Itchy Feet: A 3D e-Tourism Environment

Seidel Ingo
Matrixware Information Services GmbH, Information Retrieval & Scientific Services Department, Lehargasse 11/8, 1060 Vienna, Austria
iseidel@itchy-feet.org

Markus Gärtner
Matrixware Information Services GmbH, Information Retrieval & Scientific Services Department, Lehargasse 11/8, 1060 Vienna, Austria
mgaertner@itchy-feet.org

Michael Pöttler
Vienna University of Technology, Institute of Software Technology and Interactive Systems, Favoritenstrasse 9-11/188, 1040 Vienna, Austria
michael.poettler@ec.tuwien.ac.at

Helmut Berger
Matrixware Information Services GmbH, Information Retrieval & Scientific Services Department, Lehargasse 11/8, 1060 Vienna, Austria
h.berger@matrixware.com

Michael Dittenbach
Matrixware Information Services GmbH, Information Retrieval & Scientific Services Department, Lehargasse 11/8, 1060 Vienna, Austria
m.dittenbach@matrixware.com

Dieter Merkl
Vienna University of Technology, Institute of Software Technology and Interactive Systems, Favoritenstrasse 9-11/188, 1040 Vienna, Austria
dieter.merkl@ec.tuwien.ac.at

ABSTRACT

In this chapter we describe an e-Tourism environment that places emphasis on a community-driven approach to foster a lively society of travelers. It enables them to exchange travel experiences, recommend tourism destinations or just catch some interesting gossip. Moreover, business transactions such as booking a trip or getting assistance from professional travel agents are a constituent part of this environment. All these interactions happen in an integrated, game-like, 3D Virtual World where each tourist is impersonated as an avatar. We draw a retrospective on the specification, design and implementation of this e-Tourism environment and present the status quo. We describe how we applied Electronic Institutions, a framework developed and employed in the area of Multi-Agent Systems, to the tourism domain. Furthermore, we present our approach to connect a 3D Virtual World with Electronic Institutions. Our goal is to provide a test bed for assessing the acceptance of virtual environments, as a medium to overcome the non-tangible nature of tourism products.

KEYWORDS

e-Tourism, 3D Virtual World, Electronic Institution, Multi-Agent System, Online Communities, Game Design, Game Engine, Middleware, Front-End Computers, Human/computer interaction, Graphical User Interface, 3-D graphics, Agent, Data.

1 INTRODUCTION

In the last decades Information and Communication Technology (ICT) has revolutionized the global economy and almost every business including tourism. The rapid evolution of ICT enabled consumers to have access to a broader range of information services covering the whole tourism life cycle (Werthner & Klein, 1999).

A typical tour planning and execution cycle may be something like the following. Prior to booking, the customer is browsing the Internet to search for information and is using communication services such as forums or instant messaging to get the latest information directly from local people. Prices are compared and the cheapest offer is booked online. During the trip, the tourist uses her mobile device to get the latest news about local events. Activities and impressions are compiled in online diaries via the mobile device and made accessible to friends and family. After the trip, pictures are shared online and experiences are discussed. The majority of these activities take place in online tourism communities. An online community can be defined as the combination of commercial, technical, social and psychological aspects of groups of people (Eigner, Leitner, & Nausner, 2003). Following this trend many companies see the creation of “business-sponsored-communities” as an additional channel of distribution. In this context, companies analyze user profiles in order to provide personal advertisements and product-related information to community members. The tourism sector has been particularly active in this field, because customer loyalty not only depends on social interaction but also on the quality of the information provided, e.g., prices or opening times.

Furthermore, trip planning makes high demands on the information search (Pöttler, 2007). An online community is only successful when it attracts and retains a large number of members to

reach critical mass (Wang, Yu, & Fesenmaier, 2002). The potential of online communities lies in the ability to be integrated in the value chain for product and service design. To tap its full potential, the creation of online communities has to be technically, operationally, strategically and economically planned to meet the users' requirements. Not only social interaction is of great importance during the process of community building, but community members want to communicate as well as using a technically sophisticated platform. This technological aspect has not been emphasized enough in the tourism domain. A study that compared different online tourism communities shows that technical innovations are introduced sparingly in these communities (Dippelreiter, et al., 2009). Special focus should therefore be placed on the selection of the technological features and functionalities when creating a community in the tourism domain.

Another important aspect in tourism is the presentation of products. A tourism product is a virtual product that cannot be experienced in advance – it is a confidence product (Gratzer, Werthner, & Winiwarter, 2004). For a customer it is essential to get a good impression of the product before the trip, in order to know what to expect, so as not to be disappointed on site.

Traditionally the impression of a destination is conveyed by means of quality photos in travel catalogs and information from the travel agent. In addition, information gathering on the Internet and in online communities has become more important over the last few years. However, the presentation of the content is basically the same – textual descriptions and pictures are used to illustrate travel destinations. An approach that goes beyond these "classical" media types and provides more sophisticated visualization of tourism products are 3D product presentations.

The presentation of a product in a three dimensional space makes it easier to imagine the actual product and creates a completely new product experience. In a 3D Virtual World the user is impersonated as an avatar (a virtual, three dimensional representation of the user) and can explore the environment in a similar manner as the real world. This virtual world is composed of a landscape where the user can walk around; a virtual sky and sun resemble the natural atmosphere; furthermore, this environment is populated with buildings that can be entered through doors. For example, suppose a hotel has been visualized in the 3D Virtual World. The customer is then literally able to enter the hotel, experience its ambience, can see how the room will look like and how well the sea view can be enjoyed from the balcony in the virtual environment. Besides these advantages in product presentation, 3D Virtual Worlds also address social interaction implicitly. Just as in the real world, a user can see other users, is able to walk towards them and can start talking to them. It is fairly easy to get in touch with other people and new relationships can emerge quickly. Thus, we consider that a 3D Virtual World can be a good basis to build up an online community.

In light of these developments and new technologies, we are aiming at the creation of a novel 3D e-Tourism environment, henceforth referred to as Itchy Feet. With Itchy Feet we address the aspects of social interaction by providing instruments to interact and exchange experiences with other customers that go beyond the possibilities of conventional text-based chat rooms. It offers sophisticated visualization of tourism products, integrates travel agents and enables seamless access to the information richness of the Internet. The principal goal is to develop an instrument to support the complex interaction patterns of providers and consumers in an e-Tourism setting.

This principal goal subsumes three sub-goals:

i. provide a 3D e-Tourism environment for both providers and consumers, to facilitate versatile interaction between participants including trading of tourism products;
ii. provide a 3D e-Tourism environment that acts as a community facilitator to create and establish a lively and sustainable community involving both providers and consumers; and,
iii. provide a 3D e-Tourism environment that is information-rich to provide transparent and unified access to disparate multimedia information sources.

The technological basis for this environment is formed by a 3D Virtual World that allows users to participate in Itchy Feet. The 3D Virtual World implements various community features such as profiles or forums, in order to become the cornerstone of a lively tourism community. Users have access to a wide range of information sources that are aggregated and presented in the 3D Virtual World. In order to provide these functionalities an agent-based approach is taken. According to Wooldridge (2001), agent-based solutions should be employed whenever the information is spread across several sources. This perfectly applies to the tourism domain where information is spread over the Internet and stored in databases on different organizational levels (regional, national, international).

In Itchy Feet, the software agents reside in a Multi-Agent System that is connected to a 3D Virtual World. To this end, we rely on a framework (Seidel & Berger, 2007) that combines a Multi-Agent System methodology, namely Electronic Institutions (Esteva, Rodriguez-Aguilar, Sierra, Garcia, & Arcos, 2001) with 3D Virtual Worlds. Our system is based on a three layered architecture. The 3D Virtual World is placed at the top layer, the Electronic Institution is at the bottom layer and both these two components are connected through the middleware layer.

An Electronic Institution is similar to a real world institution where processes and rules are predefined and involved parties have to act according to these processes and rules. In Itchy Feet, Electronic Institutions are used to define business processes and rules which are enforced in the 3D Virtual World. Every user in the 3D Virtual World is the principal of an agent in the Electronic Institution that validates the actions of the user. Autonomous agents are visualized in the 3D Virtual World as avatars. Thus, the system enables active participation of humans in this agent-based society. The user is no longer restricted to controlling and observing the agent system, but is able to communicate with these agents just as with other human users.

The remainder of this chapter is structured as follows. Section 2 provides an overview of related work. The technological building blocks are presented in Section 3. The general framework connecting Electronic Institutions with 3D Virtual Worlds is presented in Section 4. In Section 5 the general framework is applied to the tourism domain and Itchy Feet is introduced. The different Electronic Institutions in this environment, the 3D Virtual World and the conceptual basis for data aggregation and presentation are presented. In Section 6 we discuss the environment and present opportunities for future research. The chapter is concluded in Section 7.

2 RELATED WORK

e-Tourism has created new distribution channels for tourism resulting in the establishment of numerous online booking platforms. These services are increasingly used by customers to purchase tourism products. A survey comparing online booking with booking at traditional travel agents gives insights on the booking behavior of customers (Bogdanovych, Berger, Simoff, & Sierra, 2006). This survey showed that people are using online booking services primarily to book domestic trips, whereas international trips are more often booked with a travel agent. The main advantages of travel agents are their expertise and the face-to-face interaction when making difficult decisions. In contrast, online booking systems are more convenient, have lower response times and provide answers to inquiries in an environment familiar to most users. Note that these results were obtained in Australia and the booking behavior in other countries might be different, due to both sociological as well as geographical reasons.

Trust in e-Commerce systems is a domain of active research and different studies show that the social presence of a web site influences trust, enjoyment, perceived usefulness and loyalty. Social presence is the sense of awareness of other people in a communication medium. Hassanein & Head (2007) conducted a study where they investigated the influence of certain interface elements on perceived social presence. Three different online stores with low, medium and high levels of social presence were created. Test subjects had to complete a certain task – buying a piece of cloth – and reported their experiences in a questionnaire. The evaluation shows that the social presence of a web site can be influenced by certain user interface elements which in turn influences the trust, enjoyment and perceived usefulness of a web site.

In another work Cyr et al. (2007) argue that online shopping experiences lack human warmth as they are more impersonal, anonymous and do not provide face-to-face communication. They investigate how loyalty is influenced by social presence and if there are gender differences. Five e-Commerce web sites with different interactive elements were created and customers had to browse one of the websites and buy concert tickets. The results indicate that social presence influences loyalty as well as enjoyment, however, there are differences between males and females. For example, the direct impact of social presence on loyalty could only be shown for females but not for males.

Web sites in e-Tourism are rather dominated by conservative user interfaces. Especially on booking platforms users navigate through a plethora of drop down lists and selection boxes to search for tourism products. To overcome these disadvantages, new interface metaphors have been developed. One approach employs natural language interaction enabling users to formulate a query in natural language (Berger, Dittenbach, & Merkl, 2004). The advantages of this approach are the same as with online discussion forums, i.e. - users can express more complex queries when using their natural language and will get more appropriate results for their search. Furthermore, they do not have to learn a special query language and are not required to structure their request in a way the computer understands. A field trial showed that most of the participants considered the natural language interface to be more comfortable than standard interfaces and explicitly stated their preference for this kind of interface.

To get insights on the quality of information posted on forums, travel blogs, etc., Schwabe & Prestipino (2005) compared the information quality of online tourism communities with traditional guidebooks. They found that online communities provide more timely information, requests can be answered more completely, and personal requests can be accomplished better. The structure of the information is the only area where guide books are more sophisticated.

Another study compared different tourism online communities and investigated the use of Web 2.0 technologies (Dippelreiter, et al., 2009). It is shown that online communities in e-Tourism mostly address the pre-trip and post-trip phase of the tourism life cycle, while support during the on-trip phase is mostly neglected. Communities are used to collect and aggregate information prior to the trip and to share experiences and pictures afterwards. Interestingly, Web 2.0 technologies such as interactive maps have only been introduced sparingly and many communities use conventional technologies. Discussion forums are also still the predominant way to elaborate on tourism topics and have not been replaced by other forms of collaborations.

Agent Technology

An interface determines how users are able to access and view the data in a system. The actual internal representation and structure of this data can be achieved by various means. Multi-Agent Systems are one possibility and have already been employed in the tourism domain for information gathering, representation and aggregation. For example, Chiu & Leung (2005) designed a virtual enterprise of independent tourism service providers as a Multi-Agent System. Agents make use of Semantic Web concepts to improve the planning stage and help customers in understanding and specifying their requirements and preferences. The authors' motivation was the lack of tourist portals that proactively assist tourists by adequately integrating disparate information sources and services. The Multi-Agent System developed by Chiu & Leung (2005) addresses these issues to create a ubiquitous tourist assistance system.

A similar approach, that also relies on agent technology to retrieve tourist information from distributed databases, has been presented by Yeung et al. (1998). A customer can use the system through a special interactive graphical user interface to enter search queries and to trace the information search and retrieval. In the background the information requests are processed by different types of software agents which communicate via the Knowledge Query and Manipulation Language (KQML) (Finin, Fritzson, McKay, & McEntire, 1994). Typically, a search request is passed to a specific information agent that has knowledge about the search topic. The information agent then queries a database and the result is sent back to the requesting agent. Special attention has been paid to platform independence – all system components are either implemented in Java or other platform independent technologies; and thus, KQML is used as a platform independent communication protocol.

The implementation of software agents usually follows a specific methodology aimed at defining the way agents need to be modeled. Several formal methodologies have been proposed in the literature. Dignum & Dignum (2001) introduced a formal methodology for the development of agent societies. They divide domain requirements into functional and interaction requirements. Functional requirements define what a system is supposed to do and interaction requirements define how the system is supposed to do it. In a subsequent work a methodology for

the design of agent societies based on the type of coordination structure was presented (Dignum, Weigand, & Xu, 2001).

Gaia, a methodology for agent-oriented analysis and design was introduced by Zambonelli et al. (2003). It was the first formal methodology specifically developed for agent-based systems. The approach is based on designing a Multi-Agent System as a computational organization. Furthermore, the methodology has been extended for the analysis and design of Multi-Agent Systems. Clear guidelines for analysis and design are provided by Gaia. Juan et al. (2002) introduced a methodology based on Gaia to improve software engineering of agent-based open systems.

The Electronic Institution methodology was developed for modeling agent organizations effectively as institutionalized electronic organizations (Esteva, Rodriguez-Aguilar, Sierra, Garcia, & Arcos, 2001). The methodology is based on the notion of institutions. Institutions represent the framework within which human interaction takes place and define restrictions and permitted actions. Such definitions are mapped onto Electronic Institutions which are the electronic counterpart of institutions. Electronic Institutions are populated by heterogeneous software agents and humans that interact by means of speech acts.

3D Virtual Worlds

Research approaches taking advantage of 3D game engines have emerged over the last few years. One of the first examples is PSDoom by Dennis Chao (2001). In his work the Doom game engine is used as an interface for the management of Unix system processes where each process is represented as a monster. Killing the monster causes the corresponding process to “die”. The intention of this work is to explore new interface metaphors that provide a more intuitive access to computers for computer illiterate people.

Moloney et al. (2003) developed an immersive design critique tool for architects. They use an open source game engine to create a collaborative virtual environment enabling students to create 3D architectural models. The environment allows students to iteratively alter the model and to directly view these changes. Moreover, reviewers are able to comment on the created models.

In the context of information visualization Kot et al. (2005) use a 3D game engine to improve data visualization for source code comprehension. This tool allows software developers to quickly perceive the structure of source code and the relationship between different source code files. Files are visualized as 3D objects in a 3D Virtual World. The user can explore the structure by walking through the virtual world. The content of a file is displayed when the user walks into a file object.

In another work Steve DiPaola & David Collins (2003) created a 3D Virtual World for the emulation of natural social paradigms. They believe that such environments convey tele-presence and help to achieve higher levels of socialization, learning and communication. The human voice is used as communication mechanism to represent the individuality of users and to create an immersion effect.

Multi-Agent Systems and 3D Virtual Worlds

Some works report on the combination of Multi-Agent Systems and 3D Virtual Worlds. Smith et al. (2003) present an approach where the agent logic is incorporated in a 3D environment. According to the authors most worlds are largely static and objects are used to trigger pre-programmed behavior. Agents are supposed to enrich the world and should make the environment more dynamic. The proposed framework consists of a society of agents in which each agent controls a 3D object. As an example, a conference room consisting of wall agents and a room agent is presented. Depending on the number of avatars in the room, the agents react and dynamically adapt the room size.

Adobbati et al. (2002) presented GameBots; a system that abstracts from the Multi-Agent System and provides a uniform interface to the 3D Virtual World. They have created a multi agent research test bed that is not limited to a specific task in a fixed environment and supports human testing and interaction. The GameBots environment supports humans-as-agents, is easily customizable (due to a scripting language), and supports multiple environments and tasks.

The Unreal Tournament Semi-Automated Force (UTSAF) project takes advantage of GameBots (Manojlovich, Prasithsangaree, Hughes, Chen, & Lewis, 2003). It is a framework that connects military simulations with a 3D visualization. The goal is to create a system that scales well on large and heterogeneous simulation environments. To this end, they developed a framework in which an agent system is used as the mediator between the military simulation and the 3D Virtual World. Agents monitor the status of the military simulation, filter relevant information and visualize entities of the simulation in a 3D Virtual World.

Nakanishi & Ishida (2004) developed a social interaction platform named FreeWalk/Q where software agents and human controlled avatars share the same environment, interaction model and scenario. They introduced different topologies and description levels to describe the behavior of an agent or a human's avatar for a more natural integration into their virtual environment.

Face-to-face communication in 3D worlds is addressed by Traum & Rickel (2002). They concentrate on issues such as proximity and attentional focus of others, the interplay between speech and nonverbal signals and the ability to maintain multipart conversations. They introduced an example scenario to demonstrate an initial implementation of their model.

A similar approach to seamlessly integrate agents and humans in a cohesive Multi-Agent System was introduced by Martin et al. (2003). In their work they describe a software prototype of a distributed collaboration and interaction system helping humans to act as an integrated part of a Multi-Agent System. They introduced so-called liaison agents which support human interaction with other non-human agents by arbitrating between them.

Payne et al. (2000) analyzed human-agent interaction and stated that agents can have different models of user interaction. In their work they describe a case study of a Multi-Agent System containing different agents, with some having functionally similar capabilities, but with different types of user interaction modalities. They argue that according to the type of user interaction a significant effect on the performance of the whole agent community can be ascertained.

Game Design

This paragraph describes the findings of the research conducted by Yee (2006 b), one of the leading researchers in the area of Massively Multi-User Online Role-Playing Games (MMORPGs). One of the aspects why people join a 3D environment is the motive of playing MMORPGs. They are a leisure activity practiced by millions of people worldwide, who are interacting with each other through graphical avatars to complete complex goals (Yee, 2006 b). However, little research has been conducted to explore the social interactions and relationships that develop between the users of MMORPGs.

Nick Yee was one of the first in this field, who focused on statistical analysis of motivation factors for playing MMORPGs (Yee, 2006 a). The stereotype that only teenagers are playing MMORPGs is a false premise. The average age of MMORPG users is 26.57 years, and on average they spend 22.72 hours each week playing their chosen MMORPG. Relating to social interaction, the majority of asked users had made more positive experiences in the 3D environment than in real life. While females emphasized the relationship, immersion and escapism within the 3D environment as the main motivation factors, the motivation for males lies in the manipulation and achievement of desired outcomes.

The reason why users are motivated to play MMORPGs has a lot to do with conceptualization and the design of the game. The difference between other entertainment products like books or music is that games are relatively unpredictable in their consumption (Hunicke, LeBlanc, & Zubek, 2004). In the field of game design there is a lot of literature related to the construction of specific games; however, there is less literature available about the best practices for designing games.

Rollings & Morris (2004) define a form of “Creative Road Map” for creating games, which comprises the following development stages: concept development, structure development and design; furthermore there are four phases of the creative process. It starts with inspiration, followed by synthesis, resonance and convergence. The inspiration phase is concerned with “where to get ideas”; synthesis means “combining the ideas”, this is followed by the resonance which describes the “creation of synergy from ideas”, and finally “finishing the concept” expressed by convergence.

They also describe the essentials of game design. Five useful questions can be asked by game designers who start to create a game: (i) Is it original? (ii) Is it coherent? (iii) Is it interactive? (iv) Is it interesting? (v) Is it fun? Another key aspect of game design is the concept of “meaningful play” (Salen & Zimmermann, 2004). The purpose of this concept is to create an exceptionally and meaningful game experience for the player.

Two diverse definitions are used for the concept of “meaningful play”. The first, descriptive approach, specifies the interaction between the game system, the game-activity and the resulting outcome. It refers to the process in which the player undertakes activities, and the system responds. The second approach, called the evaluative approach specifies the game experience that needs to be created for the player.

3 TECHNOLOGICAL BUILDING BLOCKS

Multi-Agent Systems and 3D Virtual Worlds are the fundamental technologies used in our work. First, we will introduce Electronic Institutions and then present the employed 3D Virtual World. Electronic Institutions enable the specification of regulated and well structured environments. In particular, Electronic Institutions are taking control over security aspects to ensure participants adhere to the institutional rules and fulfill their obligations. They are computational realizations of real-world institutions enabling agents to interact with each other according to predefined conventions and rules (Esteva, Rodriguez-Aguilar, Sierra, Garcia, & Arcos, 2001). Literally speaking, an Electronic Institution is the guard to ensure that all actions performed by agents are in line with the rules and regulations that apply in the institution.

One of the first implementations of an Electronic Institution was an Auction House developed within the Multi-Agent System for Fish Trading (MASFIT) project (Cuni, Esteva, Garcia, Puertas, Sierra, & Solchaga, 2004). The Electronic Institution methodology used in this project emerged from the FishMarket project. The FishMarket is an electronic realization of a real fish market created as test-bed for trading agents in electronic auction markets (Rodríguez-Aguilar, Martín, Noriega, Garcia, & Sierra, 1997).

The basic components of Electronic Institutions are i) the Dialogical Framework, ii) the Performative Structure, and iii) the Norms and behavioral rules.

The Dialogical Framework defines the language ontology and illocutionary particles that are used by the agents. It defines the organizational structure of the society of agents, comprising the agent roles as well as the relationships between them.

The Performative Structure determines the type of dialogues agents can engage in. These dialogues are named scenes. They are connected with each other to create sequences of activities or dependencies among them.

Norms and behavioral rules regulate the interaction and communication in a group of agents. They ensure the safety and stability of the system by prohibiting agents to behave in non-expected or non-accepted manners (Aldewereld, Dignum, Garcia-Camino, Noriega, Rodriguez-Aguilar, & Sierra, 2006). Norms are used to define the legality and illegality of actions, in a vague and abstract way to ensure they apply in different circumstances (Dignum F. , 2002).

The movement between scenes is realized via so-called transitions, which are responsible for routing agents. Agents leave scenes where they have been playing a given role and enter other scenes to play the same or a different role. A scene instance is generated by the owner of a scene. After a scene has been instantiated, agents may join this scene. For every scene a sub-language of the overall institutional language as well as its structure, by means of a Finite State Machine, are defined. Furthermore, certain states of the Finite State Machine have a list of agent roles, defining whether agents playing in these roles are eligible to join or leave. The arcs of the Finite State Machine are labeled with messages (illocutions). If a corresponding message is uttered, a state transition is performed by the Finite State Machine. The Norms and behavioral rules are

expressed as pre- and post-conditions of the illocutions that are admissible in the Performative Structure of the Electronic Institution.

Figure 1 depicts an example of a Performative Structure and scene in auction setting. Every Performative Structure has an `Entry` and an `Exit Point`. Agents can move from one scene to another scene by using `Xor`, `Or` and `And` transitions. Consider two agents, one playing in the `Seller` role and the other one in the `Buyer` role. Both agents start from the `Entry Point`. The first transition, depicted as an arrow with an `X` inside, is a `Xor` transition. It restrains an agent from moving to more than one subsequent scene. In our example, the `Seller` has to move to `Scene1` and the `Buyer` to `Scene2`. The second transition, depicted as a semicircle, is an `And` transition. An `And` transition defines a synchronization point which has to be passed by multiple agents simultaneously. An agent has to wait in such a transition until all required other agents have moved to that transition. Then they are able to move to the next scene simultaneously. In our case the `Seller` and `Buyer` agents have to synchronize after leaving `Scene1` and `Scene2`. The `And` transition can only be passed if an agent playing in the `Seller` and an agent playing in the `Buyer` role are present in the transition. If only the `Seller` is present in the `And` transition it has to wait until the `Buyer` joins, before it can proceed. The third transition, depicted as an arrow without `X`, is an `Or` transition. An `Or` transition is less restrictive than the `Xor` transition and allows agents to join more than one subsequent scene. In our example only the `Exit Point` is reachable from the `Or` transition, therefore the `Buyer` and `Seller` can only move to the `Exit Point`.

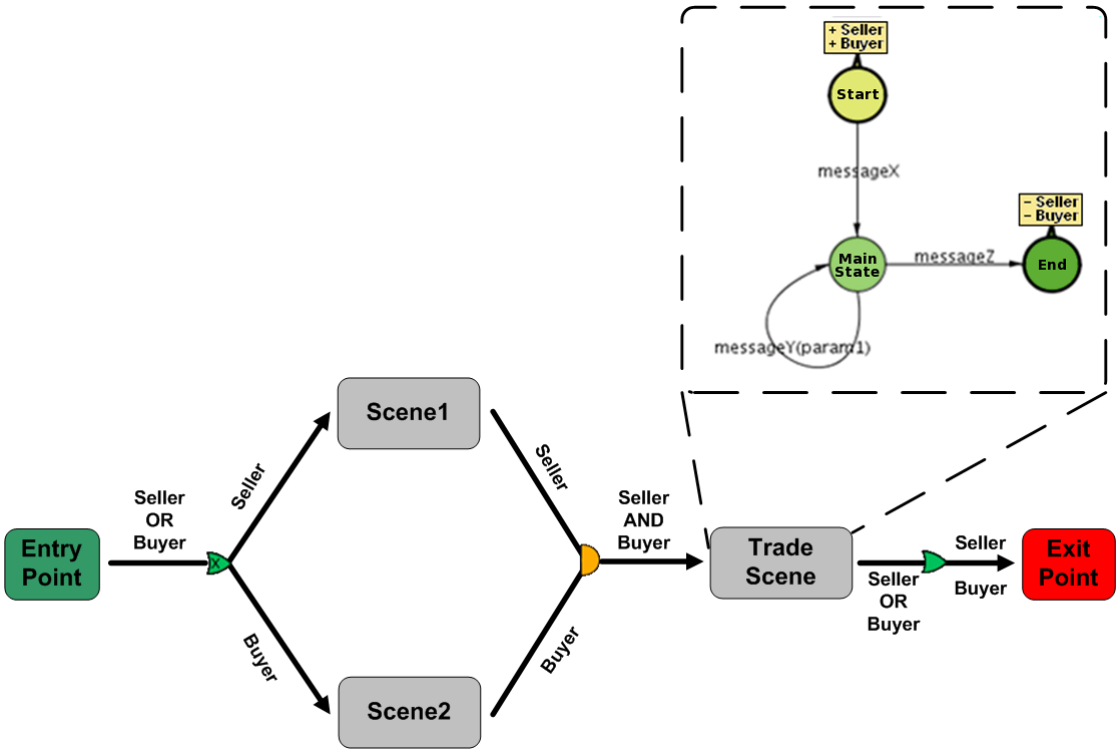

Figure 1: Performative Structure and Scene Protocol of an Electronic Institution

Figure 1 also shows the scene protocol of the `Trade Scene`. Scene protocols are represented as Finite State Machines where state changes are triggered by uttering messages. All agents in a certain scene share the same scene protocol and state. A state defines the possible messages that can be uttered and which roles are eligible to join or leave. In the `Trade Scene` `Seller` and `Buyer` agents are eligible to join the scene in the `Start` state and to leave it in the `End` state. In the `Start` state `messageX` can be uttered, while in the `main` state `messageY` or `messageZ` can be said.

3D Virtual Worlds

The second fundamental technology within the project are 3D Virtual Worlds. In order to identify a suitable 3D Virtual World, we evaluated four different 3D Virtual Worlds: two game engines - the Q Engine[1] and the Torque Engine[2]; one 3D virtual browser - Active Worlds[3]; and one 3D API - Java 3D[4]. Java 3D and Active Worlds did not provide enough functionality for our needs and could not be used. We then decided to choose the Torque game engine over the Q Engine as it has more features, is better proven and has a bigger developer community than the Q Engine.

The Torque game engine is an open source game engine developed by GarageGames. The feature list includes seamless indoor/outdoor rendering, animation support, a lighting engine, powerful editors, a scripting language and network functionality. Furthermore the royalty free licensing model allows developers to distribute and publish their games without further costs. The Torque game engine offers several editors and tools for the creation of games and 3D Virtual Worlds. These editors range from a world editor, used to arrange objects in the 3D Virtual World, over a terrain editor, used for the creation of the terrain, to a graphical user interface (GUI) editor, used for the design of the heads-up-display and the menu. The behavior of objects and the game logic is programmed via the scripting language. If the scripting language is not applicable (due to functional or speed limitations), it is possible to alter the game engine itself. The code is written in C++ and is directly compiled into the game engine executable.

Torque is an industry-proven game engine and has been used in numerous commercial and independent games. In the scientific world the Torque game engine has been utilized for research projects as well. The design critique tool from Moloney et al. (2003) is relying on the Torque game engine and IBM is using the engine for an internal research project on virtual worlds[5]. Moreover, the engine is widely used in education for teaching the principles of 3D game engines. The GarageGames web site[2] lists more than 200 schools and universities that use the Torque game engine in their class rooms.

4 A FRAMEWORK FOR 3D ELECTRONIC INSTITUTIONS

The role model for our environment is the concept of Massively Multi-User Online Role-Playing Games (MMORPGs). Millions of users interact, collaborate, socialize and form relationships with each other through avatars in such online environments (Castronova, 2005). For playing MMORPGs users must purchase a specific client and have to pay monthly subscription fees in the amount of 10 Euros to be able to access the central servers[6]. Users can view the virtual world in real time 3D graphics and use an avatar to interact with the environment. Commands are executed via user interfaces that are controlled by the mouse and keyboard.

The game World of Warcraft[7] is one of the most successful MMORPGs with more than 8 million users. In this virtual world, the collaboration becomes incredibly complex due to the interaction between beginner and advanced level types of users. In a common scenario users play in groups of 4 to 8 avatars where they fight against multiple computer controlled enemies. Other MMORPGs such as Star Wars Galaxies[8] have created collaboration scenarios of an entrepreneurial nature. Virtual goods are produced by the users themselves; supply, demand and prices are user driven. Many users say that they feel like they have a second job (Yee, 2006 b).

Conceptual Design

In our 3D e-Business environment two types of participants need to be considered: humans and agents. Agents are either autonomous or controlled by a human user. In the latter case, the couple human/agent is represented as an avatar in the 3D Virtual World. Humans and agents learn from each other and work together to collaboratively achieve certain goals. The user delegates tasks such as information gathering or product purchasing to the agent and learns from the agent which rules and restrictions apply in the environment. The user must act according to these rules. The movement and actions of the user in the 3D Virtual World are verified by the agent in the Electronic Institution.

Autonomous agents must be visualized in the 3D Virtual World such that users are able to interact and learn from them. An autonomous agent is a software agent that is capable of reacting to its environment and proactively makes its decisions based on the input from the environment and its internal decision model. The visualization of autonomous agents depends on their task. For example, an agent that actively participates in conversations may be visualized as an avatar, whereas a simple information agent may be visualized as an information monitor.

The dependence between the two systems requires that the 3D Virtual World is causally connected to the Electronic Institution. Causality refers to properties of the connection between a system and its representation (Maes & Nardi, 1988). In our case this means that whenever the 3D Virtual World changes, the Electronic Institution must change as well. Whenever the Electronic Institution evolves, the 3D Virtual World has to be modified in order to maintain a consistent relationship. Conceptually speaking, the system is composed of three layers whereof the 3D Virtual World is located at the top layer, the Electronic Institution is located at the bottom layer and both components are causally connected by the middleware layer.

The Framework Architecture

An overview of the architecture is depicted in Figure 2. The rectangles define self-contained execution environments in which each application is running. These environments may run on the same computer or can be distributed across several machines. The communication between the layers is based on the TCP protocol. The components within each layer listen to network traffic and send messages on predefined ports.

The Administration Tool is connected to the data store and used for the administration of the components on every layer. The Electronic Institutions, the middleware as well as the Torque

server can be started and stopped. The configuration is based on XML files that can be manipulated and managed via the Administration Tool. The connection to the data store enables administrators to create, manage and delete data that is used in the framework. There are generally two types of data: generic data that is used in every 3D e-Business environment and domain specific data which is only used in the context of the application domain. Examples of generic data are login data or user account data while examples of domain specific data could be flight or hotel data.

The bottom layer contains Ameli, the Electronic Institution runtime environment. The TCP port of the Ameli component is used to send all events that occur in the Electronic Institutions to the middleware. This also includes the actions of autonomous agents that run the Electronic Institutions. Depending on their roles, these agents have access to the data store and can access registration information, user profiles or domain specific data.

The Remote Server is responsible for the message exchange with external agents allowing them to participate in the Ameli system. A predefined communication protocol (which is specified in the Electronic Institutions Development Environment) enables the communication with external agents. Agents send action requests to the Remote Server which are then validated in the Ameli system according to the Electronic Institution specification. The Remote Server returns reply messages to the external agent.

Torque is running on the top layer following a client/server architecture. The server is running in dedicated mode controlling the state of the 3D Virtual World and observing the actions of the users. The server guarantees a consistent relationship with the Ameli system and changes the state of the 3D Virtual World if necessary. The connection between the Torque server and the middleware is used to exchange messages between these two layers.

The Torque client runs on the user's computer and is used to visualize the 3D Virtual World. When the client is started, a connection to the Torque server is established. The server and client run in different execution environments and may be distributed across several machines. In Figure 2, we can see that a user named Elaine has started the client and entered the 3D Virtual World with her avatar.

The middleware connects the upper layer with the lower layer. The connection to the Ameli system is used to listen to events that occur in this system and to enable the participation of user agents. The connection with the Torque layer is used to exchange messages with the Torque system. The user’s agents are managed by the Agent Manager component. Every user in the 3D Virtual World is the principal of an agent in the Agent Manager. The connection between Elaine and her agent is depicted with a dotted line between the Torque client and the agent in Figure 2. Action requests from the user are sent to the middleware and forwarded to the user’s agent in the Agent Manager component. These agents act as external agents and communicate with the Ameli system through the Remote Server.

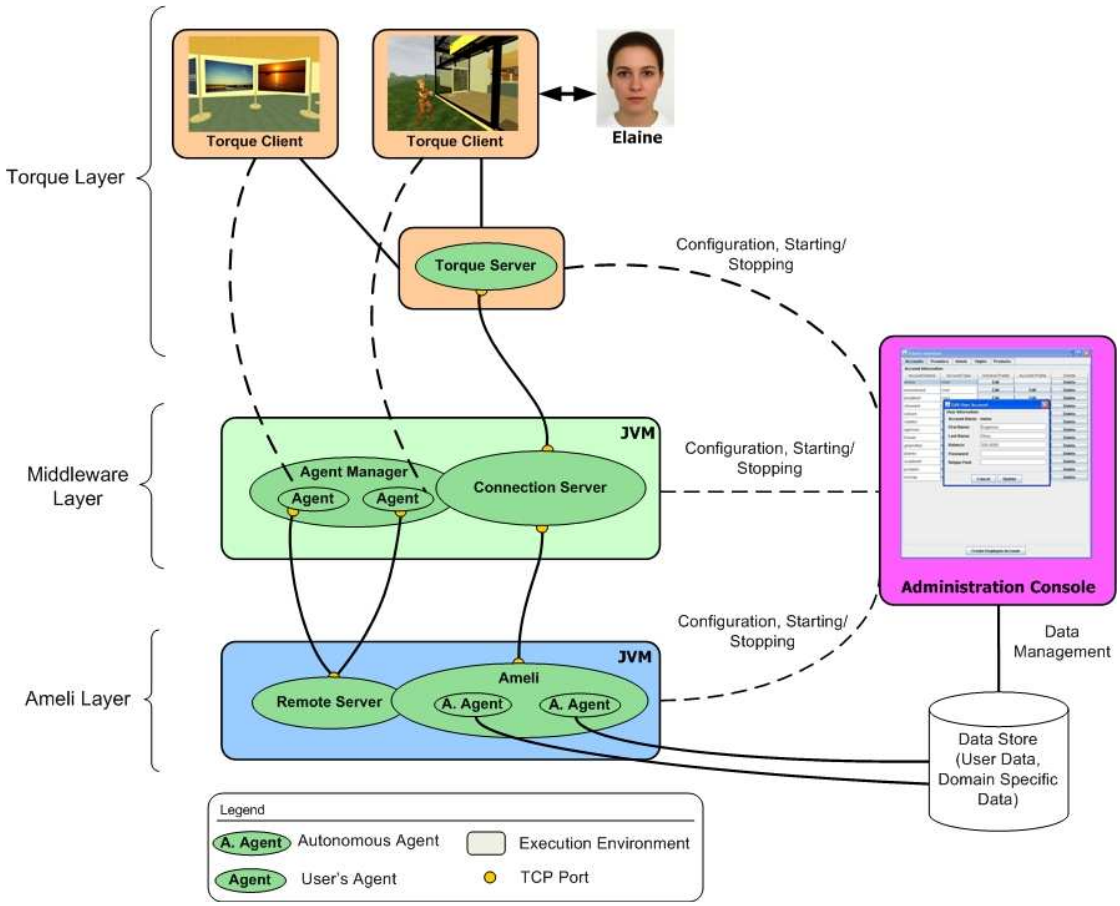

Figure 2: An overview of the framework for connecting Electronic Institutions with 3D Virtual Worlds

Connecting Electronic Institutions with 3D Virtual Worlds

To generate a mapping between entities of the 3D Virtual World and the Electronic Institution, two steps need to be carried out. First, a floor plan that specifies the layout of rooms and doors in the 3D Virtual World must be created. Second, the rooms and doors need to be linked to the entities of the Electronic Institution (scenes and transitions).

In a straightforward approach scenes are mapped onto rooms and transitions are mapped onto doors. This is illustrated in Figure 3, where the scenes of an Auction Electronic Institution are directly mapped onto rooms in the 3D Virtual World: the Information Scene is mapped onto the Information Room, the Auction Scene onto the Auction Room and the Clearing Scene onto the Clearing Room. If two scenes are connected in the Auction Electronic Institution, the corresponding rooms are connected by a door.

The 3D Virtual World in Figure 3 is populated by five avatars of which four are visual representations of autonomous agents and one avatar is controlled by Elaine. The relationship between agents in the Electronic Institution and the avatars in the 3D Virtual World is illustrated

by the symbols underneath each avatar. For example, the autonomous agent in the Auction Scene is visualized by the avatar standing in the Auction Room. The figure also includes two exemplary message exchanges between the 3D Virtual World and the Electronic Institution. These are explained in more detail in the next Section.

The relationship between the entities of the Electronic Institution and the 3D Virtual World is defined in a mapping specification. Such a specification contains the following elements: the Scene-Room relationship specifies which scene is mapped onto which room, the Transition-Door relationship specifies which transition is mapped onto which door and the Role-Avatar relationship specifies visual cues for agent roles. A visual cue helps to visually identify the duties of a certain avatar. For example, the role of a sale agent might require the avatar to wear a specific work dress. The user is then able to easily identify a sales agent in the virtual world.

The mapping must be provided for each Electronic Institution individually and is defined in an XML document. This document is parsed by the Torque server in order to trigger the appropriate actions when a user moves between rooms. Furthermore, the Torque server uses the mapping information to appropriately visualize autonomous agents.

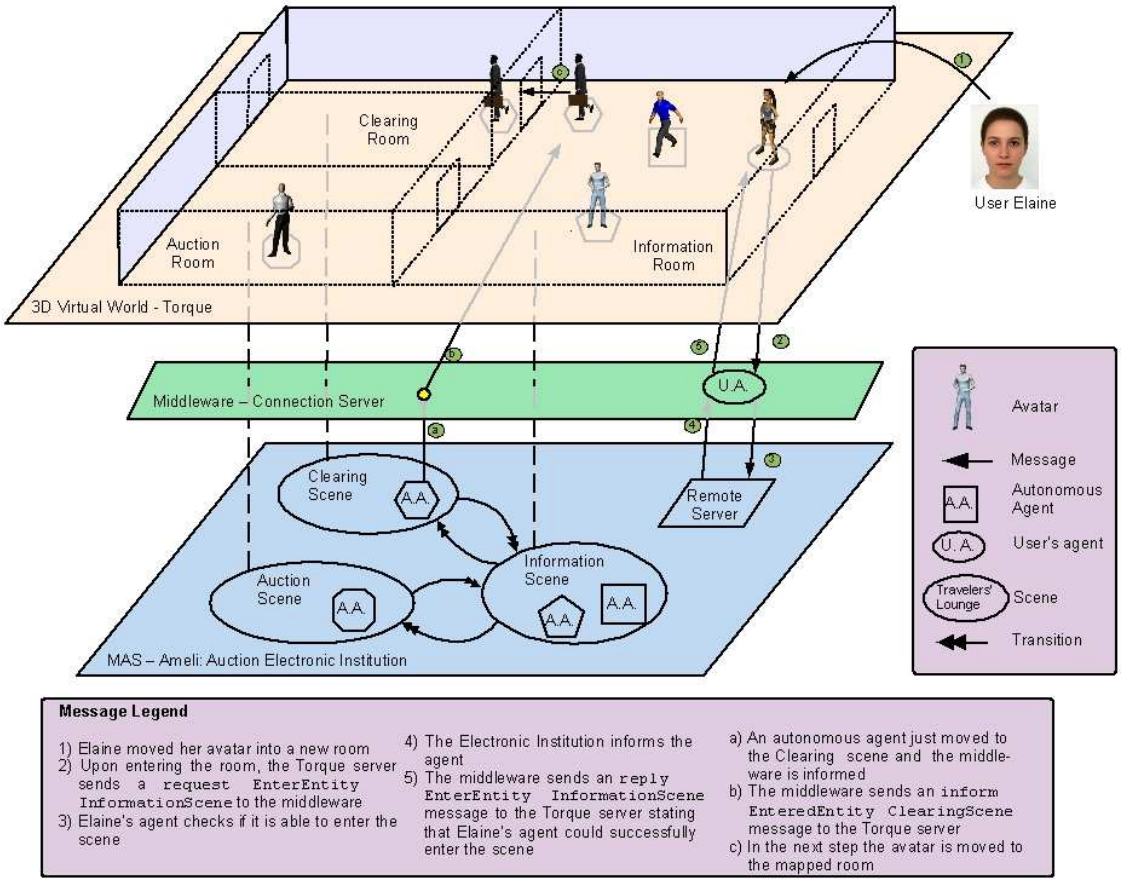

Figure 3: The component interplay in the 3D e-Business system

Message Protocol

Messages that are exchanged between the 3D Virtual World and the middleware layer are defined in a message protocol. These messages are organized in three different categories. Status messages are used to query Ameli about the current state of the system. Action messages are sent whenever an action takes place in the 3D Virtual World or in the Ameli system. Error messages are used to indicate a failure.

The message protocol is based on the following basic message types:

- request (request an action to be performed, request information)
- response (successful response to a request)
- error (error message, used as response to unsuccessful requests)
- inform (information message, inform the other part, no response is expected)

Messages contain a header and a content section. The header identifies the recipient in order to ensure appropriate delivery of the message. The content section holds the actual information. In general, the majority of the messages in the message protocol correspond to an event that may occur in the Ameli system. The messages are used to abstract the events and to extract and forward only the relevant parts of each event. For example, if an autonomous agent enters a scene, the event `EnteredSceneEvent` occurs in Ameli. The middleware is notified that this event has happened and informs the 3D Virtual World with an `inform EnteredEntity Scene` message. The message protocol is implemented in XML and the XML representation of an `EnteredEntity` message is shown in Listing 1.

```
<CS3DMessage id="32">
  <header>
     <particle>inform</particle>
     <platform>ItchyFeet</platform>
     <federation>ItchyFeet-Federation</federation>
     <ei>Auction</ei>
  </header>
  <content>
     <EnteredEntity direction="cs-3d">
        <entityType>scene</entityType>
        <name>InformationScene</name>
        <avatarid>Auctioneer</avatarid>
     </EnteredEntity>
  </content>
</CS3DMessage>
```

Listing 1: XML representation of an `EnteredEntity` message which is sent between the middleware and the 3D Virtual World

The communication between the middleware and the 3D Virtual World can be split into two different types of communication patterns.

First, the actions of autonomous agents must be visualized in the 3D Virtual World. To this end, the message protocol contains messages that are used to inform the 3D Virtual World about the movement or actions of agents. Examples of such messages are the different instances of `EnteredEntity` messages. They are used whenever an autonomous agent entered a certain entity in the Ameli system and the mapped avatar must perform a movement in the 3D Virtual World. In the case of an `inform EnteredEntity Scene` message, the autonomous agent entered a new scene and, as a consequence, the corresponding avatar must be moved to the mapped room in the 3D Virtual World. Whenever this message is received, the 3D Virtual World looks up in which room the scene is visualized and moves the avatar to the corresponding room.

An example of such a message exchange is shown in Figure 3 (messages a-c). In this example an autonomous agent has just entered the Clearing scene. The Ameli system sends out a message to the middleware layer (message a) which is forwarded to the corresponding avatar in the 3D Virtual World (message b). As a consequence, the avatar must be moved from the Information Room to the Clearing Room (message c).

Second, action requests by users must be validated in the Ameli system. Whenever a user performs an action in the 3D Virtual World, this action must be verified by her agent in the Ameli system. This communication consists of a request and a response message. Figure 3 exemplifies the use of these message types (messages 1-5). We can see that Elaine just entered the Information Room in the 3D Virtual World (message 1). Her corresponding agent also referred to as Controlled Agent must now move to the mapped scene in the Electronic Institution. For this reason a `request EnterEntity InformationScene` message is sent to the middleware (message 2). Elaine's Controlled Agent forwards the request to the Ameli layer where the agent tries to enter the Information Scene (message 3). The response is then sent to the agent (message 4) and forwarded to the 3D Virtual World by the agent (message 5).

If the agent could enter the scene the Ameli system reflects the same state as the 3D Virtual World. However, if the agent could not enter the scene, Elaine must leave the room in order to guarantee the consistent relationship between the system and its representation. This is resolved by teleporting the user out of the room.

Framework and User Administration

The management of users in the framework is accomplished by a dedicated Electronic Institution called Ether Electronic Institution. The Ether Electronic Institution is somewhat special, because it does not have a visual representation like the other Electronic Institutions in the framework. Services in the Ether Electronic Institution are accessible independent from a user's current location in the 3D Virtual World. The name is derived from the physical concept of Ether, a term used in ancient science to describe a medium that propagates light. The Ether was thought to be a substance above the clouds extending everywhere in space. In a similar manner, the Ether in our framework can be thought of as a medium that occupies every point in the 3D Virtual World.

In its general form, the Ether Electronic Institution provides services for user registration, user management and user login. Depending on the application domain of the 3D e-Business

environment, additional functionalities can be added to the Ether Electronic Institution. For example, in a shopping related environment, the functionality of a shopping cart might be realized in the Ether Electronic Institution.

The administration of the framework can further be controlled by an Administration Tool. This tool enables administrators to start and stop the different components of the environment, to configure the system and to manipulate user accounts – i.e. user accounts can be created, modified and deleted. The administration interface of Itchy Feet is depicted in Figure 4. It contains a management for user accounts and has been extended by numerous other functions to be able to manipulate the domain specific data of Itchy Feet. The interplay of the interface with the other system components is shown in Figure 2.

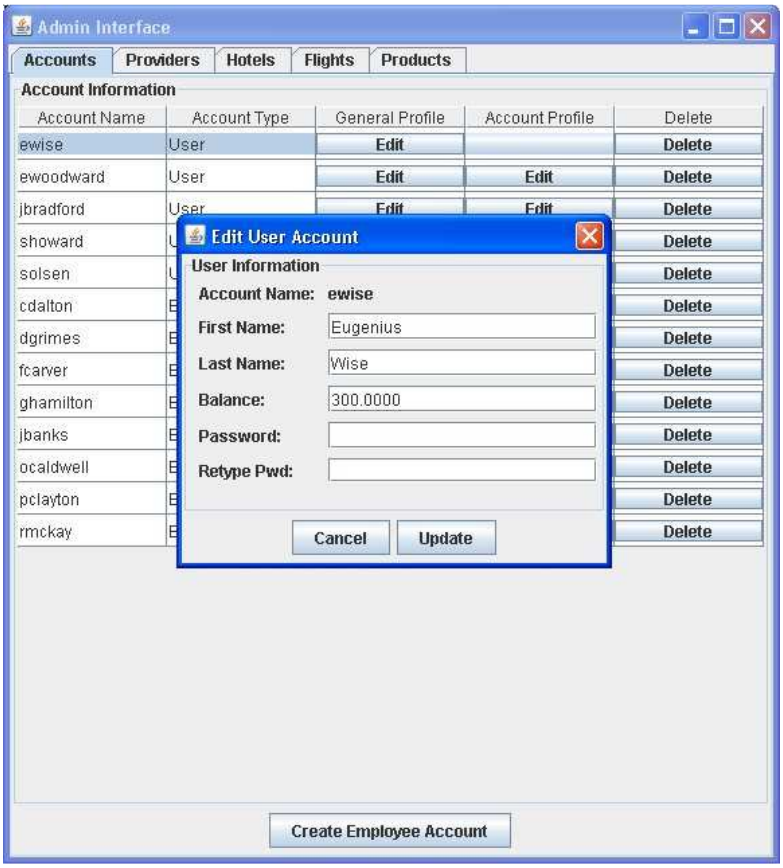

Figure 4: The Administration Tool for the data model used in the framework

5 ITCHY FEET

The general e-Business framework is showcased by an application in the domain of tourism. This application is a trading environment where users can engage in the trade of tourism products through the interaction with software agents in the 3D Virtual World. The user is able to pass the whole process of purchasing a tourism good: from the search over the selection to the actual payment.

The landscape of Itchy Feet's 3D Virtual World is depicted in Figure 5. Itchy Feet is composed of three buildings connected by paths and the Ether. The Ether is a medium that surrounds users of Itchy Feet, providing location independent services to all users. Every building as well as the Ether is mapped onto an Electronic Institution in the Multi-Agent System layer. In the following we will give a description of the Electronic Institutions within Itchy Feet.

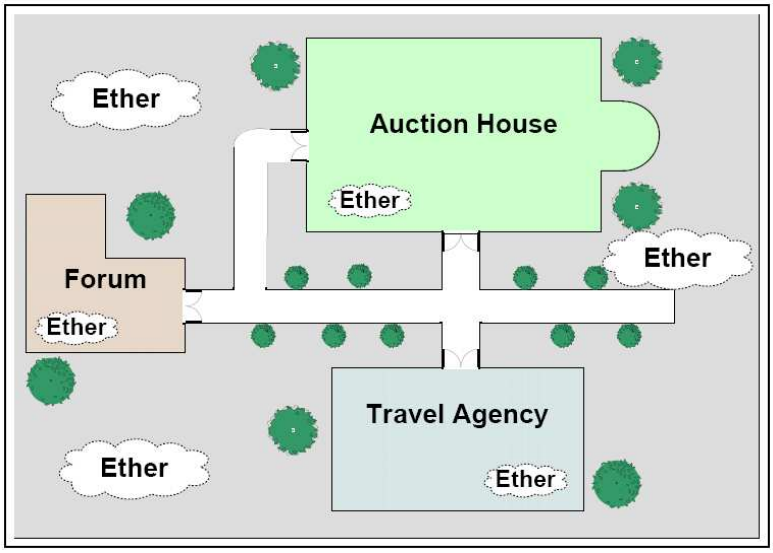

Figure 5: The landscape of Itchy Feet in the 3D Virtual World

The Ether Electronic Institution

The Ether Electronic Institution is a validation and registration service. Every user who wants to participate within Itchy Feet has to register in the Ether Electronic Institution first. Every time a user logs into Itchy Feet her credentials are validated in the Ether Electronic Institution. The Ether Electronic Institution has three scenes: the `Registration`, the `Validation` and the `Ether Scene`.

The `Registration` and `Validation Scenes` implement the registration and validation service. The `Ether Scene` provides communication services and services for listing a user's inventory, shopping cart and profile. These services can be used inside and outside of any building in the 3D Virtual World. Figure 6 depicts the Performative Structure of the Ether Electronic Institution. The key symbols identify those agent roles that instantiate (open) new scenes. The different agent roles of the Ether Electronic Institution are shown in Table 1.

Agent role	Responsibilities
RegistrationAgent	Register new users
ValidationAgent	Validate existing users
PMAgent	Deliver private messages between users
ChatAgent	Provide a chat facility to users

SalesPerson	Offer advice to users
User	Participant of Itchy Feet
AccountManager	Offer shopping cart and inventory administration services
TravelAgent	Offer travel advice to users

Table 1: The agent roles of the Ether Electronic Institution

Private messages are delivered by the `PMAgent`. A chat is established by the `ChatAgent`. An agent playing in the `SalesPerson` role offers advice to users of the chat. The `AccountManager` provides services for listing the contents of the shopping cart and inventory. This agent also participates in the Travel Agency Electronic Institution and in the Auction House Electronic Institution where it accepts payments of users. The `AccountManager` is informed of every financial transaction in Itchy Feet.

To illustrate the Ether's functionality, imagine a user playing in the `User` role. In this example as well as in the upcoming examples we assume that all scenes of the Performative Structure have already been instantiated by their scene owners (marked with the key symbol). The `User` moves from the `Entry Point` to the `Registration Scene` and registers with the `RegistrationAgent`. The `RegistrationAgent` creates a new user account and profile. At every subsequent visit of Itchy Feet, the user will have to move to the `Validation Scene` instead of the `Registration Scene` to get her credentials validated and to gain access.

After the registration or validation procedure, the `User` moves directly to the `Ether Scene`. She stays there as long as she is participating within Itchy Feet in order to be able to use the Ether's services. When the `User` exits Itchy Feet she leaves the Ether by moving from the `Ether Scene` to the `Exit Point`.

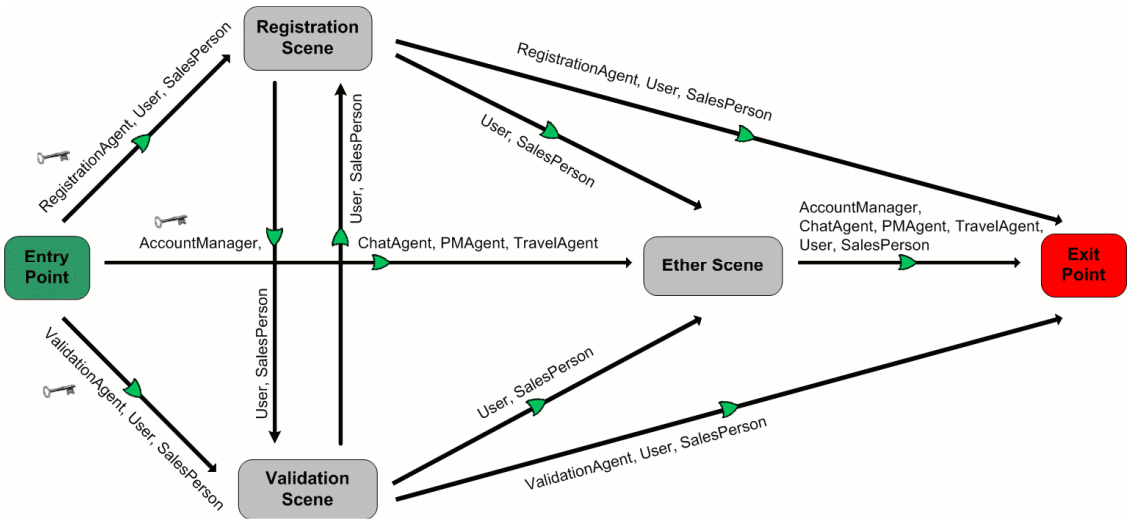

Figure 6: The Performative Structure of the Ether Electronic Institution

The Forum Electronic Institution

The Forum Electronic Institution has only one scene and is the least complex of Itchy Feet. The Performative Structure, depicted in Figure 7, consists of the `Forum Scene` which is led by the `ForumAgent`. The `Forum Scene` is directly connected to the `Entry` and `Exit Scenes` of the Forum Electronic Institution.

The Forum Electronic Institution has been realized by means of an open source forum, namely jForum[9]. A Webservice has been implemented and exposes the main functions of the open source forum such as topic or thread creation to other software components. The `ForumAgent` uses a Webservice client to access these functions. Users solely interact with the `ForumAgent`, which forwards their requests to the actual forum. The different agent roles of the Forum Electronic Institution are shown in Table 2.

Agent role	Responsibilities
ForumAgent	Pass-through services of jForum
DedicatedControlledAgent	Provide information from the ForumAgent to the public
User	Participant of the Forum

Table 2: The agent roles of the Forum Electronic Institution

An agent playing in the `DedicatedControlledAgent` role provides information received from the `ForumAgent` to the public. Such an agent could be visualized as a panel in the 3D Virtual World where the most current or most interesting threads of the forum are displayed.

To illustrate the Forum's functionality, imagine an user playing in the `User` role. The user moves from the `Entry Point` straight to the `Forum Scene`. In the `Forum Scene,` the user queries the `ForumAgent` about the latest threads. She browses the threads and wants to comment on a certain discussion. A request to create a new forum posting is sent to the `ForumAgent` which creates the posting in the external web forum. The user then leaves the `Forum Scene` and moves to the `Exit Point`.

Figure 7: The Performative Structure of the Forum Electronic Institution

The Travel Agency Electronic Institution

The Travel Agency Electronic Institution offers fixed price products. Customers may book flights, hotel rooms or all inclusive tours. The Travel Agency's Performative Structure is depicted in Figure 8.

In the `Information Scene` customers can inform themselves about products that are sold within the institution. Three `Sale Scenes` have been implemented for advising customers

individually. Every Sale Scene is equipped with a SalesPerson, an external human travel agent, who shares its knowledge and expertise with customers helping them to establish a customized travel arrangement. Flights or hotel rooms can be booked in the Booking Scene and are paid in the Clearing Scene. Product information is conveyed to the Travel Agency by using a database and external data from travel agencies on the Internet. A customer performing a search in the Travel Agency will get product results from the Auction House as well. The payment is performed by credit card in the institution's Clearing Scene. The different agent roles of the Travel Agency Electronic Institution are shown in Table 3.

Agent role	Responsibilities
HotelDataFetcher	Fetch hotel and room data from external providers
FlightDataFetcher	Fetch flight data from external providers
ProductDataFetcher	Fetch detailed product information from external providers
HotelInformationAssistant	Provide hotel and room information to users
FlightInformationAssistant	Provide flight information to users
BookingAgent	Offer booking services to users
SalesPerson	Offer advice to users
AccountManager	Offer payment services to users
DedicatedControlledAgent	Offer hotel, room and flight data to the public
User	Participant of the Travel Agency

Table 3: The agent roles of the Travel Agency Electronic Institution

An agent playing either in the HotelDataFetcher or FlightDataFetcher role provides the Travel Agency with hotel and room data from external providers. When a user performs a search, the InformationAssistant agent will query one of these agents to get corresponding data from registered external providers. This data is aggregated and combined with existing hotel and flight data in the internal database and returned to the user.

A user who is undecided about her travel plans can move to one of the Sale Scenes and get advice from a SalesPerson. If a user spots a flight or hotel she is interested in, the product can be booked in the Booking Scene. To buy the flight or hotel arrangement a user moves to the Clearing Scene and settles the invoice with the AccountManager. An agent playing in the DedicatedControlledAgent role provides flight and hotel arrangements offered in the Travel Agency to the public, for example by means of a ticker.

To demonstrate the functionality of the Travel Agency, consider a user playing in the User role. Starting at the Entry Point the user moves to the Information Scene. In the Information Scene the user decides to move to the Sale2 Scene to get advice on traveling to Scotland. Well informed the user leaves the current scene and heads back to the Information Scene where she queries the FlightInformationAssistant about flights to Scotland. Having indentified a suitable flight, the user moves to the Booking Scene and books the flight. The flight is then paid in the Clearing Scene and the user leaves the Electronic Institution by moving to the Exit Point.

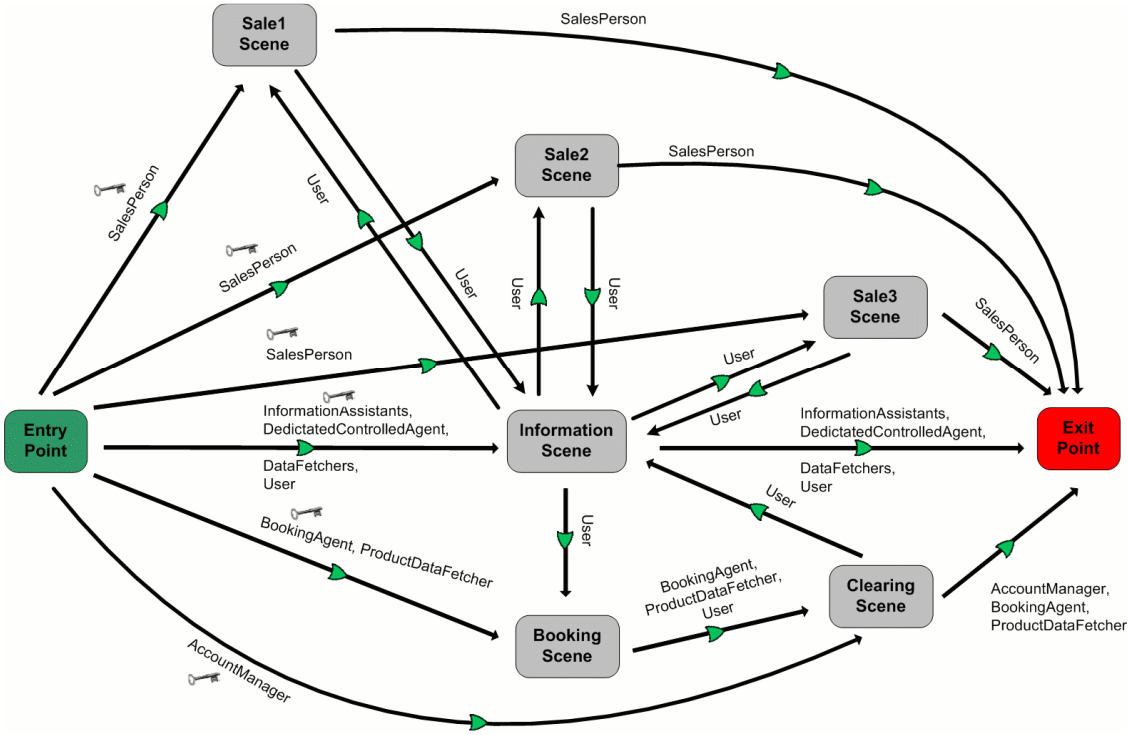

Figure 8: Performative Structure of the Travel Agency Electronic Institution

The Auction House Electronic Institution

In the Auction House Electronic Institution, flight and hotel room arrangements are auctioned. The Performative Structure, depicted in Figure 9, shares similarities with the Travel Agency.

The Auction House's `Offering Scene` is the central meeting place for the `OfferManager`, the `DataScouts`, the `Auctioneers` and the `InformationTransferAssistent`. `DataScouts` register products that have been fetched from the internal database with the `OfferManager`. The `OfferManager` then contacts the `Auctioneers` to sell them. Demand and supply is overseen by the `OfferManager`, which may instruct `DataScout` agents to bring in new products. The `InformationTransferAssistant` moves between the `Information` and the `Offering Scene` to provide the latest product information to the `InformationAssistants`.

The `Information Scene` is populated with `Users` and `InformationAssistants`. Users may query `InformationAssistants` about currently offered products. The products are auctioned in one of the three `English Auction Scenes`. Every auction scene is populated with an agent playing in the `Auctioneer` role and several users playing in the `Customer` role. A user changes its role from `User` to `Customer` as soon as she enters the `Auction Scene`. If a user has purchased a product, she has to move to the `Clearing Scene` to pay for it. The `Clearing Scene` is led by the `AccountManager` which accepts

payment and assigns the ownership of a product to a customer. The different agent roles of the Auction House and their responsibilities are summed up in Table 4.

To illustrate the functionality of the Auction House, consider a user playing in the `User` role. Starting at the `Entry Point`, the user moves to the `Information Scene` and informs herself about ongoing auctions. An auction for a flight to Ibiza is held in the `English Auction Scene 2`. The user is interested in travel arrangements for Ibiza and directly moves to this scene. In the `English Auction Scene 2` the user engages in the auction, bids several times and is finally announced the winner. The user then moves to the `Clearing Scene` where she pays for the product and the ownership is transferred to the user.

Agent role	Responsibilities
OfferManager	Oversee demand and supply, instruct DataFetcher agents
Auctioneer	Lead auctions
DataScouts	Fetch detailed product information from external providers
HotelInformationAssistant	Provide hotel and room information to users
FlightInformationAssistant	Provide flight information to users
InformationTransferAssistant	Transfer information between Information and Offering Scene
AccountManager	Offer booking services to users
DedicatedControledAgent	Offer hotel, room and flight data to the public
User	Participant of the Auction House

Table 4: The agent roles of the Auction House Electronic Institution

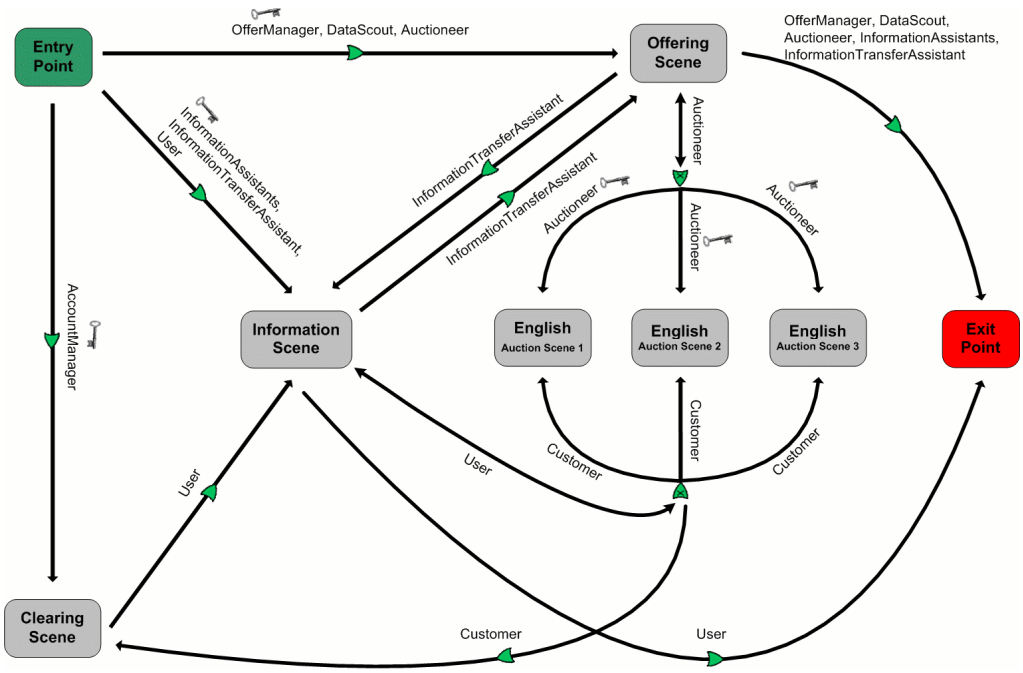

Figure 9: The Performative Structure of the Auction House Electronic Institution

The 3D Virtual World

The 3D Virtual World of Itchy Feet provides a visual representation of the presented Electronic Institutions. Except for the Ether Electronic Institution, the functionality of an Electronic Institution is within the scope of a building in the 3D Virtual World. Auctions can be performed in the Auction building, information gathering and product trade takes place in the Travel Agency building and participation in the forum is possible in the Forum building. The buildings have entry and exit doors and contain rooms that are connected via doors.

The Forum building contains one room, since all the functionality of the Forum Electronic Institution is provided in one scene. In this room, the user can launch a 2D forum interface and is able to browse the forum, create posts and start new threads. The forum interface is displayed in Figure 10. Elaine has started the forum interface and is currently showing the "Car rental in Romania" thread. She can engage in the conversation by entering a new message in a message box at the bottom of the list. Furthermore, the most interesting discussions will be projected onto walls where they can be read and followed by multiple users simultaneously.

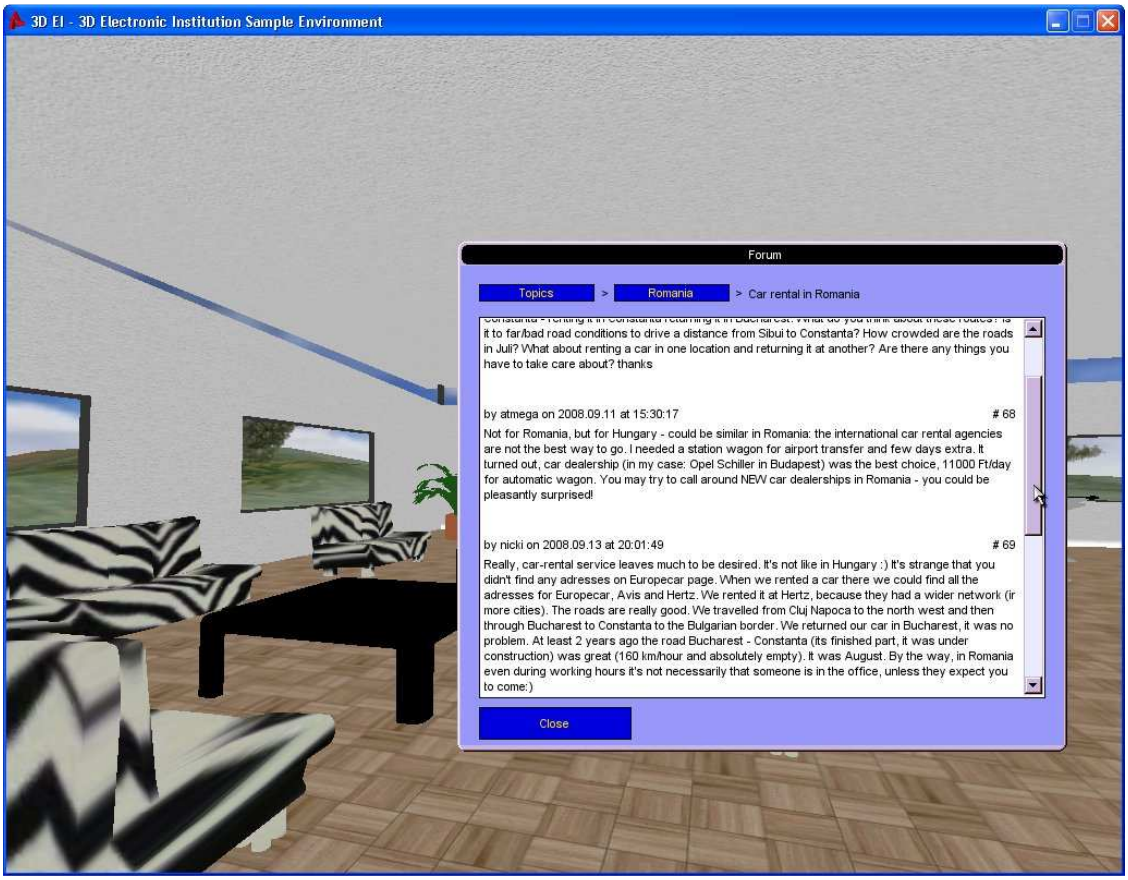

Figure 10: The Forum interface in the Forum building

The Auction building contains four rooms: an Information room, three Auction rooms and a Clearing room. In the Information room upcoming auctions are displayed, the three Auction

rooms are used to conduct auctions and in the Clearing room products are paid. A user participates in an auction by entering the current bid into an input box and confirming the bid. The current state of the auction is broadcast to all participants and displayed on the user's interface. When a user wins an auction, the product is placed in her shopping cart and can be paid in the Clearing room. The payment information is entered via a 2D input mask. When the product has been paid, it is transferred to the user's inventory.

In the Travel Agency building information facilities are available and the trade of fixed price products takes place. The building consists of four rooms whereof three rooms are Sale rooms and one room is the main Information room. In the Sale rooms, users can get professional help from travel agents that are also logged in the 3D Virtual World and are represented as avatars. Similar to a travel agency, a user can directly interact with another human being, ask specific questions and let the travel agent take care of the booking. In the main Information room, the user is able to search for tourism products. The search facilities are 2D interfaces in which the query is entered and the aggregated results are presented in a list-style manner. Products that have been selected by the user are placed in the user's shopping cart. The payment of products is similar to the Auction building; the payment information is entered by the user via an input mask. As soon as the products have been paid, they are transferred from the cart to the user's inventory.

Trading

The current version of the prototype supports two different kinds of products: flights and hotels. A hotel product represents a reservation for a hotel room while a flight product represents a seat reservation for a certain flight. Furthermore, products can be distinguished by two additional attributes.

The first attribute defines how a product is sold. A product is either a fixed price product or an auction product. A fixed price product is sold for a fixed price in the Travel Agency building while an auction product is sold via an English auction in the Auction building.

The second attribute defines how products are added to the system. A product is either added manually to the system or via a third party product data provider. Products can be added manually with the Administration Tool - a wizard is used to define the attributes and content of the product. Alternatively, products are created automatically based on real world product information of third party tourism product providers.

When the user searches for a certain kind of product, e.g. a hotel room in Vienna, the software agents in the Ameli system query several hotel search interfaces on the Internet. The search results are merged and presented to the user in the 3D Virtual World. If the user decides to buy one of the externally retrieved products, a new "virtual" product is created within the system. This virtual product contains the same information as the external one and can be sold to the user within the system.

The product purchase process is the same as in known interfaces. The user enters the Travel Agency building in the 3D Virtual World and issues a search request. The request is then sent to the user's Controlled Agent which issues the request in the Ameli system. This triggers the

autonomous agents to search for information in the internal database as well as in external data sources. All the results are merged and presented to the user in a coherent format. The user can browse the list and select certain offers that are placed in the user's shopping cart.

In a similar fashion to a real world store, the products are to be paid at a counter before the user leaves the building. The user is not allowed to leave the building if unpaid products remain in the shopping cart. The paying process is conducted with a credit card. The user enters the credit card information and the products move from the shopping cart to the user's inventory. If the user decided to buy a product that has been retrieved from an external data source, a new virtual product is created in the internal database. The creation process in the internal database is delayed until this moment in order to avoid a creation overhead and to only create products that are really needed internally.

The representation of products within the system closely resembles the way how tourism products are managed in the real world. We use the concept of room and flight contingents that can be purchased by so called providers.

A provider is a company that buys room contingents from hotels or seat contingents from air line companies and sells them to customers. The provider pays a fixed amount for a certain contingent and defines the prices for individual rooms and seats. In our model, a room or seat can only be sold if it is contained in the contingent of a provider and has an assigned price.

A product itself contains seat or room reservations identifying the seats and rooms that are sold in this product. In the case of a fixed price product, the product price is the sum of all rooms or seats contained in the reservation. In the case of an auction product, a start price has to be defined and the product will be sold for the end price that is reached in the auction. Only manually added products may be sold in an auction.

User Profiles

Profiles are one of the cornerstones of most successful and popular social networking sites like Facebook[10] or MySpace[11]. A profile is a concise representation of a user's personality and interests, allowing other users to easily get an impression of the person behind the nickname/avatar.

In Itchy Feet we also support profiles. They are filled out upon registration and can be modified later from within the 3D Virtual World. The profiles contain personal information like name, age or nationality and more touristic related information like traveler type, favorite countries or traveled countries. The Controlled Agent stores the profiles on the middleware layer and controls access to them. Hence, the Controlled Agent defines which other software agents/components are allowed to access which kind of information. A property that is especially important in the case of confidential information like credit card numbers.

Participation

This Section aims to give a general overview of the functionalities of the Itchy Feet platform by attending Elaine who visits the different places within the 3D Virtual World. Before she is able to visit the platform, Elaine must complete the registration process and is then able to use her personalized alter ego represented as a 3D character.

When Elaine walks around in the 3D Virtual World, her Controlled Agent performs the same movements in the Electronic Institution. We will illustrate how Elaine's agent moves around in the Electronic Institution and show which entities are entered and exited. Elaine will then post a question in the message forum and we will show how the message is sent to the `ForumAgent` in the Forum Electronic Institution.

In detail, users participate in the Itchy Feet system via the 3D front end, i.e. the 3D Virtual World. Currently we support two different types of user roles which are customer and employee. A customer is the common type of user that participates in the system to gather information, socialize with other users and purchase products. An employee works for a certain provider and can offer professional help to customers seeking for certain information or products. An employee is much like a travel agent in a travel agency.

The login procedure

The first time a user connects to the 3D Virtual World, she is guided through a series of screens where a user name has to be chosen and personal information about this user is gathered. A customer account can be created by anyone, while an employee account must already exist in the system before an employee connects for the first time. Upon finishing the registration, a new Controlled Agent is instantiated and associated with the new user. The entered data is stored by the Controlled Agent on the middleware layer, which also controls access to this data. Further, this Controlled Agent is used to represent the user within the Ameli system.

When the user has finished the registration phase or logs into the system, she is spawned as a new avatar in the 3D Virtual World. At the same time the Controlled Agent enters the Ameli system and also moves into the Ether Electronic Institution. This process is illustrated in Figure 11. The Figure shows the 3D Virtual World in the upper right corner and a monitoring tool of the Ameli system in the lower left corner.

The monitoring tool displays the current state of the Ameli system. In the left part all the agents that are currently present in the system are shown. In Ameli, Electronic Institutions are organized according to a three layered structure. An Electronic Institution is executed within a Federation, which is executed within a Platform. In the monitoring tool we can see that Elaine's agent has entered the Platform "ItchyFeet", the Federation "ItchyFeet-Federation" and the Electronic Institution "Ether". All the messages that have occurred in Ameli are shown in a list in the right part. In the area below the list, more detailed information for selected messages is displayed.

As can be seen in Figure 11, Elaine has been spawned in the 3D Virtual World as a new avatar. Note that Elaine is a gender bender and has selected a male avatar. The monitoring tool shows that her Controlled Agent has entered the system (1) and is now participating in the Ether Electronic Institution (1,2).

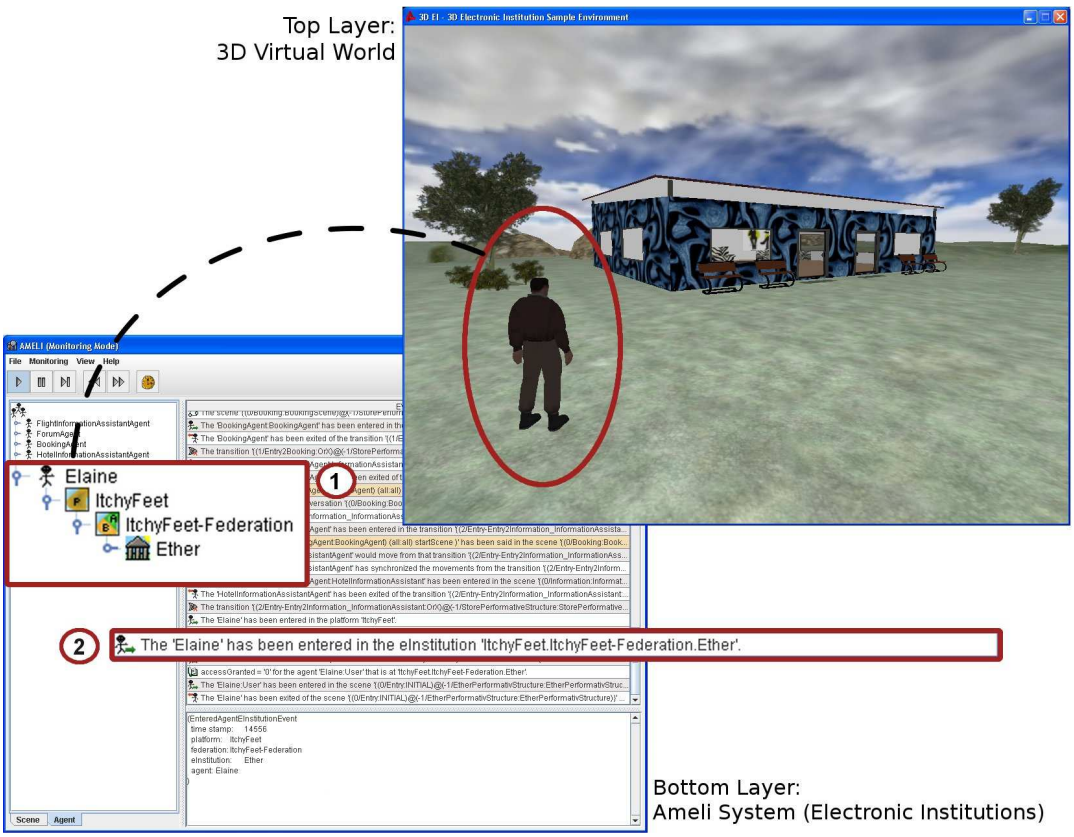

Figure 11: The user Elaine has entered the 3D Virtual World which triggered her Controlled Agent to enter the Ether Electronic Institution

Moving around in the 3D Virtual World

The avatar movement is controlled by the keyboard and the looking direction is controlled via the mouse. In the 3D Virtual World the user is able to either perform actions that are permitted in the Ether Electronic Institution or she can walk around in the world and enter one of the three buildings.

The user can enter a building by pressing a certain key when standing in front of a door. The door will open and the user can enter the building. As soon as the building has been entered by the user, the Controlled Agent tries to enter the Electronic Institution that is mapped onto this building. Depending on the user's movement within the building, the Controlled Agent "follows the movement" in the Electronic Institution and tries to enter scenes and transitions.

This process is exemplified in Figure 12. Elaine has just entered the Forum building in the 3D Virtual World and is now standing inside the building. In order to maintain the consistent relationship with the Ameli system, Elaine's Controlled Agent must enter the Forum Electronic Institution. This action has been executed successfully and Elaine's agent is now also present in the Forum Electronic Institution (1) and has entered the Forum Scene (2) in this Electronic Institution.

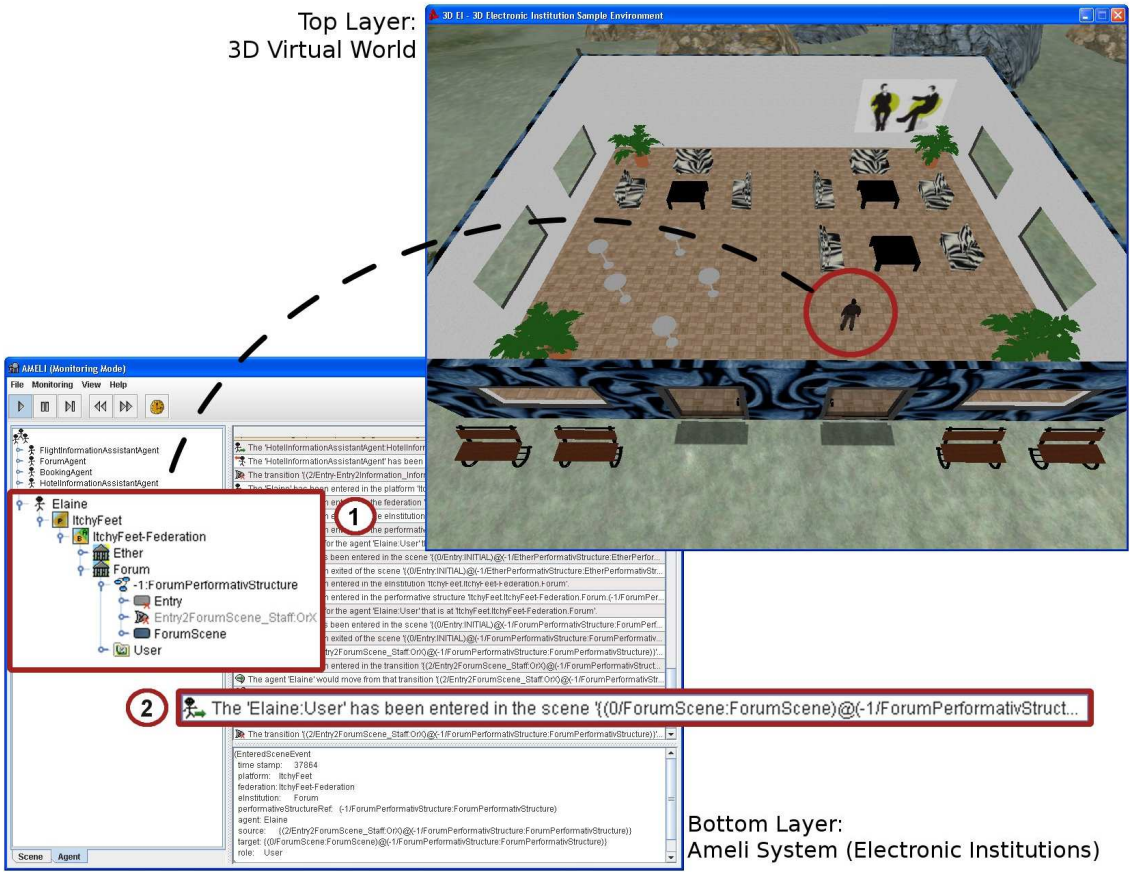

Figure 12: The user Elaine has moved into the Forum building which triggered her Controlled Agent to enter the Forum Electronic Institution

Entering a building

Inside a building, the user is able to execute the business processes that have been defined in the underlying Electronic Institution. In the case of the Forum building, the functionalities are defined in the Forum Electronic Institution. According to the Electronic Institution specification, a user is able to view threads and postings, can create new threads and is able to post messages.

These functions are realized in the 3D Virtual World via a 2D forum interface. Upon launching the interface, a request for the forum topics is sent to the user's Controlled Agent, which, in turn, sends a request to the `ForumAgent` for the currently available topics. The message is returned to the 3D Virtual World by the Controlled Agent and the topics are listed in the forum interface. The user is then able to browse the topics, show the threads of a topic and

show the postings of a thread. The respective thread or post information is also retrieved via the user's Controlled Agent and the `ForumAgent`. The same applies to the creation of new threads and posts.

In Figure 13, Elaine has launched the forum interface and is currently viewing the topic "Romania" and the thread "Car rental in Romania". The posts of the thread are displayed in a scrollable list. A new post can be created via the text area at the bottom of the list. Elaine has just entered a new message and presses the button "Post Message" (1). A post creation request is sent to her Controlled Agent. The agent sends the message "post" to the `ForumAgent` in the Ameli system (2,3). The message is processed by the `ForumAgent` and a new post is created in the external web forum.

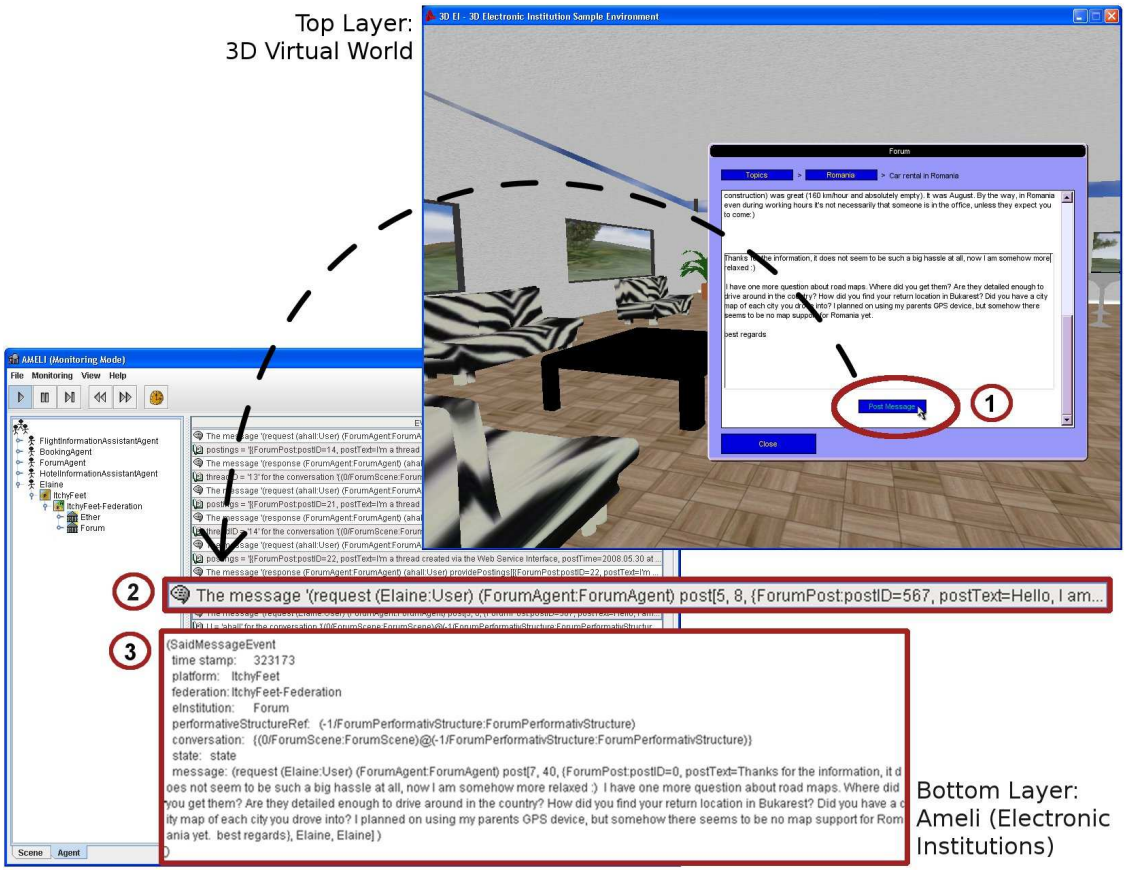

Figure 13: The user Elaine is posting a message in the Forum building, her Controlled Agent is uttering the message in the Forum Electronic Institution

6 DISCUSSION

The presented framework utilizes ideas from different research approaches to create a new type of interactive social community platform. A 3D Virtual World is used to overcome the lack of human warmth and social presence which is often perceived in traditional online e-Commerce

web sites. In a 3D Virtual World the awareness of other users is more explicit and the metaphors are more similar to the real world. These similarities might help users to engage in conversations and other familiar communication mechanisms, such as gestures, can be used as well.

The social presence that is established can help to increase the trust and loyalty of users into the e-Commerce system. A property that is especially crucial in e-Tourism systems where the quality of a product cannot easily be assessed and the customer needs to build up a trust relationship to the provider. In this context, the 3D Virtual World also enables new forms of product presentation through the visualization of a product in a 3D space. This can range from replications of hotel rooms over tourism destinations to material products such as backpacks or camping gear. The product can be experienced in more depth and the customer is able to get insights that might not have been possible with other presentation formats.

Electronic Institutions

The security of the system is warranted through Electronic Institutions. The business processes as well as the permitted actions of all participants are rigorously defined and verified by Electronic Institutions. Again, this is useful for building up a trust relationship between customer and provider and is advantageous for both parties. The customer can be sure that sensitive information and money transactions are handled correctly and the provider has the guarantee that only paid products are sold.

In the Electronic Institution software agents are responsible to carry out defined tasks within the limits of the formal specification. Besides being responsible for business transactions, software agents are used to fulfill additional functions. They carry out the tasks of information retrieval, aggregation and presentation as well. This further helps to satisfy the information demand of the customer and provides additional information for making a well-grounded buying decision.

Online Communities

The online community is a channel for the provision of up-to date touristic information and helps to create an active user base. One of the major future challenges within the project will be the development of strategies for fostering a lively society and establishing a successful online community. It is crucial to follow a certain strategy when developing an online community and to know which kind of community should be established.

In the area of community research three prevalent terms and conditions are defined: Community of Practice, Community of Interest and Community of Knowledge (Lindstaedt, 1998; Lave & Wenger, 1991). In the Community of Interest social interaction and communication are the central aspects. In contrast, the Community of Knowledge is basically knowledge-oriented, is created within corporations and is not voluntary. The Community of Practice is defined as the concept of apprenticeship. It is a practice oriented consortium that focuses on the development of knowledge and methods to solve problems based on a communication process between apprentice, who asks a question and the supervisor who knows the answer.

When an online tourism community follows the Community of Interest approach it is usually created by individuals to share the collective interests of travelling, while in the Community of Practice approach the community is mostly business-initiated and focuses on the provision of knowledge. In this regard the business-initiated tourism community in Itchy Feet should be developed using the proven concept of Community of Practice to fulfill the aim of developing collective tourism knowledge. It consists of five phases of development as well as the promotion of a well-running community platform (Wenger, McDermott, & Snyder, 2002).

A Community of Practice comprises of three components: domain, community and practice. The domain is the common body of knowledge. The members of the community agree to the constraints of the domain, and decide which activities and content are relevant. The community is comprised of the social interaction between community members. The practice is defined by the concept of apprenticeship as described before.

A Community of Practice is developed in five phases. In the first phase one or more persons attend to a certain topic. In the second phase the basic structure, the tasks and communication channels are defined. The third phase is the main phase. It is characterized by the knowledge exchange and the evaluation of the aims, tasks and communication channels. In the fourth phase the knowledge exchange eventually results in community members no longer carrying out any activities within the community. Finally, in the fifth phase there is no further demand for information and the Community of Practice ceases to be an information exchange. In order to counteract the fourth and fifth phases a concept has been developed to make sustainable online communities: Design for evolution, open a dialogue between inside and outside perspectives, offer different levels of participation, develop both public and private places, focus on value, combine familiarity and excitement and create a rhythm for the community (Wenger, McDermott, & Snyder, 2002).

Technical Discussion and Opportunities for Future Research

The realization of the environment was started with the implementation of the general framework connecting arbitrary Electronic Institutions with 3D Virtual Worlds. A middleware layer had been developed for the message exchange between the two systems and for the control of the user's agent. The Torque game engine was extended to communicate with the middleware layer, to observe and control the user's movements and to control the visualization of autonomous agents. Originally it was planned that the framework is flexible enough to support an easy change of the 3D Virtual World. However, it turned out that the 3D Virtual World needed more additional functionality than we had initially thought. As we had already implemented these features in the Torque game engine, we decided to concentrate on this game engine and make it the primary 3D Virtual World for the framework.

After finishing a proof of concept implementation of the general framework, we focused on e-Tourism as specific application domain and started with the development of Itchy Feet. After a thorough requirements analysis and design, we implemented the domain specific data model and

the Administration Tool to manage this data. At the same time, the Electronic Institutions were specified. By now the following features have been implemented:

- Tourism specific data model (e.g. including flights, hotels, contingents)
- Administration Tool for the management of the data model and configuration of the components
- Specification of all Electronic Institutions
- General Framework
- Forum Electronic Institution (agents, visualization, data binding to external open source forum)
- User participation in the 3D Virtual World and in the forum

Currently we are working on the implementation of the software agents and the visualization of the Electronic Institutions in the 3D Virtual World. The final application will include the following features:

- Implementation and visualization of all Electronic Institutions
- Users have access to all Electronic Institution functionalities in the 3D Virtual World
- Product search and purchase in the 3D Virtual World
- Community features – chat, profiles, instant messaging
- Support of multiple users
- Visualization of travel destinations and tourism products (e.g. hotel rooms)

In the process of development we encountered some restrictions and problems. The Ameli infrastructure and the Electronic Institutions Development Environment (EIDE) contain some bugs that occurred during development. The Agent Builder has problems with generating source code out of an agent specification and has difficulties with reading certain Electronic Institution specifications correctly. Sometimes the wrong scene or transition shows up when an agent's functionality is defined. The Islander, a tool to specify Electronic Institutions, has a saving issue and sometimes overwrites previously defined specifications with the current one.

The Torque game engine also turned out to be not as suitable as we had expected and contains some restrictions. The engine only provides very basic data structures and in order to use more sophisticated ones, the engine has to be manually patched and adapted. The editors are not a separate product but are mangled into the game engine and script code base. Thus, when custom changes are applied to the engine or the engine is updated, the editors can be affected of these changes and some functions may become inaccessible or the editors even stop functioning completely. Furthermore, it is difficult to add 3D content to the world as Torque requires models to have a certain structure that must be manually created in a 3D graphics application. Several other Torque internals have complicated the development even further.

7 CONCLUSION

In this chapter we have presented the concept of a 3D e-Business environment combining Electronic Institutions with 3D Virtual Worlds. Electronic Institutions are used to regulate the

environment and to provide a framework for software agents. These software agents render the environment information rich with the ability to collect, aggregate and present data. Furthermore, they assist the user in the 3D Virtual World, help her to understand the environment and autonomously process tasks that the user has delegated to them. The 3D Virtual World provides familiar surroundings for users where the same metaphors apply as in the real world. Social interaction is implicitly addressed in such environments and the 3D Virtual World shall help to establish a lively community.

This general framework has been applied to the tourism domain in the Itchy Feet project. The proposed environment offers several advantages over traditional tourism information systems. The creation of a tourism community is in line with the current trend in ICT, where customers are using online communities to share knowledge and to get information on travel destinations. Furthermore, information needs are satisfied by software agents that collect and present information to the customer in the 3D Virtual World. The 3D presentation of products enables customers to get better insights on the final product; a feature that is especially important in the tourism domain where products usually cannot be tested in advance.

The acceptance of the developed system will be tested in a usability study. For this study we are going to create an evaluation framework for 3D Virtual Worlds. The basic framework will be general enough to also be used in other 3D Virtual World evaluations. A more specific version will be created that is tailored at the tourism domain and captures domain specific properties more accurately.

ACKNOWLEDGMENTS

This work is funded by the FWF Austrian Science Fund (project reference: L363).

REFERENCES

Aldewereld, H., Dignum, F., Garcia-Camino, A., Noriega, P., Rodriguez-Aguilar, J. A., & Sierra, C. (2006). Operationalisation of norms for usage in electronic institutions. *Proceedings of the fifth international joint conference on Autonomous agents and multiagent systems (AAMAS '06)* (pp. 223-225). New York, NY, USA: ACM Press.

Adobbati, R., Marshall, A. N., Scholer, A., Tejada, S., Kaminka, G., Schaffer, S., & Sollitto, C. (2002). Gamebots: a 3D virtual world test-bed for multi-agent research. *Communications of the ACM, 45* (1), 43-45.

Berger, H., Dittenbach, M., & Merkl, D. (2004). User-oriented evaluation of a natural language tourism information system. *Information Technology and Tourism, 6* (3), 167-180.

Bogdanovych, A., Berger, H., Simoff, S., & Sierra, C. (2006). Travel agents vs. online booking: tackling the shortcomings of nowadays online tourism portals. *Proceedings of the 13th*

International Conference on Information Technologies in Tourism (ENTER'06) (pp. 418-428). Vienna, Austria: Springer-Verlag.

Castronova, E. (2005). *Synthetic worlds: the business and culture of online games.* Chicago, IL, USA: University of Chicago Press.

Chao, D. L. (2001). Doom as an interface for process management. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '01)* (pp. 152-157). New York, NY, USA: ACM Press.

Chiu, D. K., & Leung, H. (2005). Towards ubiquitous tourist service coordination and integration: a multi-agent and semantic web approach. *Proceedings of the 7th International Conference on Electronic Commerce (ICEC '05)* (pp. 574-581). New York, NY, USA: ACM Press.

Cuni, G., Esteva, M., Garcia, P., Puertas, E., Sierra, C., & Solchaga, T. (2004). MASFIT: Multi-Agent System for fish trading. *Proceedings of the 16th European Conference on Artificial Intelligence (ECAI '04)* (pp. 710-714). Amsterdam, Netherlands: IOS Press.

Cyr, D., Hassanein, K., Head, M., & Ivanov, A. (2007). The role of social presence in establishing loyalty. *Interacting with Computers, 19* (1), 43-56.

Dignum, F. (2002). Abstract norms and electronic institutions. *Proceedings of the International Workshop on Regulated Agent-Based Social Systems: Theories and Applications (RASTA '02)* (pp. 93-104).

Dignum, V., & Dignum, F. (2001). Modelling agent societies: co-ordination frameworks and institutions. *Proceedings of the 10th Portuguese Conference on Artificial Intelligence : Progress in Artificial Intelligence Knowledge Extraction, Multi-Agent Systems, Logic Programming, and Constraint Solving (EPIA '01)* (pp. 191-204). London, UK: Springer-Verlag.

Dignum, V., Weigand, H., & Xu, L. (2001). Agent societies: towards frameworks-based design. In M. Wooldridge, G. Weiß & P. Ciancarini (Eds.), *Revised Papers and Invited Contributions from the Second International Workshop on Agent-Oriented Software Engineering II* (pp. 33-49). London, UK: Springer-Verlag.

DiPaola, S., & Collins, D. (2003). A social metaphor-based 3D virtual environment. *Proceedings of the International Conference on Computer Graphics and Interactive Techniques (SIGGRAPH '03)* (pp. 1-2). New York, NY, USA: ACM.

Dippelreiter, B., Grün, C., Pöttler, M., Seidel, I., Berger, H., Dittenbach, M., & Pesenhofer, A. (in press). Online tourism communities on the path to Web 2.0 - an evaluation. *Information Technology and Tourism*.

Eigner, C., Leitner, H., & Nausner, P. (2003). *Online-Communities, Weblogs und die soziale Rückeroberung des Netzes*. Graz, Austria: Nausner & Nausner.

Esteva, M., Rodriguez-Aguilar, J. A., Sierra, C., Garcia, P., & Arcos, J. L. (2001). On the formal specifications of electronic institutions. In F. Dignum & C. Sierra (Eds.), *Agent Mediated Electronic Commerce, The European AgentLink Perspective* (pp. 126-147). London, UK: Springer-Verlag.

Finin, T., Fritzson, R., McKay, D., & McEntire, R. (1994). KQML as an agent communication language. *Proceedings of the Third International Conference on Information and Knowledge Management (CIKM '94)* (pp. 456-463). New York, NY, USA: ACM.

Gratzer, M., Werthner, H., & Winiwarter, W. (2004). Electronic business in tourism. *International Journal of Electronic Business, 2* (5), 450-459.

Hassanein, K., & Head, M. (2007). Manipulating perceived social presence through the web interface and its impact on attitude towards online shopping. *International Journal on Human-Computer Studies , 65* (8), 689-708.

Hunicke, R., LeBlanc, M., & Zubek, R. (2004). *MDA: a formal approach to game design and game research.* Paper presented at the AAAI Workshop on Challenges in Game AI, San Jose, CA, USA.

Juan, T., Pearce, A., & Sterling, L. (2002). ROADMAP: extending the gaia methodology for complex open systems. *Proceedings of the First International joint Conference on Autonomous Agents and Multiagent Systems (AAMAS '02)* (pp. 3-10). New York, NY, USA: ACM Press.

Kot, B., Wuensche, B., Grundy, J., & Hosking, J. (2005). Information visualisation utilising 3D computer game engines case study: a source code comprehension tool. *Proceedings of the 6th ACM SIGCHI New Zealand chapter's International Conference on Computer-Human Interaction (CHINZ '05)* (pp. 53-60). New York, NY, USA: ACM Press.

Lave, J., & Wenger, E. (1991). *Situated learning: legitimate peripheral participation.* Cambridge, United Kingdom: Cambridge University Press.

Lindstaedt, S. (1998). *Group memories: a knowledge medium for communities of interest.* Boulder, CO, USA: University of Colorado at Boulder.

Maes, P., & Nardi, D. (Eds.). (1988). *Meta-level architectures and reflection.* New York, NY, USA: Elsevier Science Inc.

Manojlovich, J., Prasithsangaree, P., Hughes, S., Chen, J., & Lewis, M. (2003). UTSAF: a multiagent-based framework for supporting military-based distributed interactive simulations in 3d virtual environments. *Proceedings of the 35th Conference on Winter Simulation (WSC '03)* (pp. 960-968). Winter Simulation Conference.

Martin, C., Schreckenghost, D., Bonasso, P., Kortenkamp, D., Milam, T., & Thronesbery, C. (2003). An environment for distributed collaboration among humans and software agents. *Proceedings of the Second International joint Conference on Autonomous Agents and Multiagent Systems (AAMAS '03)* (pp. 1062-1063). New York, NY, USA: ACM Press.

Moloney, J., Amor, R., Furness, J., & Moores, B. (2003). Design critique inside a multi-player game engine. *Proceedings of the CIB W78 Conference on IT in Construction* (pp. 255-262). CIB Publication.

Nakanishi, H., & Ishida, T. (2004). FreeWalk/Q: social interaction platform in virtual space. *Proceedings of the ACM symposium on Virtual Reality Software and Technology (VRST '04)* (pp. 97-104). New York, NY, USA: ACM Press.

Payne, T. R., Sycara, K., & Lewis, M. (2000). Varying the user interaction within multi-agent systems. *Proceedings of the Fourth International Conference on Autonomous Agents (AGENTS '00)* (pp. 412-418). New York, NY, USA: ACM Press.

Pöttler, M. (2007). *Die Rolle von Onlinecommunities in Reise und Tourismus.* Unpublished master thesis, Vienna University of Technology, Vienna, Austria.

Rodríguez-aguilar, J. A., Martín, F. J., Noriega, P., Garcia, P., & Sierra, C. (1997). Towards a test-bed for trading agents in electronic auction markets. *AI Communications, 11* (1), 5-19.

Rollings, A., & Morris, D. (2004). *Game architecture and design.* Indianapolis, IN, USA: New Riders Publishing.

Salen, K., & Zimmermann, E. (2004). *Rules of play: game design fundamentals.* Cambridge, MA, USA: MIT Press.

Schwabe, G., & Prestipino, M. (2005). *How tourism communities can change travel information quality*. Paper presented at the 13th European Conference on Information Systems, Information Systems in a Rapidly Changing Economy (ECIS '05), Regensburg, Germany.

Seidel, I., & Berger, H. (2007). Integrating electronic institutions with 3d virtual worlds. *Proceedings of the 2007 IEEE/WIC/ACM International Conference on Intelligent Agent Technology (IAT'07)* (pp. 481-484). Washington, DC, USA: IEEE Computer Society.

Smith, G., Maher, M. L., & Gero, J. S. (2003). Designing 3d virtual worlds as a society of agents. *Proceedings of the 10th International Conference on Computer Aided Architectural Design Futures (CAADFutures '03)* (pp. 105-114). Dordrecht, Netherlands: Kluwer Academic Publishers.

Traum, D., & Rickel, J. (2002). Embodied agents for multi-party dialogue in immersive virtual worlds. *Proceedings of the First International joint Conference on Autonomous Agents and Multiagent Systems (AAMAS '02)* (pp. 766-773). New York, NY, USA: ACM Press.

Wang, Y., Yu, Q., & Fesenmaier, D. R. (2002). Defining the virtual tourist community: implications for tourism marketing. *Tourism Management, 23* (4), 407-417.

Wenger, E., McDermott, R., & Snyder, W. (2002). *Cultivating communities of practice.* Boston, MA, USA: Harvard Business School Press.

Werthner, H., & Klein, S. (1999). *Information technology and tourism, a challenging relationship.* Vienna, Austria: Springer-Verlag.

Wooldridge, M. J. (2001). *An introduction to multiagent systems.* New York, NY, USA: John Wiley & Sons, Inc.

Yee, N. (2006 a). The demographics, motivations, and derived experiences of users of massively multi-user online graphical environments. *Presence, 15* (3), 309-329.

Yee, N. (2006 b). The psychology of massively multi-user online role-playing games: emotional investment, motivations, relationship formation, and problematic usage. In R. Schroeder & A.S. Axelsson (Eds.), *Avatars at Work and Play: Collaboration and Interaction in Shared Virtual Environments* (pp. 187-207) New York, NY, USA: Springer-Verlag.

Yeung, C., Pang-Fei, T., & Yen, J. (1998). A multi-agent based tourism kiosk on internet. *Proceedings of the Thirty-First Annual Hawaii International Conference on System Sciences-Volume 4 (HICSS '98)* (p. 452). Washington, DC, USA: IEEE Computer Society.

Zambonelli, F., Jennings, N. R., & Wooldridge, M. (2003). Developing multiagent systems: the gaia methodology. *ACM Transactions on Software Engineering Methodologies*, *12* (3), 317-370.

ENDNOTES

[1] http://qdn.qubesoft.com/
[2] http://www.garagegames.com/
[3] http://www.activeworlds.com/
[4] http://java3d.dev.java.net/
[5] http://eightbar.co.uk/2007/05/08/the-ibm-innovate-quick-internal-metaverse-project/
[6] http://www.legendmud.org/raph/gaming/mudtimeline.html
[7] http://www.worldofwarcraft.com/raf-splash.htm
[8] http://starwarsgalaxies.station.sony.com/players/index.vm
[9] http://www.jforum.net/
[10] http://www.facebook.com/
[11] http://www.myspace.com/