREATION OF A SECURE AND TRUSTED PEER-TO-PEER INFRASTRUCTURE THAT ALLOWS END-TO-END SECURITY IN COMMUNICATIONS.	12
3.3. DEVELOPMENT OF A IMMERSIVE 3D VIRTUAL REALITY ENVIRONMENT.	15
3.4. DEFINITION OF A CERTIFIED AUTHENTICATION SYSTEM, IN A VIRTUAL NATION CONTEXT, CAPABLE TO GUARANTEE THE IDENTITY OF THE USER.	18
3.5. VIRTUAL LAW SYSTEM TEMPLATE COVERING ALL ASPECTS OF THE VIRTUAL LIFE	18
3.6. VIRTUAL LAW TECHNICAL IMPLEMENTATION	20
3.7. SCRIPTING ENGINE	23
3.8. PLATFORM VALIDATION	25
<u>4. POTENTIAL IMPACT</u>	<u>28</u>
<u>SECTION 2: USE AND DISSEMINATION OF FOREGROUND</u>	<u>32</u>
<u>1. VIRTUALLIFE: LIST OF SCIENTIFIC PUBLICATIONS.....</u>	<u>32</u>
<u>2. VIRTUALLIFE: EXPLOITABLE FOREGROUND</u>	<u>41</u>
2.1. DEFINITION OF VIRTUALLIFE EXPLOITATION STRATEGY	41
2.2. EXPLOITABLE FOREGROUND	41
<u>SECTION 3: VIRTUALLIFE CONTACTS AND PROMOTION</u>	<u>43</u>

SECTION 1: FINAL PUBLISHABLE SUMMARY REPORT

1. Executive Summary

VirtualLife is an experimental and innovative framework containing advanced tools and options for creating virtual world applications. VirtualLife is not a virtual world, nor a stand-alone application, it is a scalable and customizable platform containing some basic modules and based on some fundamental innovative pillars (peer-to-peer architecture, secure communication infrastructure, legal framework, powerful scripting language); additional modules can be built on top of it on demand.

The core of VirtualLife is the innovative Virtual Reality Engine based on a hybrid peer-to-peer infrastructure that allows the sharing of computational load in experiencing the virtual environment obtaining infrastructural resource optimization and bandwidth reduction. It enhances the platform in terms of robustness, availability, scalability, load balancing.

From an higher level point of view, VirtualLife is provided with a Legal Framework that allows to conclude deals and to carry out transaction directly in-world. To obtain this aim, VirtualLife is integrated with a secure communication infrastructure based on a strong identity system that bounds the avatar to the real identity of the person behind, that is responsible of his actions as in real life. In case of infringement of the contract terms, an in-world dispute resolution is implemented within the platform. The design of such system carefully mimics the Model Agreement provided by The International Mediation Institute, www.IMImediation.org (see Example of Model Agreement Legal Appendix for more information).

This innovative approach has received some encouraging feedbacks from private universities and training companies, so that a specific applicative scenario has been customized for educational purposes (Virtual Campus). The Virtual Campus scenario takes also advantage from the interactivity enabled by the VirtualLife scripting engine. From the legal side, some Contracts template specifically targeted to the relationships existing among private universities, teachers and students, cover the main use cases.

Moreover, after a careful examination of potential business applications, thanks to the powerful scripting engine has been possible to obtain a specific applicative scenario (industrial scenario) aimed, for example, to provide a testing platform to the streetcar/railway designer/manufacturer.

The project has devoted great attention also on dissemination and exploitation activities; more than thirty publications have been written and more than one hundred fifty potential stakeholders have been contacted in order to build a business relationship.

2. Project context and objectives

VirtualLife is an experimental and innovative framework containing advanced tools and options for creating virtual world applications.

The project is aimed at creating a 3D platform based on a p2p network, so that the virtual world can be distributed on the network, and equipped with a legal framework that allows real-world compliant transactions and some form of democratic participation within the world deployment.

The goal of the VirtualLife project is to implement a secure, trusted and legally ruled networked virtual environment.

To achieve this objective, aside from what usually offered in virtual worlds (a 3D environment persistency, immersive experience, possibility to cooperate with other avatars...), VirtualLife distinguishes itself having put particular attention on the following ideas:

- Strong identity
- Decentralized peer-to-peer architecture
- Interactivity and scripting
- Legal and social cooperation framework.

Strong Identity:

In VirtualLife actions performed by an avatar can be directly connected with the underlying real-world identity of an individual. As such the user is as much responsible for his actions as he is in the real world. To this aim, VirtualLife is provided with a Strong Identity framework.

The distributed virtual world of VirtualLife must therefore have an underlying identity system and a secure communication system. Both are critical for the development of the legal services of the VirtualLife platform.

The design of the secure communication architecture was driven by the following guidelines:

1. Every avatar, Virtual Zone and Virtual Nation in VirtualLife must have an identity.
2. Every identity holder must have direct control over the use of that identity to rule out identity fraud.
3. Peers must be able to exchange information in a confidential and authenticated way.

4. The security features must not negatively affect the performance of services that do not require them.

To meet the above objectives, VirtualLife provides some security guarantees that are not present in other virtual worlds or are not extensively used:

1. The identity information is not stored online, but locally, on the client side. This means that the compromise of a password will not allow anyone to access an account from anywhere else. Similarly, no server is capable of impersonating a user in a communication or a contract since it does not have access to the full credentials of that user.
2. Communication partners can have direct confidential and authenticated communication between them, even through connections opened using NAT punchthrough. This is enabled by the peer-to-peer design of the communication layer.
3. VirtualLife identities can have outside references, providing them with a possibly stronger level of trust. Our research has resulted in techniques for communicating this trust to the user in a simple way.

Decentralized peer-to-peer architecture

One of the aim of VirtualLife is to provide a cost-effective platform for 3D virtual environment.

In this respect, the peer-to-peer network is aimed to provide the platform with some specific features as richness, responsiveness, robustness to provide an enhanced user experience to what is possible on traditional client/server architectures on regular Internet connections.

In addition, VirtualLife P2P framework is aimed to reduce the requirements of bandwidth and CPU power on the service provider of a VirtualLife-based virtual world service, and hence to reduce the total cost of ownership.

These achievements are possible thanks to some technical concepts developed within the projects and which are at the basis of the VirtualLife p2p architecture. The VirtualLife network layer allows any peer to provide services to others. The virtual reality engine and therefore also the world simulation are fully distributed. The p2p approach is applied to the networking library, the virtual reality engine and the scripting.

In particular, the nodes are connected together within a ring-shaped network. This kind of structure allows the peers to communicate directly with each other, making use of a messaging system based on three levels of messages:

- messages addressed and sent directly to the nodes
- broadcast messages, sent via the overlay and forwarded around the ring

- high frequency messages, forwarded only to directly connected peers and never sent around the ring

Also, a complex authority system for managing entities in world has been implemented, in order to improve message broadcasting and to avoid redundant communications.

All of these features contribute to build rich and animated contents for populating the 3d world.

Interactivity and scripting

One of the objectives of VirtualLife platform is to provide a powerful and a relatively easy way to allow the user to code interaction and automated behavior into the virtual world.

Scripting is used by virtual citizens to create interactive objects and to improve their building capabilities with "factory objects" (i.e. objects which create other objects procedurally. This is a useful technique to create complex modular buildings).

The scripting language is based on a specialization of the common language LUA that, in June 2011, entered the top 10 list of the most used programming languages (TIOBE index). According to the TIOBE index compilers, the major advantages of Lua are its small footprint and fast performance. These are the very reasons why it has been selected to be integrated in VirtualLife and the choice has been confirmed to be proper.

The VirtualLife platform features a script editing module integrated in the Client and a virtual machine embedded in the server. The Virtual Machine has been sandboxed in order to avoid malicious or simply wrong behaviors that could affect the virtual world usability.

The engine supports concurrency, persistency and distributed scripting and interactivity is achieved thanks to a complete event model.

Legal and social cooperation framework.

As said before, in VirtualLife actions performed by an avatar can be directly connected with the underlying real-world identity of an individual. As such the user is as much responsible for his actions as he is in the real world.

This is the main, and most innovative, objective of VirtualLife platform, i.e. a virtual world compliant with the laws and rules existing in real life.

VirtualLife is not a game. It is a multi-user immersive online environment founded on democratic principles that has the ambition to become a platform in which binding transaction can occur.

The provider of the Virtual World service as well as the users, and the users among each other, are bound by an Agreement referred to, within VirtualLife, as Supreme Constitution.

Seeing that the aim of the Project is to retain the maximal freedom and flexibility for users to create the virtual environment the way they want it to be, the Agreement intends to regulate the bare minimum only. It contains rules addressing the relationship between the software provider of VirtualLife and the respective user. Additionally, some rules, namely the *Code of Conduct*, shall also have an impact on the relationship between the different users: by becoming part of a contractual or quasi-contractual relationship between the users or at least by serving as an aid to interpretation of the contract between the users. Lastly, the Agreement also determines the legal framework according to which users may develop further rules for their Virtual Nation ("Virtual Nation Constitution"). Hence there are two different levels of laws plus those laws that are valid only between the users as parties to a certain contractual agreement within VirtualLife. The main difference between those categories is the number of legally addressed subjects.

The design of the Constitution of a Virtual Nation (i.e. a VirtualLife platform specialized in a specific context) hinges on the purpose of the Virtual Nation. For instance, a tv station could open a Virtual Nation to offer access to its broadcasts, or a bank could found a Virtual Nation to offer banking services online. Depending on the purpose, the Virtual Nation Constitution needs to contain one provision or another. If the purpose changes, e.g. if a payment system or other features are being in- or excluded, corresponding clauses need to be integrated or cancelled.

During the VirtualLife development, a specific applicative field has been chosen in order to focus the development efforts and results, the Virtual Campus.

The Sample Constitution for the Virtual Campus has been adapted to provide a specialized Constitution example. As copyright and data protection issues, which arise during classes held on the Virtual Campus, will be solved in the bilateral relationship between the private universities, the teachers and the students, further provisions in this aspect are not necessary.

3. Main S&T results/foregrounds

The fulcrum of all the happenings in all virtual world is the avatar. Behind any avatar is a real specific person that is able to interact with the 3D world and with the whole platform through the Client. One of the main differentiating factors between VirtualLife and competing existing virtual worlds is the will to implement a strong relationship between the real and virtual identity of an avatar. This is a basic pre-requisite to be able to have a virtual platform where the avatar is responsible for his/her actions in the virtual world just as much as he/she is in the real world (i.e. this is the basis to build any legal framework in the platform).

The main modules of VirtualLife architecture are the Client, the Virtual Zone and the Virtual Nation. The Client, that is the man-machine-interface to the platform, is able to perform many different tasks, starting from the communication with the Zone (see below) and other clients in order to form a "cluster of nodes" able to render and evolve the 3D simulation of the virtual world in a decentralized way, to the normal user interactions with the 3D environment (object creation, avatar movement, scripting interface...), to the interaction with the Nation to authenticate, to choose the zone in the full map for initial teleport, to retrieve/manage avatar profile, to perform activities related to the legal framework.

The Zone is mainly responsible for the simulation of the 3D virtual world. It performs this task, sharing the load with the currently connected clients. Zone and Clients form a p2p cluster-of-nodes and together keep the world simulation alive and coherent. This task is mostly performed by the virtual reality engine (also known as **vrengine**). The Zone allows the dispatching and retrieval of resources among zones (it handles this task making use of the DHT index) and the persistence of the virtual world. The Zone can be hosted on any user computer. The longer it stays on-line the more interesting it is for people to visit it. However VirtualLife does not require any single Zone to be available full-time. All Zones, just like avatars, have a unique GUID, a full Certificate and a keypair, so they have the same level of identification of other actors. Zones belong to an existing Nation.

The Nation is the software module that is responsible to maintain the logical coherence and the records for the full-world mainly from an authorization and legislative point of view. It also maintains the full arrangements (Nation Map) of the virtual Zones federated with it. The Nation is responsible for several other tasks, such as the enrolment and management of the list of Avatars belonging to it (identity, inventory, profile,...), of the list of Zones belonging to the Nation and their registration and placement within the Map;

Moreover, the Nation hosts the Legal Framework, that, from a theoretical point of view, is divided in a three-tier logical level. First of all, VirtualLife has a binding, and

fully real-world compliant, contract that regulate individuals' behaviour with respect to others actors within VirtualLife, be it other individuals or the provider of the virtual world. This contract, within VirtualLife, is called Supreme Constitution (the first level) and is somehow related to the typical license agreement that users accept when installing/using a software. The Supreme Constitution contains the fundamental principles that every user has to adhere to, when installing VirtualLife.

Additionally, it sets out the basic organisational rules according to which the laws of a Virtual Nation, the second tier of the framework, is formed. The "Virtual Nation Constitution" hence contains special and more detailed provisions as regards e.g. the protection of objects used in that Virtual Nation under copyright law, the mean to exchange goods (objects), the authentication procedure required to become a member of that nation. Only the avatars registered with a specific Virtual Nation have to adhere to that Nation "Virtual Nation Constitution".

The lowest tier of legal framework integration in VirtualLife is implemented through Contracts flow management and Online Dispute Resolution.

Avatars within VirtualLife can under-sign contract (of private nature) between each other. VirtualLife offers a framework to handle the filling and e-signing of contracts that relate to services offered by a Nation. The current framework implements a work-flow that is paradigmatic for several contract categories, and could be easily customized to other needs.

Virtual Life Network

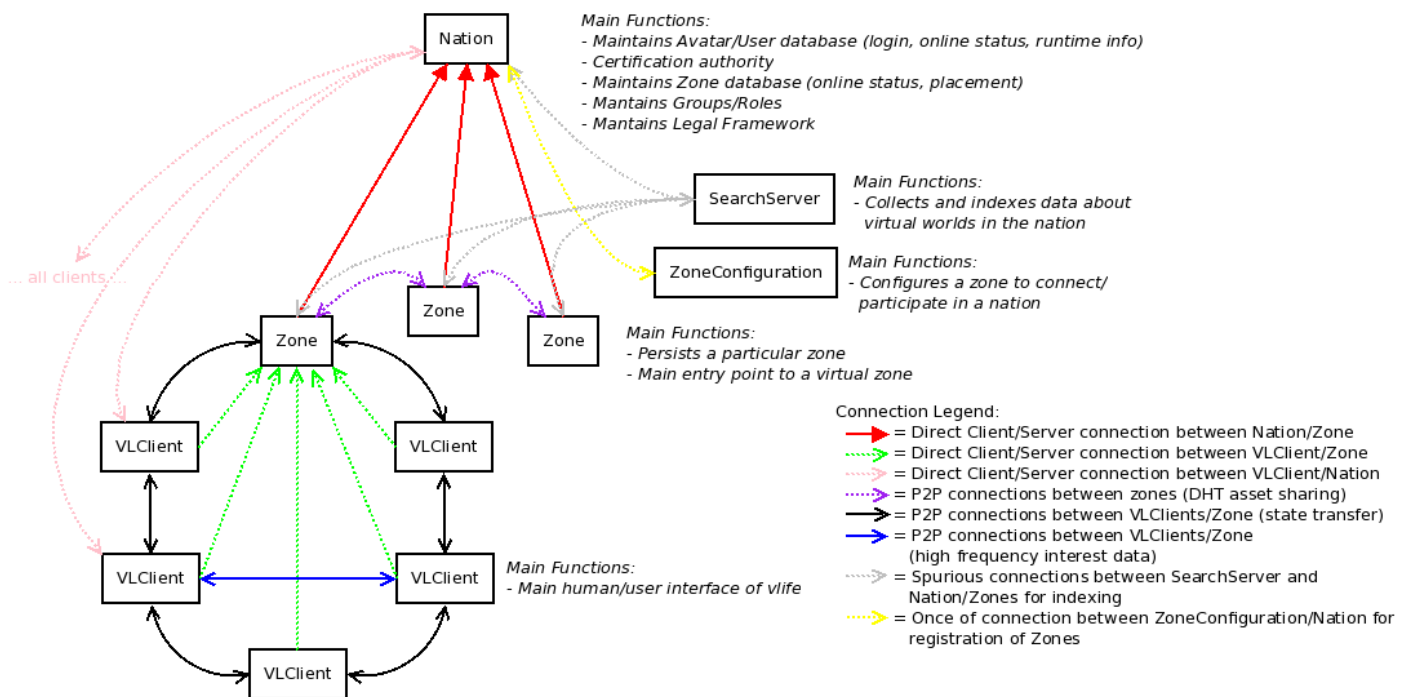


FIGURE 1: VirtualLife main components and functionality. The connection type among modules is also highlighted.

3.1. Scalable, reliable p2p architecture for a 3D environment

VirtualLife is built as a decentralized system so that it can be extendible by its users. The reduced requirements for server hardware simplify virtual world deployment and reduce its costs. Beyond a single Virtual Nation server, each Virtual Nation consists of distributed Virtual Zones that can be run by anyone who agrees to belong to it and is accepted by the Virtual Nation.

The peer-to-peer design reflects in the VirtualLife architecture as follows:

- 1) the network module in each node accepts connections from others;
- 2) the identity-based overlay network allows VirtualLife components to connect to any node by its identity and also determines the identity of any connected node;
- 3) the Virtual Reality Engine is built from ground up to perform distributed simulations; entities may be controlled by any suitable node in the Virtual Zone cluster-of-nodes and physics simulation can be performed by several nodes in the system;
- 4) the scripting engine allows scripts to be migrated between nodes so that the execution load can be distributed

The focus on distributing the virtual world simulation and balancing its load on the peer-to-peer network increases the communication overhead. To counter that, measures are taken to optimize the protocols and reduce the required bandwidth.

The end goal of the peer-to-peer approach is the cost reduction of the service provider. As a potential impact, using this technologies could allow organizations to deploy virtual worlds in a more cost-effective manner.

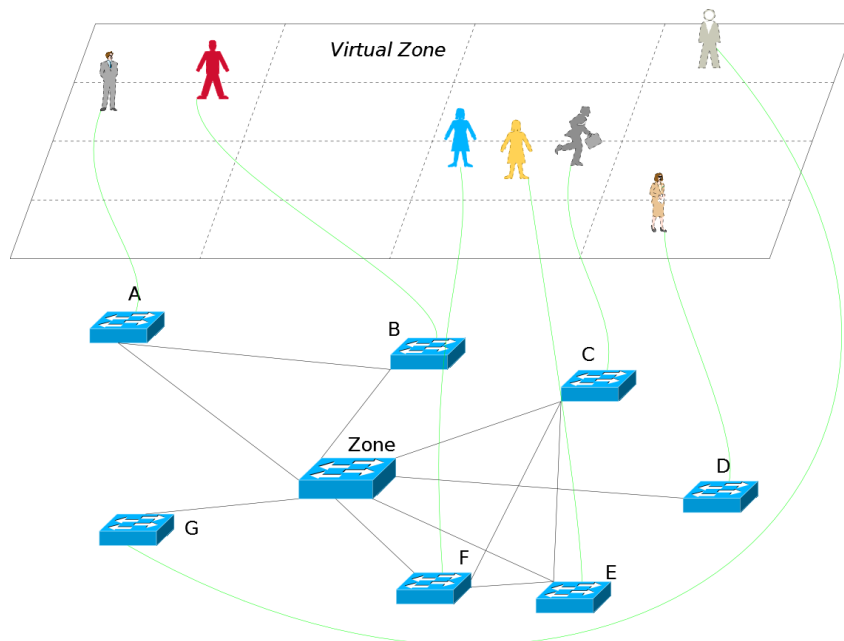


FIGURE 2: NETWORK AND P2P COMMUNICATION INFRASTRUCTURE

An experimental analysis of the VirtualLife peer-to-peer features has been carried out. Through a series of tests, the effects of the peer-to-peer technologies in a virtual world setting have been demonstrated. The goals was twofold: analyse properties of a created P2P virtual world framework and to better understand when using VirtualLife in a P2P mode makes sense.

During testing several components (scripting engine, vengine, vlnet/vlsec – the underlying network and security libraries – and performance monitoring infrastructure) of the VirtualLife platform have been stressed.

The experimental analysis has demonstrated that VirtualLife P2P infrastructure allows to considerably reduce network bandwidth consumption by the Zone nodes, which is one of the major cost inflicting factors for the central services of the virtual worlds. At the same time, consistency of the world for the clients remained on the same level, i.e. we did not detect significant improvements nor degradations in the consistency of the world. The main component responsible for that is the peer-to-peer virtual reality engine that uses advanced techniques for the distributed simulation. To summarize we conclude that:

1. User experience is maintained in the form of
 - a. Responsiveness: specifically, the overhead observed from the P2P implementation does not significantly degrade the service, while consuming less bandwidth
 - b. Correctness: the virtual world was always found to be correct within acceptable (i.e. less than that of a client-server approach) time limits.
 - c. Robustness: the virtual world was always found to be correct within acceptable (i.e. less than that of a client-server approach) time limits, even in the presence of network latency and bandwidth heterogeneity.
2. Total cost of ownership is reduced using our P2P approach:
 - a. Bandwidth usage is reduced: the amount of bandwidth to run a rich Virtual Zone is reduced when using our peer to peer approach than when using a client/server approach.
 - b. CPU usage is within acceptable limits: The total CPU usage to run a rich Virtual Zone is not worse when using our peer to peer approach than when using a client/server approach.

In conclusion, the P2P framework effectively balances richness, responsiveness, robustness to provide an enhanced user experience to what is possible on traditional client/server architectures on regular Internet connections. In addition, our P2P framework reduces the requirements of bandwidth and CPU power on the service

provider of a VirtualLife-based virtual world service, and hence reduces the total cost of ownership.

Another major innovation in VirtualLife is a distributed scripting engine, which allows to migrate scripts to the Clients according to a certain policy. This creates a strong potential for scalability: offloading load through script migration allows to create very scalable environments, as scripts typically constitute one of the heaviest parts for central services.

3.2. Creation of a secure and trusted peer-to-peer infrastructure that allows end-to-end security in communications.

VirtualLife is provided with security and cryptography services capable to guarantee trustiness and confidentiality. In particular, two libraries have been implemented: `vlnet` and `vlsec`.

`vlsec` provides the following data structures:

1. Cryptographic keys
2. X.509 Certificates
3. Access control policies
4. Digital documents

In addition, `vlsec` handles the following feature groups.

1. Key management
2. Encryption
3. Digital signatures on byte arrays
4. X.509 certificate handling
5. XaDeS digital documents and digital signatures
6. Access control features

The library enables the use the identity-based overlay network by providing the required cryptographic underpinnings of identity proofs and secure communication.

The access control mechanism allows developers to deploy identity-based blacklists and whitelists in the VirtualLife nodes. These can be used for giving a limited set of people access to certain resources or banning specific identities from using a resource.

Finally, the digital document and digital signature feature allows VirtualLife to create signed digital documents from files and VirtualLife objects.

The networking library (vlnet) is a critical module in VirtualLife because of the distributed design of the system. The vlnet library wraps an external networking library and deploys a higher-level service infrastructure. The service design follows a peer-to-peer paradigm by allowing any node to deploy services for others.

The library provides the following data structures:

1. network messages;
2. base classes for streams and services;

In addition, the library provides the following functions:

1. listening to connections and connecting;
2. deploying and running services;
3. handling streams of data;
4. providing network statistics;
5. performing NAT punchthrough;
6. opening encrypted connections with identity proofs.

The library deploys secure channel services in VirtualLife nodes.

VirtualLife network communication is organized in streams. Streams are point-to-point channels between components in the software. Any node in VirtualLife can open streams to another node. The only prerequisite is that the other node runs the respective service.

Any node can run services and all nodes do. For example, every node runs the secure channel service to be able to accept secure connections. Secure connections do not apply to all streams running on the connection. This allows some data to be sent unencrypted.

NAT punchthrough improves the peer-to-peer features by allowing nodes that are behind address translating firewalls to connect to each other.

The vlnet library also provides networking statistics that are used for measurements.

Developers of VirtualLife can freely use the described security features as they are not limited to specific services. Service separation and connection reuse allow components to share secure connections. Also, identity information is global all over the platform.

Profile operations (such as looking at the ID card, updating user profile fields) are performed by the nation server when requested by a client. There is a service in the nation server that responds to relevant requests. When a profile update message arrives, the service first checks that the user is authenticated by asking the

communication channel for the source identity. If no identity proof is associated with the connection, the service request will be denied.



FIGURE 3: ID CARD FOR VIRTUAL IDENTITY AND REAL IDENTITY.

If the query is a profile update query, the service compares the identity on the channel to the one in the update request. If they match (an avatar is trying to update its own profile), the operation proceeds. Otherwise, access is denied. However, access can have more levels. For example, if the request is to view a profile, the service can deny access only when an identity is not provided or is in a blacklist. If the identity on the channel matches the identity in the request, full avatar information is returned. On the other hand, if the channel identity is provided, but it doesn't match the identity in the request, only the publicly available information is returned. This way, the avatar can see its detailed profile, but the other users will only see a limited set.

Peer-to-peer services like the private chat service act similarly. The main difference is that every node must be ready to accept incoming connections - every client node must run the chat service. When an incoming chat request is detected, the identity of the initiator is read from the secure channel. Thereafter, the minimal profile information is looked up from the nation service and the chat window is opened in the graphical user interface.

VirtualLife user interfaces typically provide the user with information about the communication partner. This is especially true in security-critical services like chat or contract management. The identity information provided by the secure channel infrastructure can directly be passed to the profile processing tools that convert it to comprehensible representations that can be shown in the user interface.

To conclude, developers of VirtualLife services can use identity information in authentication and authorization tasks carried within the secure channel. It is not compulsory to use secure channels for all possible traffic and therefore performance-critical services can be built by balancing secure traffic with insecure one. However, the developer should always trust only these information values that are received on a secure channel.

The secure communication framework described above was designed for virtual worlds. However, this does not prevent it from being used in other applications that benefit from the capability of secure peer-to-peer connections and a strong identity system.

The architecture is useful for prototyping cryptographic protocol implementations and even building practical applications with underlying protocols.

3.3. Development of a immersive 3D virtual reality environment.

From a lower level point of view the main software modules that manages the entities (in a broad sense) and the overall 3D virtual simulation is the vrence.

vrence is responsible for several tasks, summarized as follows:

- it executes and renders the 3D simulation;
- it ensures the coherency across views of distributed clients;
- it migrates the resources needed for correct visualization in-world of entities;
- it routes state messages optimally according to the state of the virtual world;
- it manages the persistence of entities in between shutdown-restart cycles (being them for maintenance or simple un-availability of the nodes);
- it manages the synchronization on the access to entities (authority);
- it manages propagation and enforcement of Nation and Zone laws;
- it manages propagation and synchronization of Group Lists with Nation.

The vrence is based on a hybrid peer-to-peer approach that allows to use the benefits of a peer-to-peer network with the straightforward design of a client-server one. For example, the users enter a single Virtual Nation and a single Virtual Zone, but the services are provided in the peer-to-peer fashion. This simplifies the perception of the service by users. While content delivery in peer-to-peer networks is not new by itself, optimizing a virtual world using peer-to-peer network to facilitate efficient resource discovery and transfer is novel feature. It is most useful in supporting the ability of peers to create and import content.

In order to coordinate the 3D simulation among the peers (cluster-of-nodes) that participate in the virtual world, vrence implements an application level messaging system with a dedicated routing system.

The virtual reality engine operates as follows:

1. Each instance of the engine simulates its own version of the 3D-virtual world.
2. The engine represents items in the world as entities, where entities are divided

into two groups: controlled entities, and remote entities. Controlled entities are simulated by an engine, while remote entities are updated from the network.

3. Controlled entities can be modified by the local application (via direct manipulation from a user, or via a script). Subsequently, changed data is replicated to other engines participating in the virtual zone who applies the changed values to their remote entities corresponding to the modified entity.

The virtual reality engine takes care of:

1. Deciding what data needs to be sent;
2. Deciding to whom the data needs to be sent;
3. Deciding how to get the data to the remote engines.

At each frame of the engine, all modified entities since the last frame are scanned, and modified data is packed into UPDATE messages. Modified data is detected using a "dirty" flag mechanism, where only controlled entities are able to set the dirty flag for an entity. An UPDATE message generally has the destination of ALL, meaning that the update should be sent to all nodes that are simulating that particular entity. The routing module within the virtual reality engine then interprets the message destination and decides how the message should be sent, either directly, or to be relayed via other nodes.

The **vrengine** makes use of an innovative structured overlay in order to perform its routing. This overlay arranges all nodes in a cluster into a self maintained and robust ring shape. Low frequency messages are routed around this ring. High frequency messages, that consume the majority of bandwidth (UPDATE messages, particularly for changes in position and orientation) are routed directly to nodes that are interested in receiving them. The **vrengine** automatically determines which nodes it should be interested in based on the authority of the entities currently in view. It opens direct streams to these nodes, through which it receives high frequency state messages for the most accurate view of that portion of the world. The overall benefit is that network traffic can be shaped according to the state of the world.

The overlay network combines the benefits of the Pastry and Kademlia approaches to achieve a ring topology together with Kademlia's robustness. Additionally, there is also peer-to-peer traffic among the different zones, not just within a single zone.

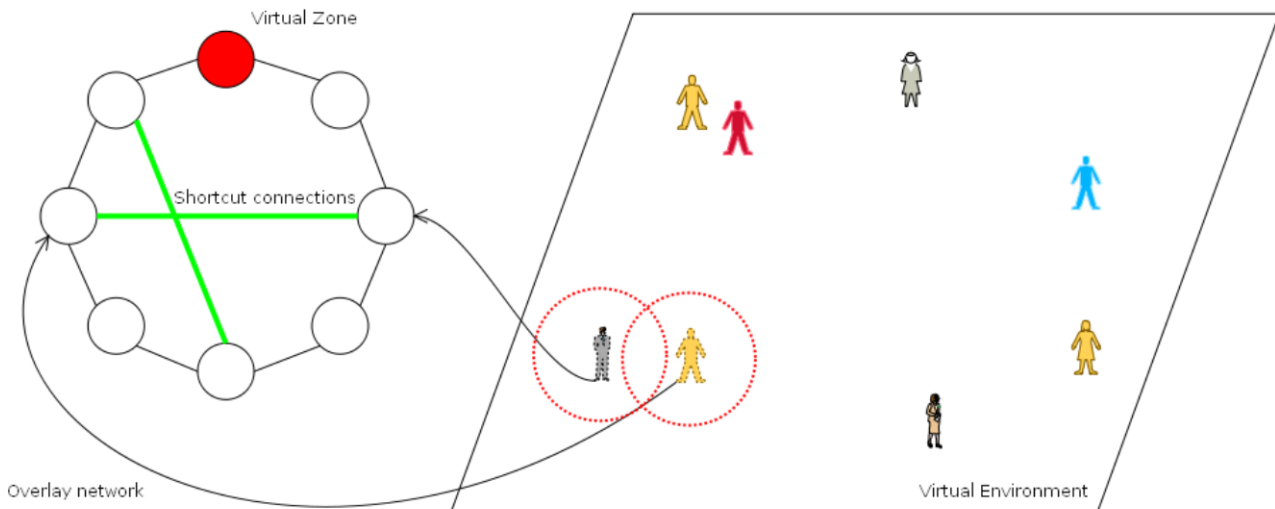


FIGURE 4: RING TOPOLOGY AND SHORTCUT CONNECTIONS

Control of entities in the virtual world is maintained by the "authority" system. Every entity that is created in the virtual world is controlled by exactly one node. This node is the only one that has the ability to send updates to other nodes. In essence, this mechanism distributes the task from a central server, to possibly many different connected machines. Authority over an entity can be transferred from one node to another, or leased by a node for a finite period of time. By default, the node that creates an entity is the authority for that entity. If the entity must persist in the world after a node goes offline, then the authority defaults to the Zone Server.

The authority system allows for the online transferral of processing and bandwidth consumption between nodes on an entity level. This means that load can be balanced dynamically according to the world state. This scheme balances both CPU and bandwidth load.

Authority is the cornerstone of load balancing. If the processing of a particular entity state is too demanding for a node, the node may transfer the authority for that entity to another node with more resources to perform the processing. As such, the Zone is able to delegate processing of world entities to connected clients, effectively sharing the processing load amongst all connected nodes.

The routing of UPDATE messages to the node-cluster is the most important and innovative task of the **vrengine**. The main philosophy is to reduce the required bandwidth usage as much as possible (for both the Zone and the Clients), while maintaining a coherent and up-to-date view of the 3D world at each client. In existing commercial platforms, this routing is mainly done via a server, requiring high-end bandwidth connections for the servers. However, the **vrengine** avoids routing via the Zone as much as possible.

3.4. Definition of a Certified Authentication System, in a Virtual Nation context, capable to guarantee the Identity of the User.

VirtualLife distinguishes itself from other virtual worlds in its approach to identity.

One of the main differentiating factors between VirtualLife and competing existing virtual worlds is the will to implement a strong relationship between the real and virtual identity of an avatar. This is a basic pre-requisite to be able to have a virtual platform where the avatar is responsible for his/her actions in the virtual world just as much as he/she is in the real world. This allows a full legal framework to be built on top of the platform, for example, to allow real-world compliant transactions to occur (see section on Legal Framework, Contracts, Online Dispute Resolution below) and to craft some form of democratic participation within the world deployment.

For this reason, behind any identity in VirtualLife are X.509 compliant certificates. Such a certificate can be issued by a Certification Authority (CA), either an externally trusted one (Verisign etc.) or a dedicated one. The Platform provides, for bootstrapping purposes, an internal CA, that does not verify the information provided during the registration.

Together with an X.509 certificate goes a keypair. The private part of this keypair is usually protected with some mean (related once again to the general policy the platform provider wants to adopt). VirtualLife, by default, protects it with a password. Commercial implementations sometimes rely on dedicated hardware devices. This integration however is beyond the scope of the project, even though it could be easily implemented on a case-by-case basis.

Within the certificate, additional information is stored that is related to the actual person behind an avatar (for example his/her age), whose level of trust is as good as the level-of-trust given to the underlying CA policy. The disclosure of such information is however normally restricted (or explicitly authorized) by the avatar, in order to respect each person's privacy needs. Disclosure of information is currently allowed by default when two avatars are related by a mutual-friendship relation.

The usage of a private key allows for strong encryption of data exchange whenever it is appropriate in the platform business logic.

3.5. Virtual Law System Template covering all aspects of the virtual life

The legal framework implemented in VirtualLife is one of its most innovative features with respect to existing platforms. In VirtualLife actions performed by an avatar can be directly connected with the underlying real-world identity of an individual. As such he/she is as much responsible for his/her actions as he/she is in the real world. Legal framework in VirtualLife is however NOT limited to this duality connection (i.e. avatar <--> real-individual) but is carried on at several levels.

First, there is an end user license agreement between each user of the VirtualLife software and the provider of that software. It contains fundamental principles of VirtualLife that every user has to adhere to irrespective of whether his Virtual Zone belongs to a Virtual Nation or is a stand-alone-zone. This EULA contains rules that cover legal aspects that are relevant for the virtual world VirtualLife and its particularities. These concern the licensing of the VirtualLife Software as well as conditions of EULA amendments, cancellation and termination of the contract, as well as clauses concerning disclaimers and limitations, law and legal notices and contact data of the software provider. Moreover, a code of conduct as part of the VirtualLife "Supreme Constitution" provides guidance on acceptable and unacceptable behaviour, disobedience of which may lead to suspension of the account and/or termination of the end user license agreement. The principle underlying this is that both the user and the software provider shall respect other users and their avatars.

A "Virtual Nation Constitution" forms the second tier of the framework and contains special and more detailed provisions, which only the Avatar of a Virtual Zone that is part of that Virtual Nation has to adhere to. It is being tailored with regard to the purpose of the specific Virtual Nation. The Virtual Nation Constitution has to comply with the basic organisational rules stipulated in the Supreme Constitution. Both license agreements are being implemented by click-wrap agreements.

A VirtualLife Privacy Policy as well as a Virtual Campus Privacy Policy state the policy concerning collecting and processing of personal data in VirtualLife in general respectively provide specific rules for the first virtual nation. The Privacy Policies line out what data is collected from and in and in connection to the user, in particular what data is necessary to run VirtualLife and why additional personal data is collected, as well as how and to which extent a further processing of the data will take place. This is necessary in order to get a valid contractual consent of the user regarding the processing of his personal data within the VirtualLife experience.

Thirdly, the platform provides a set of different sample contracts that the respective parties to a contract may deem relevant for their transaction, though they are still free to use their own contractual terms. Templates of such contracts exist and are aimed to specific avatars' groups in the Nation. These sample contracts are oriented on the educational "Virtual Campus" scenario which was chosen as the most promising field of application for the first Virtual Nation to be created.

The Virtual Campus scenario means that the first Virtual Nation will provide an environment for online education of private universities. The private universities will – like in "real life" – organise and supervise the activities on the Virtual Campus, may employ teachers who hold classes and matriculate students who want to enrol for the courses. Contracts for the employment of teachers and the enrolment of students affect the bi-lateral relationship between the private university and the teacher respectively the student. In this scenario, one thus finds pre-filled templates to be offered to both Professors group and Students group.

Professors targeted contracts will regulate their relationship with the Virtual Campus Administrative Office, while Students targeted contracts will regulate relationship between the Students and the Virtual Campus Administrative Office. As there are too many different situations for any thinkable contract, it is not possible to cover every situation by a legal clause or template beforehand. Templates will contain draft clauses and should be seen as possible options which have to be customized for the specific situation of the avatars/users. The draft clauses cannot directly be legally binding and must be negotiated by the contract parties because they cannot cover every possible sub-case beforehand.

3.6. Virtual Law technical implementation

Within the Nation, laws are also defined via a dedicated constrained language that is able to translate concepts related to copyrights and rights of use over in-world objects to the underlying vrenengine permissions system. These laws are defined in terms of permissions and right-to-change those permission for the in-world entities that each avatar category grants to other avatar categories. In VirtualLife, with respect to the permission system on entities, avatar can belong to one or more of these categories:

- Nation Administrators: the set of avatars that administer a Nation. They are listed in the NationAdministrators group. The addition or removal of avatars within this groups follows the same rules as that of other groups.
- Zone Administrators: the set of avatars that administer a specific Zone. They are listed in the ZoneAdministrators group. Each Zone has its own list of avatar belonging to this group. At the beginning of time, (using the ZoneConfigurator tool) the avatar that registers the Zone to the Nation is also its Owner and the sole (initial) 'participant' and 'admin' of the ZoneAdministrators group. The addition or removal of avatars within this groups follows the same rules as that of other groups.
- Author: this is the avatar that initially created and/or imported an entity in-world. This avatar guid is stored inside the entity description and cannot change with time.
- Owner: this is the avatar that currently owns an entity in-world. This avatar guid is stored inside the entity description and changes in time whenever an entity is either given or sold.
- Group: an avatar can either belong or not to the group that has been assigned to an entity. If he/she actually belongs to it, then this set of permission apply.
- Others: avatars NOT belonging to any of the above categories.

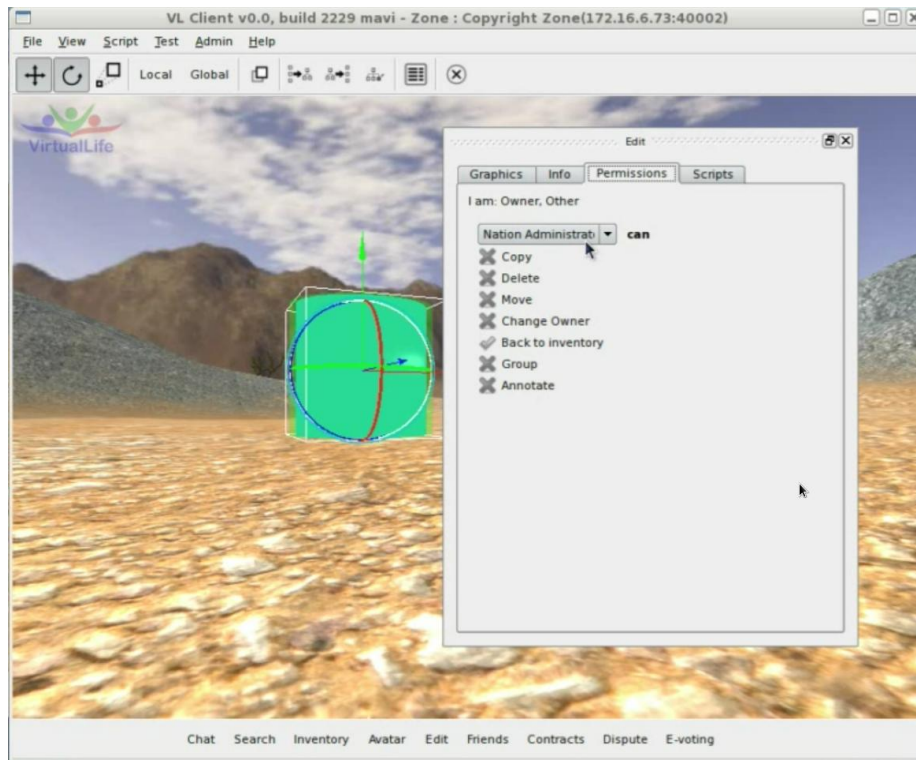


FIGURE 5: PERMISSION SYSTEM GUI.

The default permission set AND the right-to-change it, is defined at Nation level and is propagated down to the Zones at every change. Changes can be performed by Nation Administrators using the dedicated GUI in the Client.

A Nation Administrator's power is tuned within the Nation Laws, allowing for a more fair world to be deployed, i.e. Nation Administrator only needs to be 'primus inter pares' and not necessarily have a superior role.

At Zone Level, a Zone Administrator can further customize (if the Nation has given rights to do so) the default permission table, in such a way that the final set of laws applied in a specific zone is also the result of a multi-level hierarchical process. This customization also takes place via the GUI in the client (this same GUI, if accessed by a normal avatar, allows one to 'see' the currently enforced laws system).

Law enforcement

From a technical point of view the platform has a mixed approach to law enforcement. Some laws are automatically enforced by the system, especially those that somehow regulate a service offered in-world.

Some other laws, on the other hand can be infringed and can provide as a side effect the lowering of the Civic reputation of an avatar. When hitting some limit the avatar could for example be banned from entering the system.

Monitoring activities (being it automatic or performed by dedicated group of avatars) are explicitly allowed and hence accepted by avatars in the Supreme Constitution. Law enforcement on the platform cannot substitute real world enforcement but might enhance it.

E-voting

Avatars can participate to crafting the Virtual Laws for the Nation via a referendum and e-voting mechanisms implemented at the Nation level. E-voting in VirtualLife is extremely simplified and its purpose is to give a taste of how a virtual world could be ruled in a participated fashion. It does not implement the security checks on the voting protocol needed for a full electronic voting system.

All avatars are forwarded a simple question they can accept or not (within a certain time period) related to some existing or new law. Nation collects the result up to the specified time limit. It then counts the votes and notifies avatars about whether the proposed change or new law was accepted or refused. Nation Administrators have to later implement those changes.

Contracts and Online Dispute Resolution System

The lowest tier of legal framework integration in VirtualLife is implemented through Contracts flow management and Online Dispute Resolution.

Avatars within VirtualLife can under-sign contract (of private nature) between each other. VirtualLife offers a framework to handle the filling and e-signing of contracts that relate to services offered by a Nation. The current framework implements the following work-flow that is paradigmatic for several contract categories, and could be easily customized to other needs than the chosen Virtual Campus Scenario. Contracts need not only refer to stuff in-world. VirtualLife allows contracts of any kind to be signed within the platform as long as they pertain to a private-to-private relationship.

Since VirtualLife handles contracts e-signing in-world it also gives avatars the opportunity to resolve possible issues related to them in-world. This is the very reason for implementing an Online Dispute Resolution System directly in the platform. It implements the dispute resolution template and work-flow suggested by the "International Mediation Institute". In a nut-shell, in this flows a mediator is appointed by the parties interested in handling a conflict using this mechanisms. The mediator gathers information, be it private (not disclosed to the other party) or public (known by both parties), and then proposes a settlement for the conflict. If mediation succeeds then a new contract, invalidating the one that raised the conflict, and engaging the parties under new constraints is signed.

3.7. Scripting engine

Having a load-balancing mechanism within VirtualLife scalable world (in terms of 3D world simulation) would be probably useless without a powerful way to enrich the world behaviour toward an increasingly complex and interactive one. This task within VirtualLife is mostly accomplished by the Scripting Engine.

Lua language and its scripting Virtual Machine is the engine that allows interactivity and programming of complex behaviour in VirtualLife. Scripting has been targeted toward programmers, privileging power over ease-of-use.

All the objects within the world are bound to the scripting and can hence be totally controlled by it. Scripts are actually able to perform any action in the world just as if they were done directly from the client by an avatar. Scripts are also able to perform automated behaviour. They can be run either locally (in each machine, for self-consistent graphical effects) or at the "cluster-of-nodes" level. In this case they can be migrated around to improve the total overall load-balancing.

Scripting is a key feature to define complex behaviours in the virtual world. Interactive objects and autonomous agents (that must be integrated into the selected scenarios), rely heavily on it.

VirtualLife integrates a powerful scripting environment that allows to edit, run and control scripts. The programming language offers a complete binding to the VirtualLife core functionality and rich support for the most common programming tasks related to the virtual-world (e.g. 3D vector algebra, events handling, state machines, complex animations, etc.). Scripts can be executed from the command line available in the VirtualLife Client program or can be deployed in the virtual-world and became part of it.

VirtualLife scripts can control and extends the Client GUI, can communicate with each other and with the avatars, can monitor the Zone activities and can interact with the virtual world creating, deleting and modifying entities (note that a single script can create and control many world entities). Differently from other 3D virtual world implementations, a VirtualLife script is not bound to a world entity, but it is itself a world entity, that can persist in a zone, that has metadata (e.g. an owner, a name, a description, etc.) and can be searched and controlled by the avatars. A script-entity can create (among other kind of entities) also other script-entities.

A script acts in the world on behalf of its owner: it has the same privileges and permissions and it is bound by the same constraints.

Scripts can perform complex tasks and can do heavy computations. The system can migrate running scripts across the connected peers in order to balance the workload.

External software components can be bound to VirtualLife through the script binding.

Scripts can be used as a debugging or testing tools, allowing to implement a sort of autopilot that can login into the system and can drive the avatar through a sequence of complex actions.

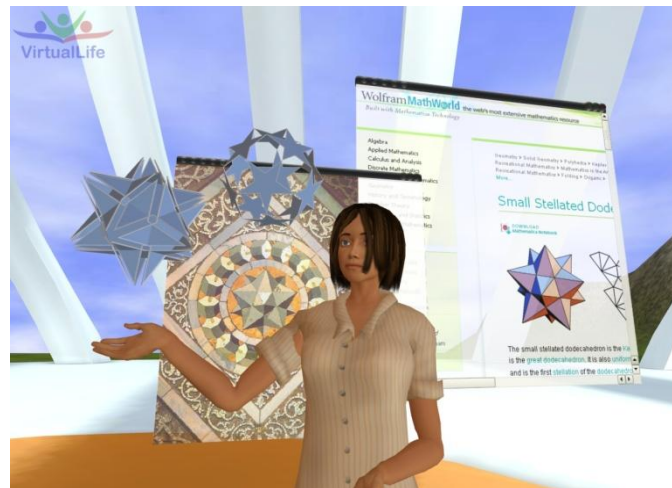


FIGURE 6: SCRIPTING EXAMPLES

Designing an interactive object can be a complex task, comparable to designing a 3D model. This task requires skilled people, that typically know some programming language. VirtualLife provides a comfortable environment to master the scripting: dedicated editor with syntax highlighting and auto-complete suggestions, the script console (to do tests and experiments) and a complete web-based guide, with many complete source examples. It doesn't provide a visual programming environment because developing it would be out of the scope of the VirtualLife project and it is still not clear how effective these tools are. On the other side, the VirtualLife scripting environment is powerful enough to allow the creation of scripts that create other scripts. Therefore it is possible to develop script-based application that allows non-programming people to create specific classes of interactive objects.

The scripting virtual machine runs in a sand-box, to protect the system against poor or malicious scripts. Moreover, each script is given a controlled time slot to run at each frame. If a script is slow and doesn't terminate in that time slot, it is suspended and it will be resumed at the next frame. Therefore a slow script (possibly a wrong or bad script containing an infinite loop) doesn't slow down the node that is running it.

The Scripting Virtual Machine is also the privileged entry point to integrate extra capabilities in the platform by linking it to dedicated (custom) libraries.

3.8. Platform Validation

The main goal of the validation process in Virtual Life is to carry out an evaluation of the platform to determine the appropriateness of the applicative scenarios selected by the Consortium both for validation and exploitation purposes.

Thus, a systematic approach to the Operational Validation has been planned. It applies state-of-the-art validation methods, like the European Operational Concept Validation Methodology, E-OCVM, that can be used for all the various contributions and results of any R&D Projects. E-OCVM methodologies are integrated with User Centred Design approach and techniques, and customised for Information and Communication Technology-oriented projects.

Based on E-OCVM, validation relates both to the identification of the operational needs of the stakeholders and to the establishment of appropriate solutions to the problems and issues identified.

The high-level Validation dimensions that have been taken into account to define the Virtual Life validation process are:

1. *user acceptability*, ease of use and suitability of the system for supporting cognitive task requirements, job satisfaction and acceptability,
2. *domain suitability*, the suitability of the content of information, display representation and system functionalities for the selected applicative domain, its work-practices and internal procedures,
3. *technical usability*, the property of a tool to be effectively used, understood and learnt by the people for which it has been designed, including look&feel aspects of the prototype as well as on the way the users will be requested to interact with it. The key aspects of the technical usability are usability and memorability, efficiency, errors incurrence and look and feel.

Based on these dimensions, a process and plan for validation has been carried out, and three categories of users/validators per each phase of the process have been identified, namely system expert, pool of users, end users.

Specific techniques have been used on the basis of the validation dimension enquired and the type of validator selected.

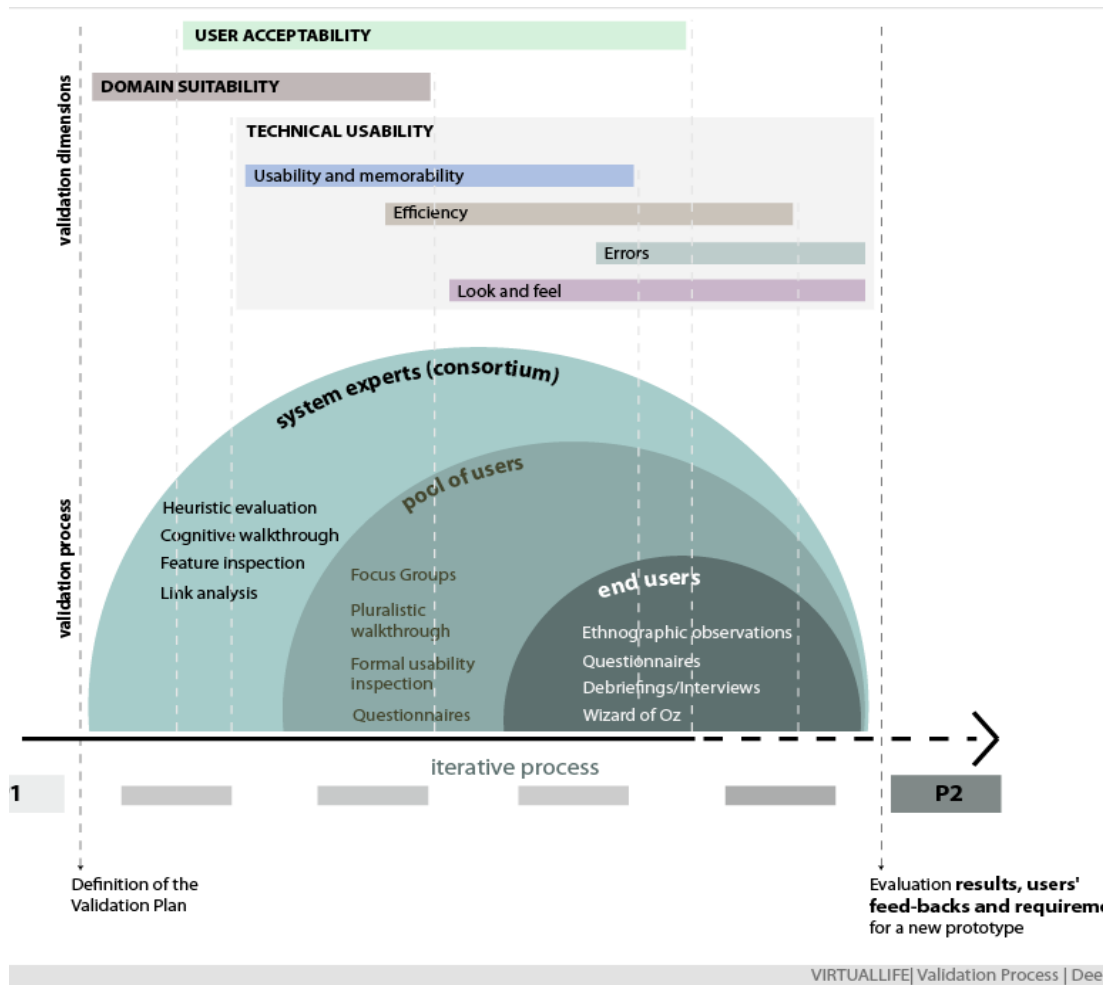


FIGURE 7: THE VALIDATION APPROACH SCHEMA

The validation conclusion demonstrate that VirtualLife offers the architectural support for adoption of the platform, whether in autonomous or assisted usage, in educational and industrial application domains (i.e. Virtual Campus and Street-car).

The validation highlighted some improvements area, in particular with respect to the usability and 3D interaction mode. Notwithstanding this finding, the users in both the domains were able to perform the planned scenarios and the validation exercises.

The innovative aspects of VirtualLife, i.e. the scripting language and tools, the implementation of script migration, load-balancing, peer-to-peer architecture, secure infrastructure provide the users with the needed framework to experiment with operational scenarios.

Domain Suitability has been fulfilled with respect to both Virtual Campus and Street-car. VirtualLife demonstrates to be fully compliant with the requirements provided by the pool of involved users. As for Virtual Campus the platform proved to enhance teachers and students to carry out their duties. In particular the possibility to visualize

complex objects, as well as their exploration; and the persistence of the virtual world, were assessed as valuable features to support the educational scenarios.

VirtualLife also proved to impact the Street-Car domain throughout the validation of the logic layout behind test cases (i.e. validate the logic controller, validate the railway apparatuses and validate the railway physical and logical structure), the definition of an easy-to-edit XML version of the logical layout, and the processing of the XML directly via lua-scripting, hence as user-generated content.

4. Potential impact

The main goal of the VirtualLife distributed architecture is to connect users and resources in a transparent, open, and scalable way. The platform has been designed and developed in order to achieve an high degree of scalability, flexibility, speed, capacity, ease of use and cost thanks to the decentralization obtained using a peer-to-peer environment.

The principal outcomes of the project, with particular attention to the innovative p2p physical engine, the user-friendly scripting language, the security protocol p2p infrastructure, the technical specification template for a Virtual Nation, are designed so as to allow a redistribution of the modules or a replication of the obtained results in a commercial vision.

The VirtualLife platform contains an innovative and strong authentication method, designed with the aim to protect part of the Virtual World against illegal intrusions and to identify and authorize legal transactions. The outcome on the trustiness of the new network infrastructure is easily understandable and can pave the way to e-business and e-government applications.

The main business models under which the consortium will take advantage of the entire platform is the delivery of customized applications. In particular below the most promising exploitation scenarios that the consortium identified are described:

Educational scenarios

The VirtualLife legal framework allow the subscription of private contracts among two parties. This aspect can be exploited in an educational scenario, that comprises education, training, teaching, academic courses, school etc. provided that the parties are private organizations/people.

In this scenario, different actors can be identified taking advantages by this technology:

- private universities that have the need of renovating and improving their offer delivering new courses through innovative media and using new technologies;
- at present, publishers have the need of renovating and improving their catalogue offering innovative media that go in parallel with their paper publications;
- distance learning could take a real advantage from virtual world platforms both in terms of administrative management and student engagement
- the system is easy to use and quite immediate; however, the generation of enriched contents requires the involvement of skilled people (e.g. 3D contents developers) to obtain contents usable in lessons by the teacher.

Private Universities could take advantages from the following issues:

1. an innovative way of delivering courses and managing them
2. a flexible platform that can be branded and customized
3. a legal framework to handle virtual contracts with employees and customers
4. a P2P infrastructure to ensure an expandable low cost virtual world and handle high traffic levels at reduced costs

VirtualLife could offer the publishers the following advantages:

1. innovative contents attached to traditional books
2. a flexible and secure platform that can be branded and customized
3. 3d contents that can be also easily re-used within traditional web or paper contexts
4. a legal framework to handle virtual contracts with employees and customers
5. a p2p infrastructure to handle high traffic levels at reduced costs
6. a customizable platform in which publishers can exploit new business opportunities and business models (just an example: universities, institution, schools, colleges, educational training centres sign partnerships with publishers, the idea is that the publisher gives them a nation that is customised with the publisher brand and in return universities could adopt the publishers' text books and credentials for students)

Industrial Scenario

In a B2B perspective, the platform can be used as testing framework for prototyping of systems and/or services. As an example, VirtualLife can act as a frontend to visualize the effect of controlling apparatuses that have impact on real world (e.g.: in the field of railway or streetcar design, it can test routes, itineraries and emulated apparatuses).

During the whole duration of the project, a large number of dissemination activities have been carried out in order to receive feedbacks from both the market and research communities. The VirtualLife Consortium attended twenty eight conferences worldwide.

Up to the end of the project, more than thirty publications have been written:

- 6 articles with DOI
- 12 papers
- 2 technical reports

- 9 master/bachelor theses
- 1 paper in a blog.

The publications were focused on the more innovative aspects of VirtualLife, that are the peer-to-peer technology application and the legal framework.

Number of stakeholders to whom a presentation of the project was delivered (in presence and/or via mail) during the 3,5 years of the project

Type of contact	Total number
PRIVATE UNIVERSITY, CONSORTIUM AND INSTITUTIONS...	47*
ACADEMICS/UNIVERSITIES/RESEARCHERS AND OTHER PROJECTS	27
COMPANIES AND INDUSTRY PLAYERS	49
PUBLISHERS AND TRAINING COMPANIES	13
PUBLIC BODIES, INSTITUTIONS AND PA	7
INDEPENDENT	22
TOTAL	165

Furthermore, VirtualLife consortium organized TrustVWs 2009 "Virtual Worlds: Trust, Security, Rule of Law" workshop within the 1st International ICST Conference on User Centric Media UCMedia 2009, Venice, Italy, 9 December 2009, (see <http://www.usercentricmedia.org/workshops/trustvws2009/>).

Within VirtualLife, two main events have been managed in order to spread the information and to receive feedbacks from possible stakeholders, the First VirtualLife Workshop (July 2010) and the VirtualLife Launch event (July 2011)

First VirtualLife Workshop

On Tuesday, July, 20th, 2010 the First VirtualLife Workshop took place in Rome – Italy. The workshop was attended both by the VirtualLife Consortium and external stakeholders.

The main objective of the workshop was that of having inputs about possible applications for the platform. Concrete ideas that can become opportunities not only for the consortium, but especially for the stakeholders; the aim was not that of selling the platform, but that of nurturing the participants interest towards it, and let them

brainstorm and thinking about concrete and useful projects and commercial application to be developed with it.

The participants were people coming from industry, education, commerce and university experiences.

VirtualLife Launch event

The participation has been encouraging and the event has given the opportunity to build a network environment of potential stakeholders.

During the morning session the Consortium presented a detailed overview of VirtualLife Platform, highlighting the most promising project results and applicative domains.

At the end of each presentation there was room for questions or comments. With regard to the legal framework, the audience demonstrated to be particularly interested in the dispute resolution system and especially in the role of the moderator, but also in issues such as reputation (the concept of social, economic and civic reputation was thus described in detail) and avatar migration from a nation to another.

Concerning scripting language and interactivity, the 3d interactive slides directly within VirtualLife were quite impressive and arose questions about the possibility of easily preparing customized presentation starting from a set of predefined functions. The consortium also stressed the fact that the scripting language (LUA) was chosen not for its easy usability but for the fact that it's extremely versatile and powerful. The peer-to-peer approach was really appreciated, especially by players from the field of education.

SECTION 2: USE AND DISSEMINATION OF FOREGROUND

1. VirtualLife: list of scientific publications

LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers	open access
Articles with DOI										
1	VirtualLife: Secure identity management in peer-to-peer systems	D. Bogdanov, I. Livenson	Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, LNICST. P. Daras, O. Mayora (eds.) Proceedings of the 1st International ICST Conference on User Centric Media, UCMedia 2009, Venice, 9-11 December 2009	Vol. 40, 2010	Springer	Berlin Heidelberg	2010	pp. 181-188	http://dx.doi.org/10.1007/978-3-642-12630-7_21	no
2	Overview of the legal issues in virtual worlds	G. Spindler, K. Anton, J. Wehage	LNICST - " -	Vol. 40, 2010	Springer	Berlin Heidelberg	2010	pp. 189-198	http://dx.doi.org/10.1007/978-3-642-12630-7_22	no
3	A comparison of three virtual world platforms for the purposes of learning support in VirtualLife	K. Lapin	LNICST - " -	Vol. 40, 2010	Springer	Berlin Heidelberg	2010	pp. 273-278	http://dx.doi.org/10.1007/978-3-642-12630-7_33	no
4	Transforming legal rules into online virtual world rules: a case study in the VirtualLife platform	V. Cyras	LNICST - " -	Vol. 40, 2010	Springer	Berlin Heidelberg	2010	pp. 279-284	http://dx.doi.org/10.1007/978-3-642-12630-7_34	no

LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers	open access
5	Virtuelle Markenpiraterie – Der Schutz realer Marken in virtuellen Welten	A. Prill	H. Große Ruse-Khan, N. Klass, S. von Lewinski (eds). Nutzergenerierte Inhalte als Gegenstand des Privatrechts – Aktuelle Probleme des Web 2.0. MPI Studies on Intellectual Property, Competition and Tax Law	Vol. 15, 2010	Springer	Berlin Heidelberg	2010	pp. 207-239	http://dx.doi.org/10.1007/978-3-642-12411-2_8	no
6	Learning support and legally ruled collaboration in the VirtualLife virtual world platform	V. Cyras, K. Lapin	Lecture Notes in Computer Science, LNCS. J. Grundspenkis et al. (eds.) Advances in Databases and Information Systems. Associated Workshops and Doctoral Consortium of the 13th East European Conference, ADBIS 2009, Riga, Latvia, September 7-10, 2009. Revised Selected Papers	Vol. 5968, 2010	Springer	Berlin Heidelberg	2010	pp. 47-54	http://dx.doi.org/10.1007/978-3-642-12082-4_7	no
7	Virtual reality models for the preservation of the Unesco historical and artistic heritage	R. Menghi, G. Maino, M. Panebarco	Lecture Notes in Computer Science, LNCS. G. Maino, G.L. Foresti (eds.) Image Analysis and Processing – ICIAP 2011, 16th International Conference, Ravenna, Italy, September 14-16, 2011, Proceedings, Part II. ISBN 978-3-642-24087-4	Vol. 6979, 2011	Springer	Berlin Heidelberg	2011	pp. 475-485	http://dx.doi.org/10.1007/978-3-642-24088-1_49	no
Peer reviewed journals										
8	Der Schutz virtueller Gegenstände	G. Spindler	Zeitschrift fuer Geistiges Eigentum / Intellectual Property Journal, ISSN 1867-237x	Vol. 3, No. 2, June 2011	Mohr Siebeck Verlag	Tübingen	2011	pp. 129-150	http://www.ingentaconnect.com/content/mohr/zge/2011/00000003/000002/art00001 , http://www.mohr.de/en/journals/law/zeitschrift-fuer-geistiges-eigentum-zge/journal.html	no

LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers	open access
9	Technical rules and legal rules in online virtual world	V. Cyras, F. Lachmayer	European Journal of Law and Technology, vol. 1, no. 3, 2010.	Vol. 1, no. 3, 2010	School of Law Queen's University of Belfast	Belfast	2010	pp. 1-26	http://ejlt.org/article/view/27	yes
10	Datenschutz in Sozialen Netzwerken	U. Schröder	Computer und Recht	No. 5	Verlag Dr. Otto Schmidt	Köln, Germany	2010	p. R54	http://www.computerundrecht.de/	no
Articles in books, journals and conference proceedings										
11	Der Schutz virtueller Gegenstände [Protection of virtual artefacts]	G. Spindler	S. Leible et al. (eds.) Unkörperliche Güter im Zivilrecht [Incorporeal objects in civil law] [in German], ISBN 978-3-16-150784-7	-	Mohr Siebeck Verlag	Tübingen	2011	pp. ?-?	http://www.mohr.de/en/law/new-books/buch/unkoerperliche-gueter-im-zivilrecht.html	
12	From norms to obligations revisited: a case of three-dimensional virtual worlds	V. Cyras, F. Lachmayer	A. Geist et al. (eds.) Strukturierung der Juristischen Semantik. Structuring Legal Semantics. Festschrift für Erich Schweighofer. ISBN 978-3-905742-80-0	-	Editions Weblaw	Bern	2011	pp. 213-234	http://www.weblaw.ch/blug/iframe.php?2011/02/	no

LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers	open access
13	Distributive multimedia and multisensory legal machines	V. Cyras, F. Lachmayer	Schweighofer E. & Kummer F. (eds.) Europäische Projektkultur als Beitrag zur Rationalisierung des Rechts, Tagungsband des 14. Internationalen Rechtsinformatik Symposions IRIS 2011. ISBN 978-3-85403-278-6	-	Österreichische Computer Gesellschaft	Wien	2011	pp. 521-528	http://www.ict-virtuallife.eu/public/20110125-IRIS-Cyras-Lachmayer.pdf	no
14	Usability heuristics for virtual worlds	V. Butkute, K. Lapin	A. Targamadze et al. (eds.) Proceedings of the 16th International Conference on Information and Software Technologies, IT 2010, Kaunas, Lithuania. ISSN 2029-0020	-	Technologija	Kaunas, Lithuania	2010	pp. 285-291	http://isd.ktu.lt/it2010/material/Proceedings/6_I TA_2.pdf	yes
15	Transforming legal rules into virtual world rules: a case study in the VirtualLife platform	V. Cyras, K. Glass, F. Zuliani	E. Schweighofer et al. (eds.) Globale Sicherheit und proaktiver Staat – Die Rolle der Rechtsinformatik. IRIS 2010. ISBN 978-3-85403-259-5	-	Österreichische Computer Gesellschaft	Wien	2010	pp. 579-586	http://www.ict-virtuallife.eu/public/IRIS2010/IRIS2010-Cyras-Glass-Zuliani-20100119.pdf	no
16	VirtualLife virtual world platform: peer-to-peer, security and rule of law	D. Bogdanov et.al.	eBook Proceedings of 2009 NEM Summit Towards Future Media Internet, Saint-Malo. ISBN 978-3-00-028953-8	-	Eurescom GmbH	Germany	2009	pp. 124-129	http://www.ict-virtuallife.eu/public/NEM_Summit2009_ebook_VirtualLife_paper.pdf	no
17	User needs and legally ruled collaboration in the VirtualLife virtual world platform	V. Cyras, K. Lapin	Methods of Artificial Intelligence. T. Burczyński et al. (eds.). ISBN 83-60759-15-4	-	AI-METH series	Gliwice, Poland	2009	pp. 69-76	http://www.ict-virtuallife.eu/public/AIM_ETH_paper.pdf	no

LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers	open access
Technical reports										
18	A model for automatically evaluating trust in X.509 certificates	A. S. Ahmed, D. Bogdanov		T-4-11	Cybernetica	Tallinn, Estonia	2010	18 pages	http://research.cyber.ee/reports/T-4-11-A-Model-for-Automatically-Evaluating-Trust-in-X509-Certificates.pdf	yes
19	Kademlia-based distributed hash tables implementation for VirtualLife	J. Ristioja		T-4-7	Cybernetica	Tallinn, Estonia	2009	17 pages	http://research.cyber.ee/reports/T-4-7-Kademlia-based-distributed-hash-tables-implementation-for-VirtualLife.pdf	yes
20	On a legal framework in a virtual world platform: lessons from the VirtualLife project	V. Cyras	WWW blog VoxPopuLI		Legal Information Institute at Cornell University Law School	USA	2011	9 pages	http://blog.law.cornell.edu/voxpath/2011/03/01/on-a-legal-framework-in-a-virtual-world-lessons-from-the-virtuallife-project/	yes
Bachelor and master theses										
21	Educational scenarios in MMORPGs and VirtualLife environment	V. Kaziukonyte	Bachelor thesis		Vilnius University	Lithuania	2011			yes

LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers	open access
22	Learning implementation in MMORPGs and VirtualLife virtual world	J. Klikna	Bachelor thesis		Vilnius University	Lithuania	2011			yes
23	Educational scenarios in Second Life and VirtualLife environment	J. Pergizaite	Bachelor thesis		Vilnius University	Lithuania	2011			yes
24	Learning implementation in 3D virtual environments using Lua	D. Stungys	Bachelor thesis		Vilnius University	Lithuania	2011			yes
25	Learning in three dimensional virtual worlds	P. Valintelis	Bachelor thesis		Vilnius University	Lithuania	2011			yes
26	The protection of historic and artistic heritage of UNESCO. Virtual reality models	R. Menghi	Master thesis		University of Bologna, Ravenna Campus	Italy	2011			yes

LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers	open access
27	Analysis of online communication and collaboration tools	V. Butkute	Master thesis		Vilnius University	Lithuania	2010		http://www.ict-virtuallife.eu/public/Magistro_baigiamasis_darbas_Viktorija%20Butkute.pdf	yes
28	Using 3D virtual worlds and platforms for educational purposes	V. Belousas	Bachelor thesis		Vilnius University	Lithuania	2010		http://www.ict-virtuallife.eu/public/Bakalaurinis%20v1.1%20-%20Jurijus%20Belousas.pdf	yes
29	VirtualLife security infrastructure	I. Livenson	Master thesis		University of Tartu	Estonia	2009		http://www.cyber.ee/home/publications/20-masters-and-doctoral-thesis/phd-master-thesis/ilja-msc.pdf/at_download/file	yes
Contribution to European Commission white papers										
30	User Centric Future Media Internet	I. Laso-Ballesteros, P. Daras			Networked Media Unit, DG Information Society and Media, EC	Brussels, Belgium	September 2008	46 pages	ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/netmedia/ucm-white-paper_en.pdf	yes

LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers	open access
31	User Centric Media in the Future Internet	I. Laso-Ballesteros, P. Daras			Networked Media Unit, DG Information Society and Media, EC	Brussels, Belgium	November 2009	31 pages	ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/netmedia/200911-user-centric-media_en.pdf	yes

2. VirtualLife: exploitable foreground

2.1. Definition of VirtualLife Exploitation Strategy

The analysis of the competitors, let us define and refine the most innovative and strong features of VirtualLife, which are: peer-to-peer architecture, secure communication infrastructure, legal framework, expandable scripting language.

VirtualLife is an experimental and innovative framework containing advanced tools and options for creating virtual world applications. VirtualLife is not a virtual world, nor a stand-alone application, it is a scalable and customizable platform containing some basic modules and based on some fundamental innovative pillars (peer-to-peer architecture, secure communication infrastructure, legal framework, expandable scripting language); additional modules can be built on top of it on demand.

Being a framework, the possible scenarios in which to deploy VirtualLife are endless, nevertheless VirtualLife Consortium focused the attention on a narrow but well defined set of targets and build specific business models on top of them. Thus it is to be underlined that the object of our exploitation plan are concrete and very well defined projects for specific targets and that projects are and will be mainly built and customized with the help of the target/customer.

The present document briefly describes them (please refer to D11.4 for a much more exhaustive description).

The four chosen macro-scenarios are:

- Education (Publishers and Virtual Campus)
- Industrial Simulation (Street-car)
- Cultural Heritage Promotion (Bologna University)
- E-commerce (Expo2015)

2.2. Exploitable Foreground

The table below highlights the main identified exploitable modules of VirtualLife.

Item 1: VirtualLife Legal Framework

This is one of the pillar of VirtualLife platform. The framework allows the user and/or the administrator of the virtual system to: create/change virtual laws, customize contracts, manage disputes and conflicts, manage user reputation. The framework has

been created specifically to be used within VL platform, but with a light extra effort, it could be also adapted to other online systems. The concept and the mechanism at the basis of it can be useful for virtual worlds or collaborative online applications in general (i.e. Moodle)

Item 2: VirtualLife Net and VirtualLife Sec. Libraries

These “modules” are at the basis of the legal framework, as they allow to ensure user identification and correspondence between real and virtual identity. Moreover they allow encrypted communication and secure transactions among users. The modules are actually used by Cybernetica within other proprietary applications.

Item 3: 3d Object Editor and manipulation tools

The powerful object editor is an interesting key features of VirtualLife platform. Its flexibility makes it possible to build complex working machinery, industrial systems and interactive lessons. At present 3 partners of the consortium (Digital Video, Nergal and Panebarco) are developing a streetcar signaling system for a targeted customer who will use it within presentations of its products and services. Moreover the system has been taken into account for effective presentations and interactive lessons.

Item 4: VirtualLife System

VirtualLife as a system has been taken into account within an already running EU-funded projects dealing with preservation of Cultural Heritage. The relevance of using VirtualLife platform in this specific project lies in the fact that it can ensure a secure communication p2p virtual platform for preservation, promotional and evaluation purposes. Further effort will be required especially addressing the needs of the primary target of the system, Unesco. The system developed within this research project could have a positive impact for the whole consortium, as it could lead to the creation of a working system devoted to cultural heritage promotion in general.

SECTION 3: VIRTUALLIFE CONTACTS AND PROMOTION

Project website can be found at <http://www.ict-virtuallife.eu>



FIGURE 8: PROJECT LOGO

A YouTube channel has been published at the following url:

<http://www.youtube.com/user/VirtualLifeICT>

A video demonstration can be found at

<http://www.youtube.com/watch?v=rXCia1XsoiE>

The VirtualLife Overview Sheet can be found at the following url:

http://www.ict-virtuallife.eu/public/Launch_event/VirtualLife_overview.pdf

Contacts Details:

Maria Vittoria Crispino *Project Coordinator*

Nergal Srl

Email: mariavittoria.crispino@nergal.it

Francesco Zuliani *Technical Director*

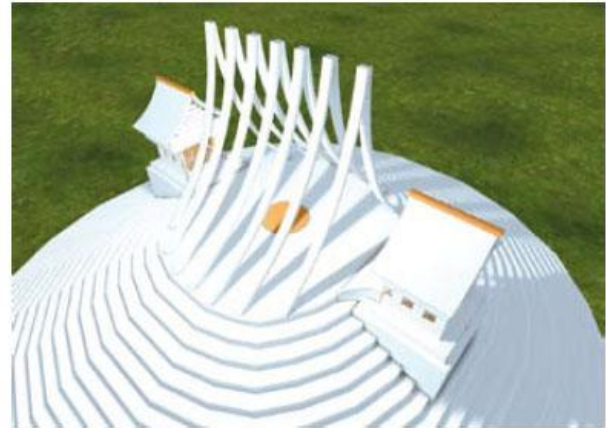
Nergal Srl

Email: francesco.zuliani@nergal.it

Marianna Panebarco *Exploitation Manager*

Panebarco S.A.S

Email: marianna@panebarco.it



**VIRTUALLIFE:
THE EVOLUTION OF 3D VIRTUAL WORLDS.**

VirtualLife combines a virtual legal system, a strong security infrastructure and a scalable peer-to-peer architecture, to provide a secure, massively multiuser and cross-platform 3D environment suitable for education, e-commerce, business and entertainment.



VirtualLife Project Coordinator:

Maria Vittoria Crispino
Nergal S.r.l.
Rome - Italy
mariavittoria.crispino@nergal.it

Exploitation Manager:

Marianna Panebarco
Panebarco & C. Sas
Ravenna - Italy
marianna@panebarco.it

THE EVOLUTION OF 3D VIRTUAL WORLDS

www.ict-virtuallife.eu

FIGURE 9: BROCHURE – FIRST PAGE

VirtualLife is a project co-funded by the European Commission within the Seventh Framework Programme – ICT – NETWORKED MEDIA. It aims at developing a virtual world platform mainly focusing on security, democracy and collaborative aspects.

A VIRTUAL LEGAL FRAMEWORK TO ENSURE DEMOCRACY AND JUSTICE

VirtualLife contains a legal framework consisting of a Supreme Constitution, a Virtual Nation Constitution and sample contracts. Moreover the system provides an in-world dispute resolution mechanism, and a voting system.



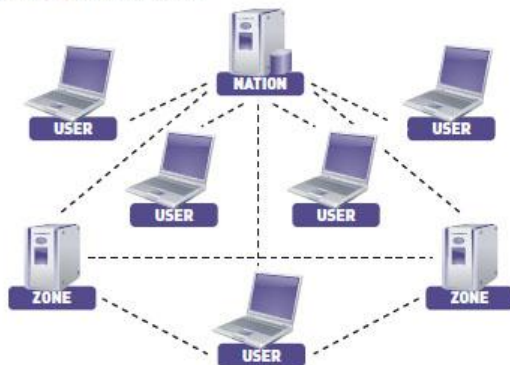
A SECURE INFRASTRUCTURE TO ENSURE COMMUNICATION AND TRANSACTIONS

VirtualLife provides strong security for its users. Each avatar has an identity card that contains information about both the virtual identity and identity of the real life user controlling the avatar.

Moreover the system makes use of the well known PKI (Public Key Infrastructure) to enforce trust, privacy, security and non-repudiation, in fact, the use of a keypair allows the user to prove ones identity to other users, ensure private encrypted communication, and digitally sign documents.

A P2P SYSTEM ARCHITECTURE INSTEAD OF A STANDARD SERVER-CENTRIC STRUCTURE

An hybrid peer-to-peer system architecture provides load-balancing, modularity and scalability, while security, integrity and persistency are autonomously handled by each node.



TOOLS AND SCRIPTING FOR AN INTERACTIVE AND COLLABORATIVE PLATFORM

The VirtualLife platform allows a high level of interaction between avatars and between avatars and objects in the 3D environment; it contains ready-made virtual tools and also permits the creation of new tools using an internal editor or importing them. In particular, a powerful and intuitive scripting language allows for the creation of complex interactive tools.

FIGURE 10: BROCHURE – SECOND PAGE

For any contact need, the list of Beneficiaries is below.

no.	Beneficiary name	Contact Person	email	Country
1 (Coordinator)	Nergal S.r.l.	Maria Vittoria Crispino Francesco Zuliani	mariavittoria.crispino@nergal.it francesco.zuliani@nergal.it	Italy
2	Cybernetica AS	Dan Bogdanov	dan.bogdanov@cyber.ee	Estonia
3	Digital Video S.p.A.	GianMarco Todesco	todesco@toonz.com	Italy
4	Geumacs	Anca Covaci	geumacs@gmail.com	Romania
5	Mathematics and Informatics Faculty Vilnius University	Vytautas Cyras	vytautas.cyras@mif.vu.lt	Lithuania
6	Panebarco S.a.s.	Marianna Panebarco	marianna@panebarco.it	Italy
7	TAVAE	Philippe Villain	p.villain@tavae.com	France
8	Universität Göttingen	Gerald Spindler	lehrstuhl.spindler@jura.uni-goettingen.de	Germany
9	Virtual Italian Parks	Bruno Cerboni	bruno.cerboni@virtualitalianparks.com	Italy
10	Deep Blue Srl	Valentino Meduri	valentino.meduri@dblue.it	Italy