Contextual Virtual Interaction as Part of Ubiquitous Game Design and Development

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Abstract: This paper relates to the problems of designing rich interaction, in the context of multi-player games, that would adequately support communication, control and co-ordination. The aspects of fun and rich experiences, usually required within the entertainment context, are easily overlooked in technologically driven system design. The concepts of a future ubiquitous game can be difficult to comprehend and evaluate in cases where a fully functioning physical prototype is not an option. One solution for the problem is Contextual Virtual Reality Prototyping that adds the missing context to the design simulations. The product can be designed and demonstrated in the corresponding environment, thus making it easier to understand the use-cases of, for example, a mobile device that has various location-dependent features. The main contribution of this research is the design and development approach that supports the creation of rich interaction. The primary emphasis of the approach is to avoid purely technologically driven design and development, but rather to provide a supporting, or even a guiding, approach that focuses on the creative process and conceptual understanding of rich interaction. This conceptually grounded content production-oriented approach to interactive system design is described and evaluated.

Keywords: Communication; Design process; Interaction design; Multi-player games; Simulation; Networked virtual environments

1. Introduction

This paper describes the rich interaction design approach that was used in designing and developing a multi-player game for networked platforms. The approach is based on the conceptual understanding of interaction manifestations. The outcome of the approach is evaluated by two experimental designs. The rich interaction can be defined as an interaction set consisting of a large number of individual interaction possibilities that are supported by hierarchical structuring and artistic selectivity. The described design approach forms the basis for rich interaction design guidelines that can be utilised when creating new services and applications for networked platforms, such as, mobile devices, digital television and personal computers.

Current multi-player games contain relatively limited interaction in terms of communication, control and co-ordination. The design and development of applications tend to follow the technologically oriented path where every interaction form and function is dictated by the platform, devices and software architecture. This often leads to systems that are not harnessing the true potential of interpersonal interaction. The problem can be explained by two factors. First, technologically oriented development is usually governed by the restrictions and conventions of contemporary systems. Secondly, the limitations of user interfaces, especially in the mobile context, are often said to cause the downscale in interactional degrees-of-freedom.

One of the basic problems in ubiquitous game design is the scope of the product. In particular, the novel game concepts, which require more than existing hardware and software, are relatively difficult to test before the final product has been fully implemented. One major issue is how to prototype games which are used in different contexts, at different locations, and even with different collaborators. What about the cases where the interaction with the prototype is not enough, but there is also the need to have interaction with the environment and with other players? Can the prospective game players and clients really 'see' the future concept from the figures? How is it possible to test a product when there is no product yet, or, when the use environment and corresponding ubiquitous artefacts are not directly accessible?

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The difficulties in computer-mediated interaction with other users, or with the virtual environment, render the gaming experiences far from satisfying. The users feel they are adapting and conforming to the intrigues of the systems when, instead, they would like to be in the 'driving seat' with all the control they need. The main reason for this problem may be because of the difficulties in designing interactively rich multi-player systems. Even with all the theoretical and creative support, system design tends to fall short of the expectations of the users.

Rich interaction allows the complex and intuitive combination of interaction sequences. Richer interaction possibilities provide the participants with flexible ways of communicating and acting within the game environment. First, the availability of various interaction mechanisms helps participants choose the ones fitting their purposes. Secondly, the combination of different communication channels makes it possible to enhance the messages, or to execute contradicting behaviours. Third, the tacit 'knowledge' can be conveyed by enabling subconscious and intuitive actions, which still are perceivable by other participants.

The rich interaction design guidelines described in this paper are constructed from the theories of communication and interaction. The starting point is to understand what the concept of interaction means in the context of multi-player networked games. This understanding is then used to create a number of interaction models, which in turn, form the basis for the design guidelines. The experimental cases, *ConsoleDEMO* and *Tuppi3D*, have been used to test and evaluate various areas of rich interaction design in practice.

The illustrated approach is beneficial for the designers and developers who work in the various fields of telecommunication services and applications. Although the described cases involve the design and development of a 3D PC game, the experiences apply to other areas of multi-user systems as well. Whether the application to be designed is multi-platform multi-player game or purely ubiquitous gaming environment, the rich interaction design can explicitly direct the development to include all the necessary interaction forms. Rich interaction design is needed, particularly, in areas of new services and applications that require more than just the basic features to function. Expectations of customers increase alongside the technological development. People are not willing to accept the traditional and cumbersome applications for very long.

The purpose of this paper is to describe and analyse one solution for multimedia supported product design and development that answers the aforementioned questions. The proposed solution is based on the utilisation of an existing entertainment industry application (i.e. multimedia network game engine) and rich media concepts in designing games which enable rich interaction. The research problem addressed in this paper relates to the design of rich interaction in multi-player game settings. The problem consists of three aspects:

1. How to design and develop rich interaction for multi-player games.
2. How to bring contextual effects and awareness to design prototypes.
3. How to avoid the technological conventions that restrict rich interaction design.

The answers to these questions have been searched using conceptual analysis and constructive approaches. The empirical part of the work consists of two design and development productions conducted by the research group. The work, thus, involves iterative phases of theoretical concept modelling, constructive design and development of the systems, and experimental testing and refinement of the systems and the conceptual models.

The rest of the paper consists of seven sections. The next section describes the focus of the work. Section 3 lays the foundations for the work, described in this paper, by illustrating the related research. Section 4 explains the theoretical background of interaction design and rich interaction. Furthermore, it presents the proposed rich interaction design approach. Section 5 describes the first of the two empirical experiments, ConsoleDEMO, while Sect. 6 outlines the rich interaction design and the corresponding content oriented production process of the Tuppi3D experiment. Section 7 illustrates the evaluations and lessons learned from the production, and identifies the benefits and limitations of the described design approach. The last section summarises the findings and the main results.

2. Contextual Virtual Interaction

Interaction in the context of this research is not directly related to the ability of the user to make choices when using a computer program. In relation to this, the interface issues, including input/output devices, are not within the main focus area, although their importance and effects cannot be overlooked. The nature of ubiquitous computing is to hide the computers within or inside artefacts, thus making the interfacing issues different than in traditional computing. However, the representative role of interaction forms in these games is as important, if not more important, than with desktop systems. To establish more solid ground for this research, interaction has to be defined within the context of this work.

The definition of interaction in the context of this research can be considered to follow the lines of natural interaction occurring in real life environments. Figure 1 illustrates the components of human-computer interaction. The interaction sequence starts from human action (if a user-launched activity, i.e. input, is considered, then the output sequence is the opposite), which is executed by means of the input device (such as the mouse in this example). Interaction techniques are used to map the user input from the device to the computer application. Finally, there is the executed interaction that occurs within the game environment represented by the system. The focus of this work is on manifestations, or forms, of interactions that can be perceived by the user and by other users. The phenomenon has also been defined as *embodied action* [1] and *virtual interaction* [2].

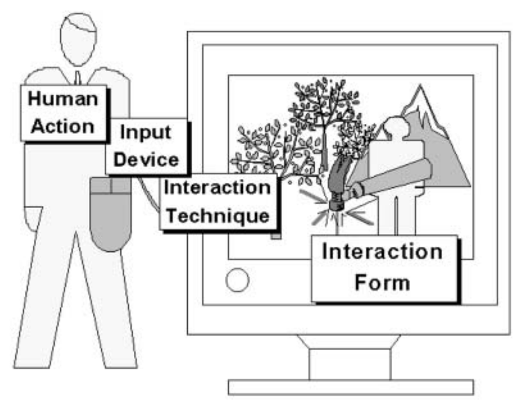

Fig. 1. The various components of human-computer interaction.

Contextual virtual interaction consists of two main areas: (1) interaction with other players; and (2) interaction with the game environment. Interaction with other players, in this context, involves mainly computer-mediated communication and interpersonal actions. The communicative aspects include speech that can be supported with various forms of non-verbal communication. The interpersonal actions are targeted at the avatar, or player character, of the other user.

Interaction between a user and the environment involves the use of information that reflects both spatial and temporal changes of the relative environment. It is important that players are able to determine where they are heading when moving through the environment and also to estimate how contact with objects can be made or avoided.

3. Related Work

There are several issues, in relation to the interaction in Collaborative Virtual Environments (CVEs), which act as motivators for this research. The basic problem with many of the networked environments seems to be the difficulties in communication, co-ordination and co-operation. From the perspective of this research, the most significant drawback is the limited and cumbersome interaction mechanisms and metaphors. This section outlines some of the issues brought forward in the related literature by drawing on the virtual environment design as background.

3.1. Interaction design

Interaction design is usually explicitly or implicitly embedded within the production process. Computer system design generally follows different production models. For example, methods in multimedia production draw on traditions from both software and the media. Traditional software production uses methods dealing with problems of functionality: system requirements, object orientation, functional prototyping, etc. Traditional media production, however, uses another methodology to deal with content problems: storyboard, script, relations between roles, etc. [3, p. 422].

The user-driven approach for interaction design has been experimented with, for instance, in the context of entertainment. For example, Drozd et al. [4] have created a system that provides people technical resources which they can use as part of their co-ordination activities. The creators of the system did not mandate co-ordination in a heavyweight way. The narrative, in their example, is not automatically maintained (e.g. through the use of some narrative 'parser' which checks progress against a script), nor are object-behaviours pre-programmed. The design philosophy has been to embed technologies in social practice and to let the participants have full control over the contents and actions of the system.

The non-verbal communication aspects of CVEs have been studied, for example, in the context of user embodiment [5], communicative behaviours [6], and realistically expressing avatars [7]. Each of these approaches can be seen as a potential solution to interpersonal interaction. Furthermore, guidelines for CVE design have been constructed and described from various aspects, such as, collaboration [8], applications [9], usability evaluation [10], and interaction techniques [11].

There are numerous models describing various aspects of interaction. Of these, the closest in relation to our work are: (1) taxonomy of embodied actions [1]; (2) hierarchical model of human actions for avatar modelling [12]; (3) layered and modular action control [13]; and (4) layered architecture and a general behavioural model for perception and action selection [14].

Although the aforementioned related research provides significant benefits to interaction design in the context of this research, they do not approach the problem in a holistic enough way for our purposes. The models and guidelines are targeted for highly specific areas, and they tend to solve only small portions of the total problem area.

3.2. Contextual virtual reality prototyping

The product design and development work of today's hi-tech industry is facing new challenges due to the fast-paced development of markets, trends and organisational structures. For example, the development of mobile products, such as multimedia phones, is usually done using interactive computerised models, or virtual prototypes, for as many design and development phases as possible.

One approach to the conceptualisation, design and development of interactive systems is to use virtual reality techniques that allow platform independent experimenting. Virtual Reality Prototyping (VRP), according to Kerttula et al. [15, p. 86] is "a process by which a product or a product concept, its behaviour and usage are simulated as realistically as possible using computer models and virtual reality techniques". The result of the process – the Virtual Reality Prototype is thus "a simulation of a target object aimed with an adequate degree of realism that is comparable with the physical and logical functionality and the appearance of a possible real object, achieved by combining different simulation models..." [15]. The main issues and problem areas to be tackled by VRP research are somewhat similar to the ones discussed in this paper. The need to build demonstrative prototypes in a short time (rapid prototyping), the requirements of interactive prototypes (functional, physical and tangible products) [15] and the demands of global design teams for distribution support [16] are all highly relevant issues. One important aspect not directly discussed or answered within the aforementioned literature is the need for support in creative content-oriented design. The prototyped concepts are usually physical products (e.g. mobile multimedia consoles) or work solutions (e.g. functional assembly lines of future factories). The entertainment domain involves many aspects that have not been dealt with, such as, engagement, compelling experiences and rich media content. However, the research community has started to adopt game engines as platforms for scientific research experiments [17]. This trend may well direct the research and design towards aforementioned issues.

When considering the issues related to interactive virtual prototypes of ubiquitous games, the aspect of immersion should be taken into account. The contemporary computer games that contain the highest level of immersion are generally the ones that attempt to simulate the interaction of real world within the context of the game. It is claimed that this replication of the interaction from the physical world to the virtual world is never completely realistic, and severely limits the potential for productivity (see, for example, Bowman and

Hodges [11] and Preece [18]). On the other hand, the nature of these games is usually more in the simulation of some real or fictional setting and the corresponding interactions. This aspect clearly justifies the approach of replicated interactions, as it is important to provide a realistic look-and-feel of the future real world situations.

The work presented in this paper is closely related to the VRP issues described earlier. The major factor differentiating this approach from the earlier ones is the enlargement of the virtual prototyping to also cover content oriented design, virtual environment, use case, and other contextual issues of the application under development. Manninen [19] has proposed the term *Contextual Virtual Reality Prototyping* to be used to describe this expanded scope of the prototyping with rich interaction.

3.3. Game design

Although there is an increasing body of theoretical and, in particular, empirical literature, game design is still a relatively ambiguous area. The area of ubiquitous game research being relatively young, many of the sources consider the traditional computer game design. However, the well-proven conventions and design practices can be applied to the new application domain if they are suitably modified. Some examples from the traditional game design literature are described in this section.

According to Rouse [20], the game design determines what choices the player will be able to make in the game-world and what ramifications these choices will have on the rest of the game. Game design determines what win or loss criteria the game may include, how users will be able to control the game, and what information the game will communicate to them, and it establishes how hard the game will be. In short, game design determines every detail of how the gameplay will function.

Weisman [21] presents three lessons that should be taken into account when designing multi-player games. The origin of the lessons is within the non-computer world of a Dungeons and Dragons role-playing game meant for a small group of people. Weisman, however, applies the following lessons to computer games: (1) Furnishing the visuals widens the audience; (2) What the players bring to the game is as important as the game itself; (3) The social aspect of play is all-important and leads to further socialising, which in turn, leads to more play.

Multi-player games have some common denominators with so-called god games. According to Bates [22], these games do not have pre-set 'win' condition. The game designer must still design a compelling activity that is fun for the player, but instead of pushing in a given direction, the players are allowed to choose their own paths. In a way, the games can be related to sandboxes that are filled with opportunities for action and self-expression.

Computer games are very close in structure to films. According to Clanton [23], films are mostly about action. As games focus on action, a film is the closest linear narrative form to games, much more similar than either plays or novels. In fact, whether a game contains a story or not, much of the craft of filmmaking applies to computer games as well. The Tuppi3D experiment was highly influenced by film and game production processes, although the main goal of the production was neither purely game nor film.

Bates [22] claims that no one person can come up with all the creativity necessary to make a game successful. Game design is a collaborative art, and needs contributions from all the disciplines, including story, art, programming, gameplay, sound and music. Everyone involved in the production of the game has a claim on the design, and the design process must be flexible enough to include each person's contributions. This statement is highly relevant in the design of ubiquitous games. Multi-modal and multi-platform games cannot be designed with solely the technological approach. Instead, they need even more support from the content-production experts.

Unfortunately, game design experiences and theories are not enough when designing more holistic applications, such as pervasive multi-player games. To approach the problem of design with a wider scope, the research described in this paper concentrates on the aspects of rich interaction design.

4. Rich Interaction Design

The rich interaction design approach is integrated to the practical content production process of the multi-player game. However, the successful application of the approach requires knowledge from the fields of interaction theories and interaction design. This section outlines the concept of rich interaction and introduces the rich interaction design approach.

4.1. Rich interaction

In the context of this work, the term *rich interaction* follows the definition provided by Manninen [24]: "... interaction set consisting of a large number of individual action and interaction types and possibilities that allows more complex interaction sequences. The complexity refers to the more natural forms of interacting, but due to the limitations in simulations, the virtual counterpart tends to stay far behind from the real-world one." Laurel [25] has provided one definition for the level of interactivity. In her definition, at least part of the interactivity could be characterised by three variables: frequency (how often you could interact), range (how many choices were available), and significance (how much the choices really affected matters). However, rich interaction is not just a quantitative measure – there is an as important qualitative aspect as well. The attempt to replicate every detail of real world interaction is similar to the approaches of trying to increase the graphics resolution, or the data transfer bandwidth. Although there are several application domains requiring a high degree of realism, there is usually a need to maintain a certain amount of selectivity in the process of replication. The issue has been described with terms such as *selective fidelity* [26] and *artistic selectivity* [25].

Rich interaction is, thus, not only related to the speed and the frequency of interaction. Aspects of qualitatively rich interaction also require full attention. For example, Laurel [25] has proposed an approach to interaction in which computers are considered a form of theatre rather than tools, and where the focus of design is on engaging users with content rather than with technology. She suggested that various behind-the-scene activities are required to maintain engagement and to orchestrate the user's experiences.

The need for richer interaction, and corresponding interaction forms, originates from the nature of human perception. "Humans like parallel information input. People make use of a combination of sensory stimuli to help reduce ambiguity. The sound of a letter dropping in a mailbox tells us a lot about how full the mailbox is. The echoes in a room tell us about the material in the fixtures and floors of a room. We use head movement to improve our directional interpretation of sound. We use touch along with sight to determine the smoothness of a surface. Multiple modalities give us rich combinatorial windows to our environment that we use to define and refine our percept of the environment. It is our way of reducing ambiguity." [27]

As this paper focuses on interaction forms, or the manifestations of interactions, the interface issues are not directly addressed. Although, the means of achieving multi-modal interaction may include complex interfaces, the work described here emphasises content instead of interfaces, or, as pointed out by Evard et al. [28]; "... rich interactions do not *require* rich interfaces."

4.2. Implications for interaction design

According to West and Hubbold [29], one challenge for CVE design is to make the environments engaging and bring them to life. They argue that, in part, this relies upon good ideas for content and activities, but it ultimately depends on the techniques for coding complex behaviours and managing the interactions between participants, and between participants and the environment. They further claim that, although the hardware makes it possible to display visually rich environments, the ways in which users can interact in those environments remain inadequate. So, although technology is not the focus of this research, it provides the basic set of enabling factors deciding what type of content and what kind of activities are feasible in terms of implementation. However, as stated by Limber [30]; "... skilled groups of artists and scientists are required to generate compelling virtual experiences. The structure of these groups is unique, and its collaborative success depends on the careful integration of computer technology and creative content."

There are several examples in the related literature stating that gestures and facial expressions play an important role in human interaction [2, 5, 7, 31]. According to Robertson [1], mutual perception is one of the most important features in distributed systems, such as, multiplayer games. Only with reversibility of perception are the remote participants able to control and adapt their actions without too unsure feelings of the message.

In designing interactive systems, it is vital that the participants quickly realise they have control and understand what are the parameters of that control. In this way, the users can easily learn the simple relationships between their actions and the system itself [32]. "Users want software that supports but does not take away their sense of control, so they can do what they want when they want, and not be constrained by the software." [33, p. 265]. According to Rouse [20], the true point of non-linearity in games is to grant the players a sense of freedom in the game-world. The players can have unique playing experiences by telling their own stories through the game. The non-linearity can provide some degree of authorship to the player and, thus, enrich the interaction.

In a way, the implications provided by Sandin, Preece and Rouse are even more important in the context of ubiquitous gaming. If the games can be played anywhere, and with anybody, the design can hardly follow the traditional approach of linear game design. Latta [34] states that "... virtual communities need richly compelling content to be attractive, but the issue is far more complex than the placement of games, avatars, and objects within environments."

4.3. Rich Interaction Design Guidelines

The first dimension in rich interaction design is the hierarchical interaction model which defines the layers of interactions. Figure 2 illustrates the hierarchical interaction model and corresponding application examples as inverted pyramid structures. The inverted pyramid is used to emphasise the number of possible acts, variables, or degrees of freedom in each level. The main idea of this structure is to divide and classify the actions included in interaction, to create a hierarchical structure starting from low-level signal-type actions and ascending to the level in which the cognitively generated goals and objectives define the purpose of the interaction itself. The fields of robotics and artificial intelligence, as well as, the game industry have used similar hierarchical structures.

In the context of this research, the hierarchical interaction model was applied, for example, when designing a simulated playing card set for *Tuppi3D* experiment. The model emphasises a bottom-up interaction design instead of the activity-oriented top-down approach. The main idea was to start the construction by modelling and programming the lower levels of interactions that are applicable to a deck of cards. The levels of abstraction were then included to improve the usability. However, the higher levels of interaction can be left to the players, thus making it possible to use the same simulator to play almost any card game existing today. For example, the bottom-up approach makes it possible to deal the cards one by one to a number of players. On the other hand, if the player wants to skip this manual task, a higher level interaction can be selected and the 'deal' abstraction used instead. So, both options are fully available to the users, which, in part, creates rich interaction (i.e. freedom of choice, flexibility, user control, and non-deterministic complex action sequences). This method enables the development of a fully functional card deck with no restrictions imposed by any set of rules. The manipulation of cards follows the lines of natural interaction. Figure 3 illustrates the card game interactions organised according to the hierarchical interaction model.

The second dimension in rich interaction design is the interaction concept model, which illustrates the range, or possible forms, of interaction. Figure 4 represents the model

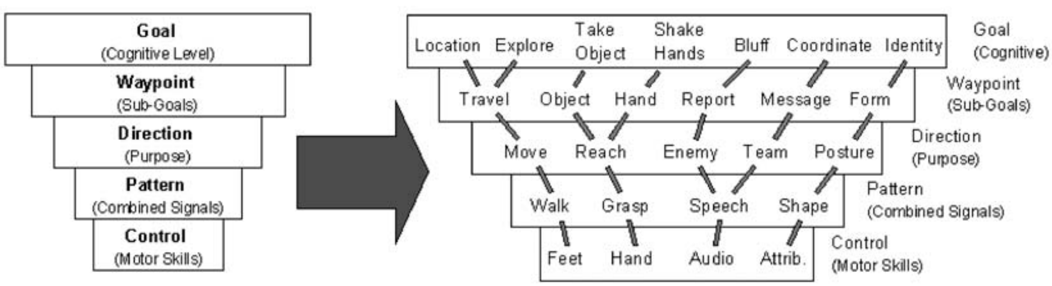

Fig. 2. Hierarchical interaction model and application examples.

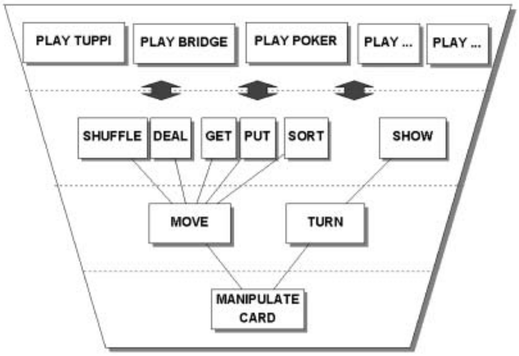

Fig. 3. Hierarchical structure of the card game interactions.

depicting the first layers of the applicable interaction forms. Further decomposition is not illustrated due to image size restrictions. The model illustrates the main interaction forms that can be found, partially in the physical world, and partially in current multi-player games. The conceptual understanding of the interaction forms was used in the experiments as a guiding philosophy defining the mapping of the feature set. The aim was not to follow the model in every detail, but instead, it was used as background material from where the corresponding set of interaction forms was selected.

The concept model of interaction forms acts as a concrete set of examples and categories of interaction manifestations. The boundaries of the classes are not necessarily solid, instead there are several occurrences where the overlap is mainly an issue of perspective. The model consists of 12 main categories: (1) avatar appearance, (2) facial expressions, (3) kinesics, (4) occulesics, (5) autonomous/AI & automatic, (6) non-verbal audio, (7) language-based communication, (8) spatial behaviour, (9) physical contact, (10) environmental details, (11) chronemics, and (12) olfactics.

While some of the aforementioned categories are self-explanatory, some of them require brief explanations. For example, the movement of the head and body (kinesics) in space (spatial behaviour), to re-orient (spatial behaviour) and focus on a fellow player (occulesics) for presenting a winning triumph (facial expression and non-verbal audio) can be decomposed into various interaction form categories. Furthermore, the automatic (autonomous & AI) dodging movement (kinesics, spatial behaviour) that tries to avoid the opponents axe blow (environmental details, physical contact) consists of several categories and their combinations.

The application of the aforementioned models to the design is not as straightforward as to implement them to the requirement specification. The concept model cannot be seen as a strict set of features which needs to be implemented to achieve rich interaction.

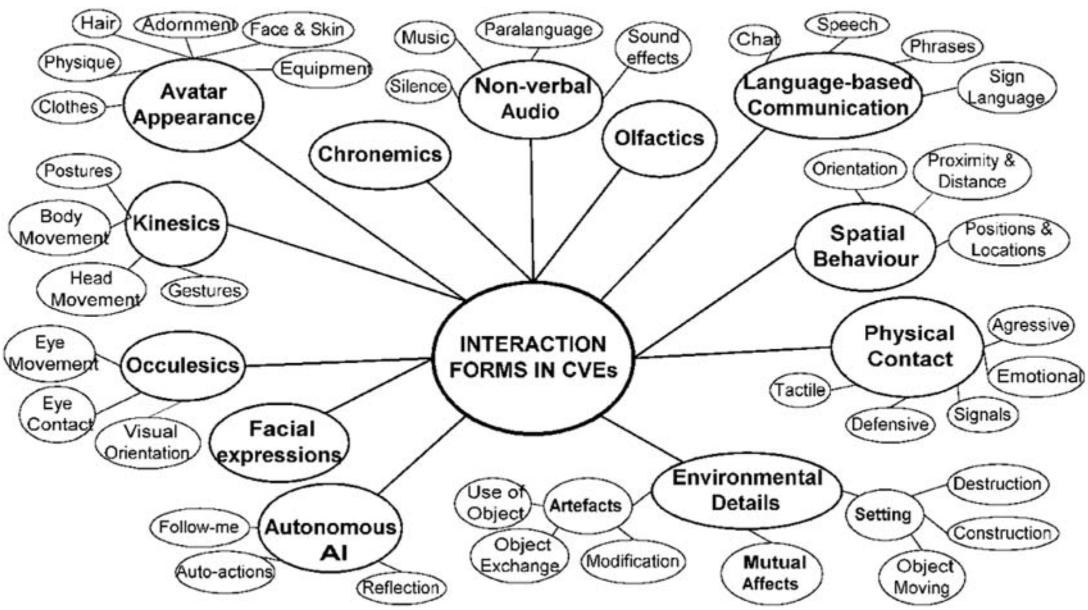

Fig. 4. Concept model of interaction forms.

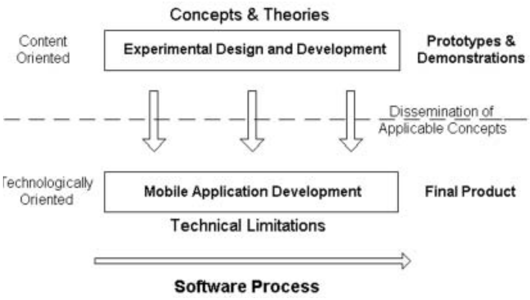

Fig. 5. Two-layer design and development process.

Instead, the design and development has to be adapted to support the creation of rich interaction. In the described approach, the technologically oriented design and development process of the mobile multi-player game is supported by a rich interaction design counterpart, running on top of the contemporary PC platform and utilising more processing power and high-end 3D graphics. The main reason for this two-layered design process is the difficulty in combining both technical and creative work into the same production. The limitations and obstacles revolving around mobile platforms can easily kill the creative potential of the design. Figure 5 illustrates the two-layer design and development process in which the rich interaction research and design belongs to the experimental content oriented layer. This layer of production feeds the technologically oriented production with the applicable concepts.

5. Future Directions Through Contextual Virtual Prototypes

The background and rationale for the experiments described in this paper originates from the multi-player game design conducted at the University of Oulu co-ordinated Monica research project. The experiments – ConsoleDEMO and Tuppi3D – are part of the public demonstration of the project. The main objective of the project was to develop a game application that would act as a case example of the value-added service creation process for mobile devices.

The first empirical experiment, ConsoleDEMO, was used to demonstrate the utilisation of *Contextual Virtual Reality Prototyping* in mobile application development. The main emphasis in this approach was the enlarging of the virtual prototype to cover also the environment, use case, and other contextual issues of the product under development.

To simulate the contextual aspects of the future ubiquitous game concept, a suitable virtual environment platform had to be selected. The purpose of the platform was to provide a level of immersion, enable interactions, and control autonomous actors, as well as, to allow access for multiple simultaneous users via the network. In this sense, the virtual environment acts as a virtual laboratory, which can be used to design, develop, evaluate, and market games and game products with the aid of Contextual VRP.

The main idea of the ConsoleDEMO experiment was to create a demonstration of a hand-held mobile game console by using the Contextual VRP approach. The demonstration simulates a small city environment which users can explore by walking around. The product prototype (i.e. the game console) can be used to access various information and services located in the 'city'. Figure 6 represents the concept model of the console and the corresponding use environment. The screen of the console provides a map view to the user's location. In addition, a destination identifier from the starting point to the point of destination appears on the map as dotted line.

Fig. 6. Mobile console used for navigation support.

Fig. 7. Same location of the world viewed with and without the console.

For example, allowing the user to view the world through a semi-transparent screen of the mobile console, and to see any virtual objects located there, the demonstration shows the possible functions and activities the user can do. Figure 7 illustrates the same location of the world viewed with and without the mobile console. The penguin (the right hand side picture) is a virtual object and, thus, is visible only through the screen of the console. This feature of the prototype illustrates one possible location-dependent, augmented reality type of interaction where the user can use the console as a looking glass to access the virtual aspects of the particular real world environment. Other features implemented in the prototype include, for instance, moving the console to the field of view, a radar to show the directions of the objects, a location-based power-up collection, location-based information download, and several console configuration possibilities.

The experimental game concepts include augmented reality and location dependent 'Catch the Penguin' and the pseudo-physical version of Pacman. Both game concepts were meant to be played out in the open, i.e. in the park and on the streets of the city. The console enabled the players to see the virtual objects, provided the networking support, and handled all the game-related controls and statistics.

The demonstration did not utilise highly realistic interaction techniques between the user and the prototype. The main input devices were the keyboard and the mouse. However, the mouse interactions were replicated as realistically as possible in trying to estimate and imitate the real-world case. This meant that it was possible to 'press' the buttons of the console by pointing and clicking them with the mouse.

The *Unreal Tournament* game engine was selected as the technical base for the demonstration as, at the time, it was the most suitable game engine for applications such as this. Firstly, the engine has stood the tough test of real world 3D game development. Secondly, the lead programmer of the demonstration had some previous experience working with the engine (i.e. game development), so the effort to get started was not high.

Technically, the development work was mostly related to programming and graphics. The aim was to recycle at least some of the program code from the earlier projects, but it turned out that most of the code, graphics, sounds and other material had to be created from scratch. The first playable, although relatively restricted, version of the demonstration was created in one week. The overall development time for the complete interactive demonstration was less than 100 working hours.

6. Tuppi3D Experiment

The second empirical experiment, Tuppi3D, was designed and developed in order to test and demonstrate the rich interaction design approach in a more holistic manner. The experiment was developed on top of the existing 3D game engine by designing and constructing all the necessary rich interaction features of the game and the game world. The task concentrated on research issues, such as analysing the needs and possibilities for rich interaction, demonstrating the relevant concepts and providing creative support for the mobile game design and development. The focus was on rich interaction (freedom of choice, activities, gestures, expressions, environment, audio, illusion, experiences, etc.) and team play (social setting, community, communication, etc.). The experiment was used to simulate the game concepts, the gaming environment, and the potential rich interaction features to be included in the mobile version of the game.

The *key issues* in designing and developing the prototype were as follows:

- Understanding the design and development process of interactively rich multi-user applications.
- Using the interaction concept model and hierarchical interaction model in the design and development of the application.
- Simulating and modelling of the look and feel of the familiar concept and community (i.e. the Tuppi card game) in a computerised environment.

6.1. Design rationale

The case described is part of a research project involving the production of a computerised version of *Arctic Bridge* (or *Tuppi* in Finnish), a traditional team-based card game which has its origins in northern Finland. The game shares many similarities with Bridge – its more widely known counterpart. The aim of this case was to construct a team game that would follow the idea of the original real world version. The rich interaction experiment was constructed in the form of 3D representation of the game, its players and the corresponding thematic environment.

The experiment design follows the traditional lumberjack theme with various environment and atmosphere effects that support and enrich the interaction and intensity of the experience. Artefacts within the environment are not only used to provide the context, but also to present 'side stories' for the users (e.g. fishing, tree climbing, etc.). The main features of the experiment include various card manipulation possibilities and several forms of interpersonal interactions (e.g. non-verbal communication). The system is designed to provide a flexible and rich set of interactions, which can be freely combined by the players.

The main playing scene consists of a log cabin with a central table for card hitting. The interior of the cabin is spacious enough to allow up to 16 people to be accommodated for an exciting card game. Usually four people take part in the actual game play, while others act as observers. Figure 8 illustrates the interior of the log cabin with one player in action (left) and the first-person view of the card table (right). Players 'act' their roles according to their personal interests. The enactment and embodiment requires a large set of atomic actions that can be combined on the fly by the players. The purpose of these actions is to allow the players to express themselves beyond the pre-designed interactions (i.e. supporting flexibility and freedom of choice).

One of the ideas behind the playing card simulator is to enable human-directed card play in situations where there are no traditional cards available. This means that the players can define and decide the rules, number of players, and corresponding parameters without application related restrictions. The simulator can thus be used as a general card game core with the possible add-on rule sets and other game

Fig. 8. Log cabin with one player avatar performing a winning act and the view through the players 'eyes'.

dependent features. Rich interaction possibilities are thus increased by allowing users to select the actions and activities they would like to perform. The experiment is not a game in the sense that there are no predetermined challenges or goals. It merely acts as a virtual 'sandbox', where users can freely play and fulfil their imagination.

6.2. Rich interaction design as part of the production process

The starting point of the work was to follow the traditional multimedia, game and film design processes from synopsis through media editing to programming. Although the system under development does not fit into the traditional multimedia or film context in terms of being purely presentational material, the basic process was considered to be close enough to start with. The main phases in the process are briefly described in order to illustrate the role of the rich interaction design in various phases of the process. The overall task was highly iterative and experimental in nature, so although the phases are described in a certain order, this does not necessarily correspond to the actual realisation of the work.

Synopsis being the first written outline of the production describes the most important aspects concerning the design. The approach and selected methods are decided at this stage. Rich interaction is visible as a design philosophy. The rich interaction design approach can be specified in the form of methods (e.g. the production involves rich interaction design drawing from the thematic material) and detailed content ideas (e.g. bottom-up manipulation structure for the playing cards).

Background & Context Research offers an endless source of material for interaction design. The main difficulty is the need for resources to tackle the task, which is not always perceived as a productive part of the development. However, this phase provides enriched interaction possibilities originating from the context and theme of the background. If the thematic coherence exists, the designers have a potential resource pool for interaction features that are intuitive and well accepted by the users.

Script Writing as the first major creative effort should focus on the enrichment of interaction, although the adaptation to the medium will be the final phase of implementing the features. The main aim of this phase is to create a solid base for rich interaction and experiences and to explicitly highlight the relevant interaction concepts.

Visualisation and Concept Art make the written descriptions visual. The visualisation process creates the final look-and-feel for the manifestations of various interactions. Although most of the interaction forms are visual, the same rules apply to the sound design.

Interaction Design, starting from the interactions illustrated by the manuscript and going all the way to the user interface, is an explicit production phase in making the rich interaction concrete. In a multi-player game, the interaction design is not just about human-computer interaction and physics models, but also tackles issues such as interpersonal communication and group dynamics

Level Design includes designing the spaces and places for interaction, environmental cues and affordances for actions. This phase provides a more concrete illustration and plan of the virtual environment that forms the scene for the actions. The level design overlaps with the interaction design – the environment affords certain interactions and some interactions require specific features from the environment. Rich interactivity, in this phase, mainly relates to the dynamics of the virtual world (i.e. is the world static, or can it be manipulated?).

Materials, Models & Animation is largely about modelling and animating the avatars. The complexity of the human model requires a lot of work. Richness in interaction forms is realised in terms of avatar appearance, body language and gestures.

Media Editing does not directly support rich interaction design and development, although the fine-tuning of the interaction forms can be used to enhance their effectiveness (e.g. caricatures of the facial expressions).

Programming is the part of the production that makes the world alive. Most of the rich interaction functionality is set alive in this phase (e.g. animation sequences, physics model, control, etc.).

Integration is the phase in which all the bits and pieces are put together, to work as a functional system. Combining graphics, audio, scripts, environment and models is an example of actions that need to be completed. In a way, this task is an ongoing activity starting from the first functional prototype until the final version is ready.

7. Evaluation of the Rich Interactive Design Process

The success of the design process was not measured against any specific heuristics or quality criteria. Instead, there are several issues that validate the level of success. The practitioners' point-of-view is reflected in the response received from the project management and from the industrial partners. The overall feedback was very encouraging and the industry representatives felt the experiment was on the right track by offering novel support for mobile application development. The opinion was very much in favour of the approach and this has resulted in a continuation research project where the two-layer design process will be further experimented.

Furthermore, the selected approach, with the two experimental designs, covers a significant area of design and development by considering inter-disciplinary issues, such as, industrial design, marketing, behavioural sciences, communication, and the arts. The involvement of the industrial partners increases the reliability and significance of the results and their applicability, although both of the described experiments are merely laboratory prototypes and not commercially produced products.

The validation of success from the research point-of-view is based on the conceptual development of the interaction models. The logical construction of the interaction form model draws on the theoretical and empirical analyses [24]. Furthermore, the quasi-experimental implementations indicate the significance of the rich interaction design approach.

7.1. Contextual virtual prototyping approach – ConsoleDEMO

The virtual prototype of a mobile product, such as the media phone, is relatively limited without the environment and context in which the product is used. The core functionality and the user interface issues can possibly be tested and demonstrated with the prototype, but the missing or non-immersive context may reduce both the appeal and the clarity. The Contextual VRP, on the other hand, provides enormous possibilities in all cases where the need for the context and environment exists. The ConsoleDEMO illustrated in this paper serves only as an example of such a scenario. The product and the corresponding use environment are both fictional in terms of design and development. The main purpose of the demonstration is to present the concept of Contextual VRP, and therefore, relatively little emphasis has been placed on the competence of the example product (i.e. the mobile game console) itself.

The network 3D game engine as a prototyping platform provides beneficial features that are ready-made solutions for designers. Integrated development tools provide direct access to the game engine resources, such as scripting of actions, geometry modelling, photo realistic texturing, and to the hundreds of control parameters to configure the applications to best suit the requirements. Network support with multi-user capabilities enables the testing and demonstration scenarios that require multiple participants (e.g. location-based grouping services). The interactive multimedia application provides possibilities for seeing and using the product before it is actually manufactured. The traditional concept design with still images, scenario descriptions, or films, does not allow users to experiment with the concept. Virtual prototyping has solved this problem, but it still lacks support for realistic use cases that also include the environment.

It should be pointed out that the Contextual VRP constructed in this work is relatively limited, both in size and in complexity. The development of a bigger, more functional and more professional demonstration would require a larger team. Even the smallest game-related projects nowadays seem to have at least a dozen people working on them. This is due to the fact that computer games and their modifications are becoming increasingly complex: a large amount of work is required to create the graphics, animated 3D objects, sounds, levels, and the program code. On the other hand, the same kind of resource hunger seems to apply to all areas of multimedia design and production. In any case, one of the major suggestions originating from this work is to promote the exploitation of ready-made platforms and engines that are originally developed for other purposes. By using this approach, it is possible to save time and other resources and, still, be able to provide appealing and realistically interactive product concept demonstrations.

7.2. Content-oriented design – Tuppi3D

In the beginning the idea of Tuppi3D experiment was not systematically processed, but instead the effort was targeted on evaluating and simulating concepts that seemed entertaining. Features, such as environmental decorations, seesaws, breakable chess pieces, semi-intelligent rabbits, etc., all proved to be entertaining when experimented with, and more effort was, thus, placed on these. On the other hand, the hard work of solving the not-so-entertaining problems often resulted in possibilities to implement additional entertaining features.

One issue providing evidence of the success of the rich interaction design, is the comparison between the mobile version of the game and the 3D version described in this paper. The flexibility, control, communication and co-operation possibilities are much more satisfactory in the Tuppi3D when compared to the current implementation of its mobile platform counterpart. The results from a video analysis of the game sessions indicate that the players had found innovative ways to use the system features in communicating and collaborating with each other. Furthermore, the environmental themes enriched the experiences of the players.

The analysis also indicates that the participants can effectively use various forms of communication, if the system is designed to support them in a memorable, yet invisible, way. A creative combination of the various communication channels makes it possible to enhance the overall interaction and further increases the usefulness of the collaborative virtual environments.

One example illustrating the rich interaction design in the form of non-designed challenges provided by the system relates to the simulation nature of the application. In this case, the subject of one experiment was exploring the virtual environment when he encountered the log cabin. Just by sheer curiosity, the subject wondered whether it would be possible to climb on to the roof of the cabin. After a series of fruitless running and jumping attempts, the subject pushed a barrel next to the cabin wall and tried again by first jumping on to the barrel. When this was not enough, the subject brought another barrel next to the first one and tried again – now running and then jumping. At this point, the subject's aim and the pattern of behaviour were clearly visible. After a half-hour effort, the subject had brought more items next to the cabin and constructed stairs leading to the rooftop, thus gaining access to the 'top of the world'. This experiment is an excellent example of a user-created challenge within the environment – the designers certainly had not planned this type of activity!

Perhaps the most important issue was the entertainment factor of the system; both the design team and the outside test users spent an enormous amount of time just fooling around in the virtual environment – and having fun! Of course, it is a prerequisite for computer games that they need to be fun to use. However, the main aim of this work was not directly to develop a system that was fun, but the fun factor was hoped to be 'increased' as a side product of the rich interaction design approach.

7.3. Discussion and lessons learned

The first lesson learnt is the ambiguity in the fun factor. It is very difficult to estimate which features are going to be fun to use. Fortunately, just by experimenting with various features with the aid of rapid prototyping, it is possible to encounter some features that are both entertaining and easy to implement. For example, no one envisioned that the virtual seesaw in Tuppi3D experiment would be fun to use, but since it was easy to implement, and since it could be useful in accessing higher areas in the environment, it was thought to give it a try. After gaining enough empirical evidence, i.e. spending several hours of bouncing up and down with various aerobatics, it had to be admitted that the concept was a success. However, the application of seesaw concept to the ubiquitous game system is not feasible as such. It is, thus, possible to construct applicable concepts by using the rich interaction design approach, but the successful transfer of these concepts to the ubiquitous domain is not necessarily solved. In a way, the design approach described in this paper offers only supporting layer for the ubiquitous game design.

The rich interaction design process can provide systems that are fun to use, although this is not always the case. The trick with rich interaction design is in getting all the interaction elements into the system and then allowing the users to find their own way of having fun.

The contextual VRP approach was a relatively easy and efficient way of testing various concepts and of 'selling' the idea to the management. The board meetings with industry representatives were suitable places for demonstrations and concept trials. Due to the interactivity and rich media, the concept came out clearly, even to the partners that were not constantly following the details of the research and development.

Still, the contextual VRP approach has been criticised because it relies on a synthetic experience and environment. The physical prototypes (i.e. duct tape, wires and off-the-shelf components boosted with imagination) were claimed to be somewhat more concrete (e.g. physically), especially during the focus groups and user tests. However, the work described in this paper focuses on the concepts that are too difficult, or too expensive, to prototype using the traditional methods. The approach described in this paper is by no means the best practice for every possible design case. However, the case that cannot be prototyped just by relying on imagination and rough mock-ups may well benefit with more engaging simulation of the concepts.

The concept of rich interaction and its role for the production was not clear enough. The models and guidelines were not concrete enough to be explicitly exploited. However, the models were used implicitly as a philosophical background for the whole production, so their role was not totally without value. Based on this observation, the rich interaction design guidelines have to be presented in a clear 'cookbook' format. The models served the designers by providing explicit map and scope of the design area. This helped the group to take different aspects of interaction into account without neglecting any potential design issues.

All in all, the rich interaction design process is a relatively complex task and it usually requires a multidisciplinary team to treat the concepts and ideas - each team member providing a specific point-of-view to the concept. Still, the rich interaction design approach should be explicitly defined throughout the production process.

7.4. Benefits of the approach

The rich interaction design experiment can feed the ubiquitous game development process by approaching the design and development from the content-oriented direction. The knowledge and results acquired from experimenting with the high-end audio-visual environment provides the embedded system development with an additional perspective that supports, without conventional limitations, the traditional technological-oriented tasks.

With the two-layered design and development approach consisting of two separate teams, the project was able to meet the short-term goals as well as provide enough creative assets for the current and future versions of the application. This helped in designing innovative concepts and compelling content by making it possible to evaluate abstract concept ideas while the technological development was steadily conducted.

The shared understanding between the separate teams was achieved with the aid of illustrative demonstration material, such as videos, experiments, and narrative descriptions. When comparing the two designs – the 3D version based on the PC platform and the mobile version – the benefits and drawbacks of each solution were clearly visible. So, instead of arguing for the different visions on paper, the designers and developers were able to try out these totally different solutions. Empirical hands-on experience significantly outweighed the design documents. Furthermore, it opened up the possibility to combine the two experiments in a multi-platform and scalable game system.

The project was successful in introducing a creative content production for mobile application development. Contextual Virtual Reality Prototyping combined with conceptual understanding of rich interaction provided satisfactory results. The rapid prototyping and development enabled by selecting a proprietary game engine as the design and development platform made it possible to focus on the interaction design and achieve empirical experiences already at the beginning of the production.

From the rich interaction design point of view, the importance of non-verbal communication in multi-player game environments was brought forward and demonstrated in theory and in practice. Furthermore, the rich interaction design philosophy led to a solution where the user controlled the environment instead of the environment controlling the user.

The results are significant for multi-player game designers as they illustrate the importance and possibilities of non-verbal communication in networked settings. Thus, it is possible to reduce the limitations and restrictions of computer mediation by enabling more flexible and natural interaction, either by using virtual environments or by designing multi-modal interface artefacts. Although the naturalness and intuitiveness of face-to-face communication is hard to achieve, the ubiquitous games provide additional and novel ways to enhance the weak areas of interaction.

7.5. Limitations of the approach

The contextual VRP approach can only be used effectively to prototype concepts that can be easily modelled and simulated. For example, if the physical game environment consists of elements that require high levels of detail that are essential for the game, the construction of the simulation may be too demanding. Furthermore, the simulated approach does not necessarily demonstrate the realistic experiences and compelling aspects of the gameplay. For instance, the action-packed fighting game provides much stronger sensations when physically running out in the open than when sitting in front of a computer.

Although the creative and content oriented work was implemented on top of a less limiting platform, a number of restrictions reducing the applicable interaction features still exist. The specifics of the proprietary game engine may prove to be too limiting, so the balance between cost versus benefit can be difficult to estimate. However, in this case, the differences between the 3D game engine running on a PC and contemporary mobile devices are still relatively large. So, even with the limitations of the PC platform, it was possible to outrun the vividness and dynamics of the interaction features when compared with the mobile platform.

The rich interaction design approach can drastically fail if production lacks freedom. The successful application of the two-layer design process requires enough support and trust from the management, so that the team can fruitfully express their creativity. This can be seen as a potential risk from the management side.

8. Contribution and Conclusions

This paper describes a conceptually grounded rich interaction design approach to multi-player game development. The main emphasis of the approach is on avoiding purely technologically driven design and development, and to provide, in its place, a guiding approach that focuses on the conceptual understanding of rich interaction. With this approach, it is possible to design and develop rich interaction for multi-user systems without limiting the process with the technological conventions. However, successful application of rich interaction design requires a clear and concrete conceptual understanding of interaction.

The described Contextual VRP approach, as an instantiation of rich interaction design, provides designers a way to enlarge their field-of-vision by adding the extremely important use environment and context to the prototypes. The contributions of the VRP research can be utilised with this new approach, thus making it possible to enhance the scope, efficiency, and re-usage factors of the product design, development, and marketing. With the proposed approach, the products can be tested and demonstrated in the corresponding environments, and, in this way, make it easier to understand the use-cases of, for example, a mobile device that has location-dependent features. Furthermore, the evaluation of the concept requires a less cognitive load in terms of discovering the real-world counterparts of the VRP interactions.

The main contribution of this paper is a design approach, which guides the designers and developers to include adequate support for interaction in computer mediated multi-user services and applications. Furthermore, this paper provides theoretical and practical insights to rich interaction design. Although the main portion of the research is situated in the context of multi-player game design, the results can be applied by interactive system designers and ubiquitous game developers working within the area of multi-user virtual environments.

One of the limitations of the approach is the need to work on what is not, from technological perspective, the core activity of the production process. This may cause difficulties in achieving the shared vision, and thus, severely reduce the benefits of the approach. The lack of understanding of the rich interaction concept and the corresponding design philosophy, limits the use of the approach. Concrete rich interaction design guidelines are needed to solve this problem.

The advantage of the described approach is that rich interaction design can provide meaningful and theoretically grounded interaction forms to be developed for multi-user systems. Audio-visually compelling demonstrations enhance the possibilities for shared understanding, and thus make the dissemination of the concepts easier. In addition to this, the rich interaction design approach provides more flexible and communicative systems.

The analysis provides several implications for design. Contextual Virtual Reality Prototyping, with the corresponding demonstration, indicates that there is true potential in a propriety game engine such as *Unreal* for prototyping and designing ubiquitous game concepts. The increasingly important multiplayer aspect makes it possible to test how several simultaneous users would play the game in a specific place, when interacting with the world and with each other.

From the design point of view, the main task, however, is to use artistic selectivity and the principles of game design to achieve engaging and compelling systems. The conceptual and theoretical models of communication and interaction should be utilised in order to make solutions natural and intuitive. The need to understand the whole concept of interaction in virtual environments is evident if the communicational needs of the users are to be supported.

The described rich interaction design approach is not limited to the mobile application context, so the results can be applied to the design of networked virtual environments in general. Interaction design focusing on interpersonal communication and collaboration can benefit from the insights provided in this paper.

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