A multi-protocol framework for the development of collaborative virtual environments

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Abstract—Collaborative virtual environments (CVEs) are used for collaboration and interaction of possibly many participants that may be spread over large distances. Both commercial and freely available CVEs exist today. Currently, CVEs are used already in a variety of different fields: gaming, business, education, social communication, and cooperative development. In this paper, a general framework is proposed for the development of a cooperative environment which is able to exploit a multi protocol network infrastructure. The framework offers support to concerns such as communication security and inter-protocol interoperability and let software engineers to focus on the specific business of the CVE under development. To show the framework effectiveness we consider, as a case of study, the design of a reusable software layer for the development of distributed card games built on top of it. This layer is, in turn, used for the implementation of a specific card game.

I. INTRODUCTION

A collaborative virtual environment (CVE) is a space where several people, often spread over different locations, interact with each other. The aim of these people is to share ideas and experiences in a cooperative setting - hence the name [11]. Recently, the term “Web 3.0” has been introduced to refer to the future aspects of the Web; some groups think that the Semantic Web will play the role of the main new technology in this context, while others consider CVEs as the most important advancement of the Web [2].

Both commercial and freely available CVEs exist today. These systems are used in a variety of different fields such as gaming, business, education and cooperative development. A number of companies have started exploiting CVEs, like the prominent Second Life [3], for business purposes. Second Life has also been used in the educational field; on-line lectures have been given and pedagogical usefulness of this novel medium has been investigated by a considerable number of colleges and educational researchers [4]. One of the most famous application area for 3D CVEs is gaming. Even older games like Doom [5] can be considered as an early form of CVE.

This paper proposes a general framework for the development of cooperative virtual environments which exploits a multi protocol network infrastructure. The framework offers support to concerns such as communication security and inter-protocol interoperability and let software engineers to focus on the specific business of the CVE under development. The framework was designed to build applications independent from the communication technology, which means that it is possible to seamlessly add new communication protocols, as new features, without affecting the remaining code. For instance, an existing application, featuring only Bluetooth technology, can be integrated with Wi-Fi technology in a transparent way. Moreover, as stated early, users can join the environment by using different technologies. To show the framework effectiveness we consider, as a case of study, the design of reusable software layer for the development of distributed card games. This layer is, in turn, used for the implementation of a specific card game, i.e. the Italian card game named Tressette [6].

A deep study was conducted to guarantee a high degree of reusability, therefore a great number of card games can be developed, such as Poker, Blackjack, Spades, Uno, etc., and the same card game can be easily deployed on different platforms.

The rest of the paper is organized as follows. Section II briefly surveys the related work. Section III presents the framework design. Section IV describes the case study. Section V concludes the paper and outlines some possible future work.

II. RELATED WORK

Collaborative virtual environments, also referred to as collaborative workspaces (CW) or networked virtual environments (NVE or NVE-VE), have been around since the late 80s. The key areas and methodologies regarding the most pioneering CVE systems from 1987 to 2003 are discussed in [7]. There exists a variety of application domains for CVE systems such as gaming, business and education.

A virtual environment enabling physics experiments to be cooperatively accessible via Internet, named iLabs, has been proposed in [8]. The objective of iLabs is to let students and educators work together in a collaborative way by using a three dimensional CVE, in the field of physics education. Virtual reality (VR) technologies have been exploited in [9] to achieve a Collaborative Learning Environment with Virtual Reality (CLEV-R) as a sort of VR campus where students go to learn, socialize and collaborate on-line. This research also investigates the use of mobile systems for e-learning.
The use of CVEs for implementing a novel business modeling approach is described in [10] where the authors provide a complete and usable environment for collaborative (re-)design of business processes by extending a number of 3-D tools.

A study on whether virtual worlds such as Second Life and World of Warcraft (a well-known MMORPG developed by Blizzard Entertainment) can offer a basis for trade (B2C and C2C e-commerce) and whether credible studies of e-collaboration behavior and related outcomes can be performed on them has been conducted in [11].

As stated in the previous section, to test the effectiveness of the framework proposed in this paper, a reusable software layer for the development of distributed card games was realized and a specific card game was developed on top of it. Many open source projects regarding the development of a framework to build card games can be found on the web. AJAX Cards [12] is a framework for the development of single-player card games on the web by using HTML, CSS and JavaScript. Future plans involves the inclusion of AJAX support for multiplayer games. The Lua card game framework [13] provides a web page in which it is possible to develop multiplayer card games by uploading images for cards and scripts, written in the Lua programming language [14], to describe the rules of the game. None of the above referenced frameworks takes contemporaneously into account multiplatform deployment, heterogeneous communication technologies and security, which are instead the benefits inherited by using our framework for CVE development.

III. FRAMEWORK DESIGN

This section explains in details the framework designed to provide basic tools to build collaborative virtual environment. The basic building block of an environment is the Room entity, which represents the cooperation space on the side of each participant. Such entities interact among them by means of communication channels achieved by exploiting specific abstractions that hide modules which handle the needed communication technologies. A typical scenario, the framework is able to support, is shown in Fig. 1 where different types of devices interact among them by using different communication media.

The design of the framework has been carried out by taking into account the following aspects:

- the evaluation of technologies suitable to achieve a portable software;
- the definition of a software architecture whose modules are as decoupled as possible in order to guarantee a high degree of reusability, and which is able to support the deployment of domain-specific collaborative applications in a distributed environment;
- the achievement of a multiprotocol network infrastructure able to shield clients from details about communication technologies;
- the choice and analysis of a domain-specific application as a case of study in order to assess the framework effectiveness.

For the last point, we realized a reusable software layer, for the development of distributed card games, built on top of the framework. Many card games were analyzed to identify the most significant and generic entities and operations. Subsequently, proper abstractions were defined to build a common basis for the development of concrete card games.

The resulting architecture, shown in Fig. 2, is composed of 3-layers:

- application clients
- domain-specific API
- cooperative multi-protocol framework.

The next subsections explains the study performed for this work, the solutions adopted in order to build the mentioned layers and the way they were decoupled.

A. Communication

One of the main goals of this work was to design a framework which is able to provide a set of features suitable for the development of a multi-protocol network infrastructure.

The framework supports multiple architectural patterns for distributed communication such as peer to peer (P2P) and...
client/server. In this paper, the devices which host the component in charge of the data elaboration will be referred to, by abuse of terminology, as servers while the others as clients.

Two distinct hierarchies were designed to handle all the aspects regarding the communication between devices. The highest level abstractions of the mentioned hierarchies are represented by the following two interfaces: ServerCommunicator and Communicator.

The first interface provides services thought to create a communication channel while the second one deals with the handling of the connection. Only these two interfaces are accessible from client code, the implementations of the concrete classes cannot be seen. The design pattern Factory [15] has been used in order to create concrete instances. This allows the entities which need to communicate with a remote object to transparently use different communication protocols just by resorting to the suitable concrete factory object.

1) Devices scanning: To join a virtual environment, advertising and discovering operations are needed. Two interfaces, Discoverer and Advertiser, were respectively devised in order to let a player search for an existing environment or create a new one.

To build a multi-protocol network infrastructure, different implementations of these two interfaces can be exploited. For instance, if an application provides Bluetooth and Wi-Fi connection, a user could advertise the cooperation environment, he previously created, by using both Wi-Fi-based and Bluetooth-based implementations of the Advertiser interface, simultaneously. On the other hand, a user that wants to join an environment will use only the needed implementation of Discoverer. During the registration phase the server creates a channel with each client based on the chosen communication technology. These details are hidden by the ServerCommunicator and Communicator interfaces so there is no need to concern with these aspects during the development of the domain-specific cooperation logic.

B. The environment

This section describes the modules designed to build the environment in which the cooperation takes place. Specifically, the Room entity has been devised in order to achieve such a goal. It is in charge of handling basic operations such as participants’ registration, opening and closing of the cooperative sessions and provides services which let a participant to join the environment, send and receive data. To account of the participant role, the following specific interfaces were defined: ServerRoom and ClientRoom. Room data are hosted on the side of the participant playing the server role, so it is necessary to make them remotely accessible to the other participants. The Remote Proxy design pattern offers a solution to this problem by hiding communication details and making data to appear as they were locally available. Actually, the goal of the Remote Proxy pattern is to give a local representation for an object that lives in a different address space [15].

The proxy entity implements the ClientRoom interface on the client device while on the server a skeleton entity is created. The hierarchies previously introduced are exploited to obtain a modular separation that leads to a system which can be naturally evolvable, i.e. it is possible to easily integrate new communication technologies without requiring modification of the existing code.

C. The client applications

One of the framework requirements is the capability of binding any client application to the cooperative environment built on top of it, regardless of the application nature. This decoupling has been obtained by resorting to the Observer pattern [15]. The object representing the cooperation room, maintains the reference to a list of observers whose aim is to receive notification data about the status of the environment and update the respective client application. For instance let us suppose there are four participants A, B, C and D. With reference to Fig. [1], A uses an Android app on a mobile phone connected, via bluetooth, to B, which also uses an Android app
and is in turn connected, via Wi-Fi to a LAN. C is a desktop client connected to same LAN and D a web application which runs over the Internet and it is reachable from the LAN through a router. Each of these applications has to register itself as observer of the room and be able to properly handle data received from the environment.

D. Session handling

While a cooperation session is active, it may happen that a user disconnects, e.g. because a connection problem or because he needs to temporarily leave. During the registration phase, the host, into which the room resides, generates a token for each participant. This token is used to handle the session according to an application specific policy.

For example in a game environment, these disconnection events could last for few seconds, thereby if they are handled properly it is possible to avoid ending the game in unexpected way. When a player leaves temporarily a game, he can rejoin the environment by using the token previously obtained. The main benefit of the use of the tokens is that only players which originally joined the environment can rejoin after a disconnection. Obviously a timeout can be set for the session which originally joined the environment can rejoin after a disconnection. Tokens can also carry identification information, e.g. digitally signed messages, allowing users’ authentication.

IV. CASE STUDY

As a case of study, the design of a reusable software layer for the development of distributed card games was built on top of the framework. In order to build such a layer it was necessary to study in depth the main characteristics of existing card games and figure out what elements can be considered as a basis on which to build a new card game. The following aspects were analyzed, during the study:

- the possible set of values associated with the cards;
- the set of seeds associated with the cards;
- order relationship among cards;
- number of players and possible partnerships;
- actions available for a player during his turn;
- actions available for a player during the turn of another one;
- the interaction among players;
- score computation;
- card picking;
- card distribution;
- how the next turn is chosen;
- the conditions by which a player or a group of players is declared as the winner.

The fundamental entities and relations of a generic card game were identified, as a result of the study, and are shown in the class diagram depicted in Fig. 4.

A. Architecture for a generic card game

A certain number of abstraction were designed in order to capture the essential elements which characterize a generic card game. The abstract class Card can be used to model cards of different games, it implements the Comparable interface so that a comparison is possible among the cards. Seed and Value interfaces are abstractions which describe the corresponding two features of the card concept. The entities deck and team are respectively represented by the abstract classes Deck and Team. These classes provide some services which are common to every card game. Other operations, i.e. the way the cards are distributed, depend on the nature of the game: in Poker hands are of five cards, in Tressette with four players, see section IV-C, ten cards are given, at game begin, to each player.

The operations needed to handle the hand of a player, the set of cards distributed to every player, are generic enough to suit a generic card game well, so the concrete class Hand has been purposely devised.

There are two more entities that were identified during the mentioned study: the player and the game coordinator. The first serves the purpose of letting a user interact with the game performing actions like checking the hand, playing one or more cards and so on. The second has different tasks to accomplish, such as elaborating and communicating information about the current status of the game and coordinating the actions of all players. The player and the game coordinator will not necessarily be located on the same machine. The framework has been thought to build a distributed system in which each device can either adopt the role of a server or the role of a client, so the entity player will be assigned to every user while the entity game coordinator only to the user whose device act as a server. It is also possible to implement a centralized coordination approach where the coordinator is not tied to any player and reside on a different machine.

The game coordinator knows the players who participate in the game so a communication between objects on different machines will take place. The Player interface and the abstract class called AbstractPlayer are exploited to hide the true nature of a player, so the game coordinator will never know whether it is communicating with a remote object, whether it is interacting with the local user or whether it is interacting with and intelligent artifact.

The Proxy pattern [15] was exploited so that a transparent communication channel can be created between the player...
and the game coordinator (see Fig. 5). The ProxyPlayer class implements the Player interface and forwards all the requests, received by the game coordinator, to its associated client. On the client machine the SkeletonPlayer module, another class that implements the Player interface and knows the real player, receives the forwarded requests.

The communication between a server and a client is bidirectional, so the player needs a way to communicate to the game coordinator. The game coordinator carries out a number of operations; the whole set of operations can be split up in subsets, each of them deals with a specific aspect of the system. In the light of the previous consideration, three interfaces were designed:

- GameCoordinatorElaboration;
- GameCoordinatorCommunication;
- GameCoordinatorRegistration.

The first interface defines operations regarding the server, while the second and the third ones were thought for the client. The Remote Proxy pattern was used once again to let a player communicate to the game coordinator. This time the proxy and the correspondent skeleton implement the GameCoordinatorCommunication and GameCoordinatorRegistration interfaces. To gather the operations of the two interfaces mentioned previously and to hide the implementation details of the proxy and the skeleton, the following two interfaces were created:

- ProxyGameCoordinator;
- SkeletonGameCoordinator.

It was also created the GameCoordinator abstract class which implements the GameCoordinatorElaboration, GameCoordinatorCommunication and GameCoordinatorRegistration interfaces, to provide a default implementation for a portion of the whole set of operations and a module to handle properly the entity game coordinator on the server. The player and the game coordinator, just like the room entity, use the services provided by the ServerCommunicator and Communicator interfaces (see Fig. 5).

B. Security aspects

During the design phase the existence of fake client application was taken into account. Therefore the system was designed so that the server checks the validity of the data received by each client. Whenever a fake client tries to play an unexpected card the system would be able to recognize this anomaly. If an anomaly is detected a notification will be sent to each client to communicate the presence of a fake client and subsequently the game would be ended.

C. Tressette: a specific card game

Tressette, an Italian card game, was built on top of the framework. The application was thought for Android and personal computer devices; the Java programming language was used in order to guarantee the portability of the software and the Bluetooth and the Socket technologies were chosen as communication technologies.

Tressette is played with a standard Italian 40-card deck and the cards are ranked as follows from highest to lowest: 3-2-Ace-King-Knight-Knave and then all the remaining cards in numerical order from 7 down to 4. The game may be played with four players playing in two partnerships, or in heads-up play. In either case, ten cards are dealt to each player. In the developed application the players play only in two partnerships. The object of the game is to score as many points as possible until a score of 21 is achieved. Players must follow suit unless that suit does not remain in their hand, and players must show the card they pick up off the card pile to their opponent. More information about the Tressette card game can be found in [6].

The entities that have been introduced for implementing the Tressette game are reported in the class diagram depicted in Fig. 6. There was no need to override any methods of the Hand class, its services resulted generic enough for the application. TressetteCard is a concrete class which extends Card, it introduces an operation to mark a card as playable or not: in this game a card can be played only when specific conditions hold, see [6] for more details. The Enum Shape represents the concept of seed, so it implements the Seed interface, while the concrete class called TressetteValue realises the Value interface. TressetteTeam extends Team, it keeps track of the game score. Analogously TressetteDeck extends Deck with game-specific deck handling aspects. In the method elaboration of the TressetteGameCoordinator class lies the core of the logic of the game, here the turns and scorers are updated and the winners are proclaimed. TressettePlayer provides specific operations for Tressette, like the TressetteCard class does. It was necessary to define two more interfaces to handle specific aspects of the game: TressetteCode and TressetteMessage. The first interface serves the purpose of exchanging messages between the room and a client, while the second one defines all the statements available for a user.

V. Conclusions and future work

We presented a modular framework for the development of domain specific CVEs. One of the main feature of our proposal
is the support for a transparent and seamless multi protocol interaction among participants. The framework is not tied to any particular architectural distributed communication pattern and can be exploited to support any of them. The effectiveness of the framework has been experimented by implementing on top of it a reusable software layer for the development of distributed card games. Future research directions include others practical experimentation of the framework in more heterogeneous distributed settings, e.g. involving web-services [16] and cloud based applications [17]. The proposed framework can be used for building collaborative environments in many fields. For example, existing e-learning platforms based on CVE (e.g. [18]) could be extended in order to gain the multi-protocol features we have introduced in the framework.

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