# Chapter 1

# Introduction

In this chapter we outline the key reasons that motivated us to conduct this research and problems it attempts to address.

Our initial motivation was very practical in nature. We were concerned with the problem of improving the shopping experience of the customers in online shops. One of the possibilities to achieve this is provided with 3D[1] product presentation.

The use of 3D product presentation on the Web was a hot topic in late nineties. Many businesses tried to enhance their Internet sites with 3D models of the auctioned goods to offer customers better product presentation facilities. Unfortunately, the majority of investments in 3D shopping didn't pay off. The lack of success was usually coupled with issues like costs of 3D modeling, visualization performance and slow Internet connection [Hurst, 2000].

Nevertheless, recent developments prove that in the near future 3D models may be faster and cheaper to create than quality photographs [Frueh et al., 2005]. Furthermore, broadband Internet connection is becoming much more popular than dial-up and the performance of computers as well as the visualization algorithms have improved quite significantly. These factors turned the attention of retailers back to 3D technology.

Further in this chapter we explore the key topics that in our opinion should motivate the researchers in the area of 3D E-Commerce, highlight the important characteristics of 3D environments that improve the shopping experience and describe how those can be integrated into future E-Commerce portals.

## 1.1 Motivation

One of the reasons why researchers and developers in the nineties started to work on providing 3D visualizations of the products in the E-Commerce portals is because they saw this new technology having a potential to create more realistic experience about the product. With the help of the Internet they expected this experience to be easily transmittable to the customers, so that customers have a similar understanding of the appearance and the features of the product as they would have gotten in a real store.

[1] stands for 3-dimensional

Unfortunately, beyond these simple expectations not much research ground was laid, which became one of the reasons for the temporary retreat of 3D technology in E-Commerce.

Some studies analyzing the benefits of *3D product presentation* started to appear when the idea of 3D shopping was already well abandoned. Proving the usefulness of 3D visualization some researchers [Daugherty et al., 2005] claim that a virtual experience (3D product presentation) has the potential to be richer than both direct (manipulation with a real product) and indirect (the "classical" catalogue type of product presentation) experience because it can be simulated, framed, annotated and contextualized. However, the conducted study [Daugherty et al., 2005] showed that when tactile affordances are the most relevant for the product (e.g. touching the fabric), a virtual experience may have the same effect as indirect experience.

The possibility of *scanning physical interaction behaviors* of 3D objects proposed by [Pai et al., 2001] draws an even more optimistic picture. The scientists have managed to produce a fully automated device for scanning the interactive 3D-models of real world objects that include deformation response, contact texture and contact sound. During the scanning procedure a robotic arm (supplied with a microphone) moves around the object and applies different kinds of deformation to the object, as well as records the sounds that are produced on contact with the object. The scanned information is then attached to the resulting 3D model and helps to make the interaction with the virtual object as close as possible to the interaction with the real one. Using this technology in combination with haptic devices that allow users to "feel" virtual objects [Whitton, 2003] may result in the ability of physical interactive behaviors (i.e. the sensation of touching a fabric) to be easily transmittable through the Web. So, with the help of 3D technology the product presentation on the Web can be advanced almost to the level of product presentation in the real world.

Although, the future of 3D product presentation looks optimistic we are convinced that in order for 3D technology to succeed in commercial applications it has to offer much more than just product visualization. In our opinion, isolated 3D visualization can not satisfy all the demands of the customers and on its own is unable to change the face of E-Commerce. One of the key goals behind using 3D technology in commercial applications is to introduce the beneficial aspects that are present in brick and mortar environments into computer-based solutions. The possibility to fully experience the product in brick and mortar stores is quite important, however, there are many more attributes that contribute to the shopping experience in traditional commercial environments.

One of such attributes is *impulsive decision making* of the customers (or unplanned purchases). Impulsive decisions play a highly important role in traditional commerce. Some researchers even take an extreme view saying that if we would go into stores only when we needed to buy something, and if once there we would buy only what we needed, the economy would collapse [Underhill, 1999]. Such a view is rather too pessimistic, but the importance of unplanned purchases is quite significant and taking it away from traditional commerce would most certainly have a severe economic impact.

Today's economy is extremely vibrant. We have an enormous variety of products present on the market, and with so many information sources available it gets harder and

harder for consumers to plan their purchases. That's why many purchasing decisions are made, or can be heavily influenced, on the floor of the store itself. As an example of this, a study conducted by [Underhill, 1999] showed that up to 70% of all the purchases in a supermarket are unplanned. This trend is also strong in other industries, i.e. [Marcha and Woodsidea, 2005] highlights the significance of impulsive purchases in tourism. Despite the existing evidence stressing the importance of the unplanned purchases in brick and mortar environments, there is no clear mechanism present in nowadays E-Commerce systems to support this trend. One of the reasons for this is that the form-based nature of the web sites makes them very limited in presenting large volumes of information. In contrast, the 3D representation in this respect is as rich as the real world and can easily support impulsive purchase decisions of the consumers [Chittaro and Coppola, 2000].

Another important set of drawbacks of E-Commerce in its present form is tightly connected with the fact that human beings are "social animals" [Runciman and Merton, 2000]. The real world is a highly social place and *social interactions* is one of the basic natural needs of human beings [Girgensohn and Lee, 2002]. It is false to assume that commercial activities of some kind do not require social interactions. Even such a simple activity as shopping usually involves (and is highly valued for) social interactions with fellow shoppers, sales assistants, clerks etc. These social interactions are not only useful for the exchange of important information about the products but also to satisfy the social needs not directly connected with the product [Underhill, 1999]. Social interactions play an important role in traditional commerce and will definitely be an important factor in the future of E-Commerce [Preece and Maloney-Krichmar, 2003]. They are, in our opinion, as important as product presentation.

One of the most popular kinds of social interactions present in brick and mortar stores is the interaction between buyers and sales assistants. *Sales assistants* there have a function to offer help in a store, provide additional information on products and simplify the decision making process by helping to find a good that satisfies the customer's requirements and various constraints. One of the major drawbacks that E-Commerce is facing today is the lack of such sales clerks. There is strong evidence that in physical stores customers find interaction with a sales person very beneficial [Chowdhury, 2004]. People value and are willing to pay for the reduction of perceived risk, the optimal configuration of the transaction for their specific usage context, and the enhancement of the in-use experience, which shopping assistants can provide them with [Chowdhury, 2004].

The technology that is capable of enriching E-Commerce with social interactions and sales assistants is *3D Virtual Worlds*. 3D Virtual Worlds are immersive environments that combine 3D visualization with the notion of physical presence and have an emergent feature of being highly social. These characteristics make 3D Virtual Worlds a very promising technology for commercial activities in the Internet.

Apparently, 3D Virtual Worlds represent one of the few successful online businesses that are making money on the Web [Hunter and Lastowka, 2003]. Millions of people around the world spend an average of 20 hours per week in Virtual Worlds based computer games. Usually those users have to pay a monthly fee of around US$ 10 just for

being able to participate [Hunter and Lastowka, 2003]. Moreover, not only are participants paying for the experience of being there, but also to trade virtual goods. Surprisingly enough, in some games virtual items are sold for real money and in many other games the virtual goods are exchanged for virtual money (which still can be easily converted into real world currencies). Virtual items may be quite expensive and range from simple artifacts to virtual properties. A virtual property may end up being nearly as expensive as a real one.

In December 2004 the Project Entropia multi-user game entered the Guinness Book of Records when it sold a virtual treasure island for an equivalent of US$ 26500 [Starodoumov, 2005]. This was considered the most expensive virtual item at the time and many financial analysts considered this purchase being a very good investment. Just less than one year after this, the sale of a virtual asteroid in the same game for US$100,000 set a new record for the most valuable virtual item [Meehan, 2006].

Every day more and more people join Virtual Worlds and get involved with the variety of virtual trading activities, contributing to the development of the phenomenon of *virtual economies* [Castronova, 2001]. The extend of virtual economies can be observed on the example of Norrath, the online world created by Sony, which in 2003 had more residents than Miami and higher per capita GNP than Bulgaria. The inhabitants of the Norrath game literally live and work in the virtual environment of the game. They spend their time and in return receive money, products, services or experiences. The economic study that analyzed a number of different economical parameters [Castronova, 2001] has revealed that in 2000 Norrath could have been 77th richest country in the world (roughly equal to Russia).

If selling virtual items in Virtual Worlds is that profitable and widely used, why not sell real items there? Some retailers are already selling their services in Virtual Worlds and some even make a living out of it. Veronica Brown, a fashion designer, earned an equivalent of US$ 60K in 2005 by running a fashion shop in the virtual environment of Second Life [Sipress, 2006]. She created designer dresses for the avatars in the Virtual World and had to quit her real world job to continue doing it on a full time basis. Although, this service is still concerned with virtual items it is actually not any different from all the other services being offered in the real world. We are convinced that our society is well prepared for the merge of the two economies and will benefit from trading with real world services and goods in the Virtual Worlds. The virtual trading environments are already well populated with enthusiastic customers who are simply waiting for the appearance of new products from the real world.

The major reason for the enormous attractiveness of the Virtual Worlds technology as the facilitator of selling real products is the unlimited number of possibilities they provide to stage experiences for the inhabitants. Staging experiences is highly important today. Our economy has successfully evolved from product economy through service economy to the *experience economy* [Pine II and Gilmore, 1998].

This economical evolution can be best observed on an example of a birthday cake. As a vestige of the agrarian economy, mothers made birthday cakes from scratch, mixing farm commodities (flour, sugar, butter and eggs) that together cost mere dimes. As the goods-based industrial economy advanced, mothers started to pay a bit more (around $1-$2) for premixed ingredients. Later, when the service economy took hold,

busy parents stopped cooking themselves and ordered cakes from bakeries or grocery stores. The cakes there cost about ten times as much as the packaged ingredients. Now, in the experience economy times, parents neither bake the birthday cakes nor even throw the party. Instead, they pay at least ten times the price of the cake to "outsource" the entire event to some business (like Chuck E. Cheese's, the Discovery Zone, the Mining Company, etc.) that stages a memorable event for the kids – and often throws the cake for free [Pine II and Gilmore, 1998].

As shown by the birthday cake example, one of the paradoxes of the phenomenon of experience economy is that experiences today are often much more valuable (expensive) than the products or services they adhere to [Pine and Gilmore, 1999]. The commerce world of today is extremely competitive. Many retailers do not open the stores to create new markets anymore, they open them to steel someone else's customers [Underhill, 1999]. In such tough conditions providing an exciting experience is one of the major factors of success. In many industries like entertainment, business, travel and even health care, more and more experiences today are bought and sold together with products and services or even separately from them. And this trend is going to continue [Pine and Gilmore, 1999].

Virtual Worlds are quite efficient in staging experiences. They are capable of simulating the experience associated with a particular product and can also recreate (and even enhance) the experience associated with the process of purchasing the product. Ultimately, Virtual Worlds extend our experience economy capabilities [Gordon, 7315].

Studies in South Korea have recently shown that users prefer Virtual Worlds to television [Weinstein and Myers, 8 06], which so far was the most popular experience provider. People visit Virtual Worlds and are ready to spend their time and money there just for the sake of the experience they receive. Most of the participants would explain that they are so involved with a virtual activity that nothing else seems to matter, the experience itself is so enjoyable that they are ready to do it just for the sheer sake of doing it. Such a state is defined in the literature as the *optimal experience* or the *flow* [Csikszentmihalyi, 2002].

The concept of the flow appeared as the result of a study on the topic of what makes people happy. The term flow refers to a state of consciousness that is sometimes experienced by individuals who are deeply involved in an enjoyable activity [Csikszentmihalyi, 2002]. According to the authors [Csikszentmihalyi, 2002] the state of the ultimate happiness (the flow) can be achieved while having a high degree of concentration on some task and if a person involved with the task is continuously presented with challenges that are up to this person's skills and making the challenges harder reflecting the growth in skills. Video games based on the metaphor of the Virtual Worlds are very good flow facilitators. Flow is one of the key reasons why people enjoy playing such video games and are ready to devote so much of their spare time to visiting the corresponding Virtual Worlds [Said, 2005].

Many brick and mortar stores are very eager to embrace the flow, because in this state customers enjoy the shopping and are very likely to make a purchase and, more importantly, are more likely to come back to the same store again in a hope to experience the flow once more [Siekpe, 2005]. It is remarkable that most of the participants of the Virtual Worlds seem to continuously experience this state. While in brick and

mortar stores significant efforts are required to generate the flow, in Virtual Worlds it is something that seems to be quite easily achievable. Even the participants of non-gaming Virtual Worlds (where no clear challenges are expressed and no specific tasks are assigned to the users) are still able to experience this state. It is believed that interactivity and immersion, which are integral properties of Virtual Worlds, are the significant flow facilitating factors [Hoffman and Novak, 1996].

The aforementioned benefits associated with the Virtual Worlds technology attracted the attention of many researchers and developers. A group of researchers participating in the international "Metaverse Roadmap" project, focused on predicting the future of 3D Virtual Worlds, highlight the significance of using Virtual Worlds in non-gaming activities [Cascio et al., 2007]. The outcomes of the predictive study conducted within the frame of this project suggest that many of the ordinary activities we today associate with form-based interfaces will migrate into Virtual Worlds. In particular, it is predicted that rapid prototyping, customized and decentralized production, logistics and transportation will soon have a strong presence in Virtual Worlds. The project also stresses the importance of the notion of *mirror worlds*, which are informationally-enhanced virtual models or "reflectors" of the real world. They hypothesize that mirror worlds similar to the currently available Google Earth[2], but supplied with detailed 3D models of significant buildings and surrounding objects in the real world, will become an every day reality by 2016. They outline a scenario of a Virtual Town, which contains a virtual replication of popular social locations of the associated real town. In the virtual town users virtually meet each other, efficiently review their joint entertainment options and coordinate entertainment plans. According to the report presented in [Cascio et al., 2007] such scenario will become feasible in 2012.

Another important report highlighting the significance of 3D Virtual Worlds was recently released by Gartner. *Gartner predicts that 80% of the Internet users will be actively participating in non-gaming Virtual Worlds by the End of 2011*. Gartner advises businesses that this is a trend that they should investigate and experiment with [Gartner, Inc., 2007].

Despite the enormous potential of 3D Virtual Worlds, there is a number of unsolved problems. One such problem is the *lack of a proper methodology*, which would specifically target Virtual Worlds. Most of the Virtual Worlds today are developed on an adhoc basis or utilize methodologies that are not specifically designed for Virtual Worlds and are mostly concerned with the design side of the "look-and-feel" of the inhabited space. Because of this many Virtual Worlds are poorly programmed, hard to maintain and do not offer efficient and safe mechanism to introduce new functionality [Kim et al., 1998].

Another important drawback of 3D Virtual Worlds is that with its current chaotic nature (which is due to the lack of a proper methodology) there is *no clear mechanism to regulate the interactions among participants in the Virtual Worlds*. The problem of regulating interactions of participants received significant attention after the collapse of the Ginko Financial – the Second Life's best-known virtual bank [Gardiner, 2007]. This bank initially promised very high returns (around 44% p.a.) on virtual deposits, but ended up bankrupt, unable to repay approximately USD 750,000 to its investors. Existing mechanisms employed by Second Life proved to be unable to protect the

[2]http://earth.google.com

inhabitants from losing their investments and to punish the Grinko founders, despite the fact that many people predicted Grinko's insolvency straight after it's appearance [Gardiner, 2007].

Virtual Worlds are open systems visited by a huge number of people and so designers, developers and users are faced with a number of safety and security risks such as malevolent or unintentional overstraining of computational resources, deviant behavior, destruction of data and code, etc. Having no well established means of interaction regulation is a serious concern for businesses, which are very eager to invest in Virtual Worlds.

Selling real goods and services will immediately attract high volumes of real money, so those risks will become much more costly and the need to regulate the interactions will dramatically increase. Even now many disputes occur in Virtual Worlds, which due to the chaotic nature of the interactions can only be regulated via a post factum code change by the developers. Such changes usually take a significant amount of time, simply because the Virtual World in question wasn't initially designed following a proper methodology and the interactions of the participants were not well specified in advance. This means that in its current form Virtual Worlds are not yet quite ready to become a widely acceptable platform for online trading of real goods and services.

Both Gartner's report [Gartner, Inc., 2007] and the "Metaverse Roadmap" report [Cascio et al., 2007] suggest that there is a strong need to establish institutional control over the behavior of participants in Virtual Worlds before active business involvement is possible.

Researchers, who investigate different aspects of *virtual law* [Bray and Konsynski, 2006, Hunter and Lastowka, 2003, Lastowka and Hunter, 2004], are also concerned with this issue. Some authors consider extending the reach of national legal frameworks [Mayer-Schoenberger and Crowley, 2006], but also express the concern that such approach is likely to backfire. Not only will national regulation increase competition among Virtual World providers operating in different jurisdictions, but it will also push Virtual Worlds along the same path that the regulation of Napster pushed music sharing – towards a decentralized peer-to-peer model in which providers will eventually disappear and there will be no hope for the real-world law makers to directly influence the governance inside such Virtual Worlds [Mayer-Schoenberger and Crowley, 2006]. Other researchers [Bray and Konsynski, 2006] stress the significance of the attempts of Virtual Worlds inhabitants to establish social order (calling this phenomenon *Virtual Institutions*), but also mention that such Virtual Institutions are so far only capable of introducing a set of norms of socially acceptable behavior, but offer no mechanism to enforce these norms.

In this thesis we address the aforementioned problems by extending the notion of Virtual Institutions with a strong conceptual end technological basis. We define Virtual Institutions as 3D Virtual Worlds with normative regulation of participants' interactions and propose the *Virtual Institutions* methodology to be used for their development.

For the control of participants' interactions in Virtual Institutions we use the Electronic Institution [Esteva, 2003] technology, which is seen as an application that defines and enforces a set of rules limiting the behavior of participants inside Virtual Worlds.

The specification of the Electronic Institution is the initial step of the methodology that helps to clearly define the activities that the participants can engage in and the rules of the interactions amongst them (interaction protocols). With such an approach all of the security aspects of the system are controlled by the institution, which ensures the validity of interactions, meaning that the specified rules can not be violated. Moreover, the proposed approach creates a possibility of quickly changing the rules on demand and even opens the future perspective for inhabitants to have influence over the rule changes and the evolution of the rules.

The proposed methodology is supplied with a number of tools that help in specification, verification and rapid development of commercially-oriented 3D Virtual Worlds. Some of the implementation steps can be automatically completed once the specification is created. Moreover, there are tools for deployment and runtime verification of the interaction validity.

An important aspect of the implemented infrastructure for Virtual Institutions is the availability of facilities for implicit training of autonomous agents by humans. By implicit training we mean that agents are trained to act like humans by observing them, without any explicit training efforts required from the humans. Such an approach is particularly useful in creating computer-operated sales assistants in virtual environments that can be trained to emulate human-like intelligence. The implicit training concept is one of the central parts of the architecture and we suggest to employ it more often than the explicit programming of the agents.

The motivation presented in this section interlinks a number of different research areas and operates with some terms that might be unfamiliar to a general reader. To provide better understanding, next we present the concept taxonomy of Virtual Institutions.

## 1.2 Taxonomy of Virtual Institutions

The concept of Virtual Institutions originates from various different areas of Computer Science. In order to illustrate these areas Figure 1.1 outlines the taxonomy of concepts related to Virtual Institutions and positions Virtual Institutions within these fields.

The highest level concept in the taxonomy is the concept of Virtual Environments. Virtual Environments are systems covered by the following definition.

**Definition:** ***Virtual Environments*** *are imaginary spaces often manifested through a medium [Sherman and Craig, 2003]. Such spaces may exist solely in the mind of its originator or be broadcasted so that it is shared with others [Sherman and Craig, 2003].*

For the purpose of this dissertation we distinguish between the following two types of Virtual Environments: Normative Virtual Environments (which employ a set of rules to constrain the behavior of their participants) and Immersive Virtual Environments (which offer immersive experience to their participants).

Providing Immersive experience means supporting a high degree of immersion. Immersion is a metaphorical term derived from the physical experience of being submerged in water. We seek the same feeling from a psychologically immersive experi-

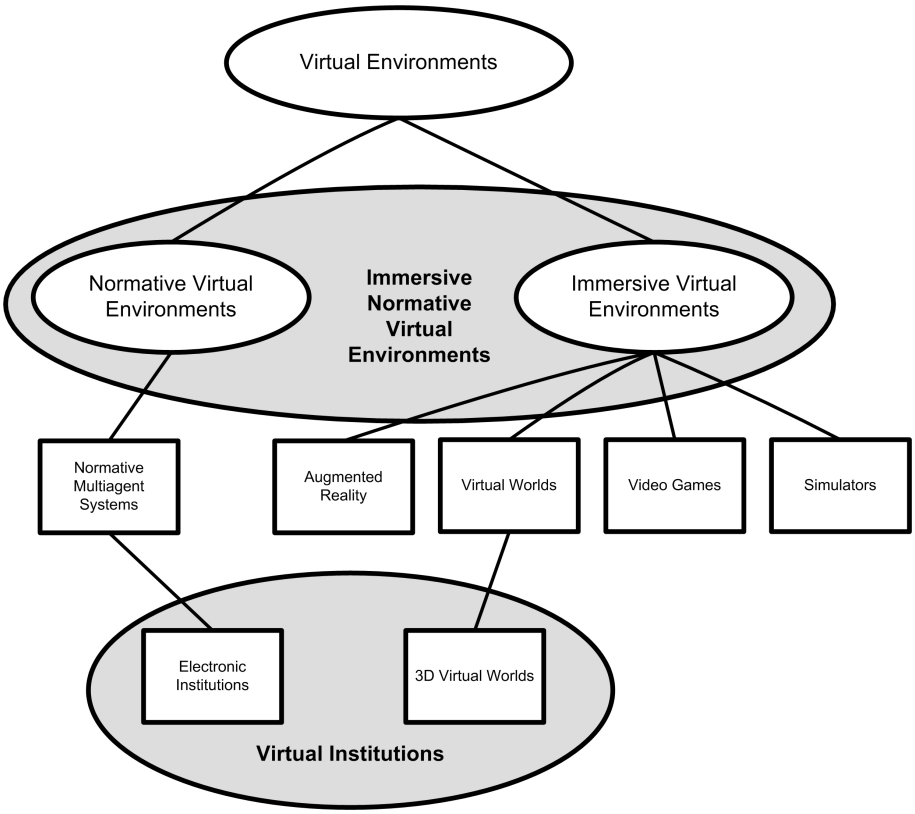


Figure 1.1: Concept Taxonomy of Virtual Institutions

ence as we do from a plunge in the ocean or swimming pool; the sensation of being surrounded by a completely other reality; as water is from air, that takes all of our attention, our whole perceptual apparatus [Murray, 1997].

There are two different types of immersion:

- **mental immersion** state of being deeply engaged; suspension of disbelief; involvement [Sherman and Craig, 2003]
- **physical immersion** bodily entering into a medium; synthetic stimulus of the body's senses via the use of technology [Sherman and Craig, 2003]

Both mental and physical immersion can be applied to Virtual Environments. It is possible to mentally immerse a user into an imaginary environment, meaning that the user can be deeply involved with the experience provided by this environment. Physical immersion has a more complicated relation to Virtual Environments. Being physically immersed means that the user is experiencing the environment through available sensors (i.e. able to see, touch, smell the Virtual Environment).

The prime focus of our research is on Immersive Normative Virtual Environments (INVE). This concept originates from the overlap of Immersive Virtual Environments and Normative Virtual Environments. We define INVE as follows:

**Definition:** ***Immersive Normative Virtual Environments*** *are Virtual Environments, which provide participants with immersive experience and employ a set of rules to control the validity of their interactions.*

This thesis is concerned with a particular instance of the Normative Virtual Environments class, called Virtual Institutions. Virtual Institutions originate from the area of Electronic Institutions (a subclass of Normative Multiagent Systems) and 3D Virtual Worlds (a subclass of Virtual Worlds). Further definitions of each of the aforementioned concepts are given in Chapter 2.

Next, we identify the research problem this thesis is addressing and describe the evolution of ideas that happened through the process of conducting this research.

## 1.3 Research Problem

The initial research problem we faced was: how to enhance E-Commerce with social interactions, support of implicit decisions, advanced visualization of products, collaborative shopping, attracting as many customers as possible and letting them spend as much time as possible in the store, learn personal information about the customers and provide them with a personalized shopping experience?

This problem can be addressed by moving E-Commerce into believable environments closely imitating the real world. We selected 3D Virtual Worlds for this task as we find them being an appropriate technology for supporting the above mentioned features.

But, as we know that Virtual Worlds are missing a clear way to regulate the interactions between participants, the next challenge we had is how to regulate participants' interactions in a 3D Virtual World. We found the answer to this challenge in the area of Normative Multiagent Systems, namely employing the Electronic Institutions methodology for the development of Virtual Worlds.

It is the first attempt to introduce normative regulation of interaction into Virtual Worlds and there is a number of issues we had to take into consideration. Not only a Virtual Institution has to offer both immersive experience and be consistent with a correct execution of the institution, but it also has to ensure that the enforcement of the institutional norms is not violated by the visualization. Based on this, the next challenge was how to establish a close conceptual, as well as technological, relationship between Virtual Worlds and Electronic Institutions? To address this challenge we developed the concept of Virtual Institutions, which was formalized into a number of specification requirements that can be used for the development of the Virtual Institutions technology.

In order to ensure technological consistency of Virtual Institutions and utilize best software engineering practices for their implementation, it was necessary to produce a corresponding methodology. So, the next challenge was how to create a methodology that supports the development of Virtual Institutions and consistently enforces the strict adherence of the visualization to the rules set by the Electronic Institution.

As a result, we developed the "Virtual Institutions Methodology", described all the necessary steps that have to be followed in the development of Virtual Institutions and proposed a technology to support each of the methodology steps, as well as the deployment of the implemented systems.

The next problem we faced was the agent-oriented nature of the underlying Electronic Institutions technology used in the implementation. Electronic Institutions are usually concerned with autonomous agents, not humans. Direct human inclusion into Electronic Institutions was not properly investigated. Moreover, efficient mechanisms for direct inclusion of autonomous agents into Virtual Worlds are also not available. So, the next challenge was how can the Virtual Institutions methodology, on the one hand, support the direct inclusion of the autonomous agents into Virtual Institutions and, on the other hand, support direct human involvement into Electronic Institutions.

Regarding the human inclusion into Electronic Institutions, one of the conceptual difficulties we faced was that most of the normative environments (including Electronic Institutions) regulate the interactions in a way that every action that is allowed in the system is described in the specification and any other action is prohibited. Such an approach is not acceptable for the development of Virtual Worlds. Most of the features that are automatically supported by most of the Virtual Worlds visualization platforms concerned with Virtual Worlds do not usually require any institutional regulation. Such features include walking, jumping, changing head position, slowing down zooming up etc. Therefore, we decided that for Virtual Institutions we needed a different approach, namely to allow executing any action apart from the actions that Electronic Institution prohibits to execute.

The inclusion of autonomous agents into Virtual Worlds presented another significant challenge. One of the practical motivations behind having autonomous agents as participants of Virtual Institutions was to create autonomous sales clerks that help human shoppers in the store. Such an approach would help to save human resources and, in end effect, would become a significant financial gain for the E-Commerce retailers. The problem is that with the current state of Artificial Intelligence it is not realistic to produce fully intelligent and believable autonomous agents for this task. As a trade off we came up with an idea of implicit training, where humans and agents interchange each other to be able to satisfy all the customer enquires and the agent constantly extends its intelligence by learning from this principle (so that future human involvement can be reduced). The research challenge associated with this issue is how to develop an infrastructure which would support implicit training?

Summarizing all of the above challenges, we formulate the main research problem this thesis addresses:

**Problem:** *How to build believable and heterogeneous normative environments for commercial activities in the Internet?*

In the context of this research problem the term "heterogeneous environments" refers to environments populated by both humans and autonomous agents.

Next, we present the objectives this thesis sets for solving the research problem and describe the research method that is used to achieve the objectives.

## 1.4 Objectives

The aim of the thesis is the development of the Virtual Institutions concept and exploration of research issues associated with it.

Therefore, the high level objective of our research is the establishment of the concept of Virtual Institutions. This objective is decomposed into a number of lower level objectives presented below:

- To define and formalize the concept of Virtual Institutions.
- Experimental validation of Virtual Institutions concept.
- To develop a methodology for design of Virtual Institutions.
- To develop a technology that supports a methodology for Virtual Institutions development.
- To provide facilities for programming autonomous agents in Virtual Institutions through training mechanisms.
- To apply Virtual Institutions to the domain of electronic business.

## 1.5 Research Method

To illustrate how the identified research objectives are addressed and how the research problem is solved we again present the list of objectives and identify corresponding research hypotheses and the research method selected to achieve each of the objectives:

- *To define and formalize the concept of Virtual Institutions*. The research hypothesis associated with this objective is that the concept of Virtual Institutions, as an instance of the Immersive Normative Virtual Environments class, can be successfully established as a combination of two metaphors: 3D Virtual Worlds and Electronic Institutions. In order to validate this hypothesis the basic exploratory research was conducted, where the reasons for the establishment of the new metaphor are described and the advantages over previous solutions are explored. By means of descriptive research the new concept was formalized (using Z Specification language), the features of Virtual Institutions were summarized and described, and the mapping between concepts in 3D Virtual Worlds and Electronic Institutions was established.
- *Experimental validation of Virtual Institution metaphor*. The research hypothesis associated with this objective is that the formalization of Virtual Institutions is indeed valid and functional. This hypothesis was investigated by means of a prototype that was developed following the requirements expressed in the concept formalization. The prototype provided a proof of concept for Virtual Institutions.

- *To develop a methodology for Virtual Institutions*. The research hypothesis associated with this objective is that a platform independent software engineering methodology for development of Virtual Institution can be created. This hypothesis was validated by means of applied exploratory and applied descriptive research. As a result, a set of practices required for development of Virtual Institutions were collected.

- *To develop a technology that supports a methodology for Virtual Institutions development*. The research hypothesis associated with this objective is that applying the Virtual Institutions methodology can be facilitated through employment of technological facilities. By means of applied descriptive research the basic architecture supporting the execution of the methodological steps, as well as further runtime maintenance of Virtual Institutions were presented. A proof of concept for the technologies used on each of the steps of the methodology, as well as for the deployment architecture was obtained through a number of implemented prototypes.

- *To provide facilities for programming autonomous agents in Virtual Institutions through implicit training mechanisms.* First hypothesis associated with this objective is that it is possible to develop methods for learning from user behavior in Virtual Institutions. Basic descriptive as well as applied exploratory research was conducted to find the appropriate method for co-learning between autonomous agents and humans. On this basis the developed prototype was used to prove the usefulness of the implicit training and to demonstrate how the use of Virtual Institutions can improve the training of autonomous assistants. Applied descriptive research was used to explain how the developed prototype should be improved.

  Second hypothesis is that it is possible to develop mechanisms for collection of data about the behavior of the participants of Virtual Institutions. The means of applied exploratory research were used to understand what data should be collected for observation, what the data format is and how this data should be used. The integrated data sources which arise with using Virtual Institutions were determined. A prototype was developed to validate the correctness of the selected mechanism of data collection.

- *To apply Virtual Institutions to the domain of electronic business*. The hypothesis associated with this objective is that Virtual Institutions can be successfully applied to the domain of E-Commerce. This hypothesis was validated by means of applied explanatory research. The detailed literature review highlighted existing evidence and provided new supporting information in favor of using Virtual Institutions in E-Commerce. The analysis of the literature helped to select the most promising application domain for Virtual Institutions within E-Commerce, namely E-Tourism. A conducted user study identified the key issues of E-Tourism that the new technology can solve. The benefits of Virtual Institutions were then illustrated on a number of scenarios associated with the "World Trotter" prototype.