Formalizing and Promoting Collaboration in 3D Virtual Environments – A Blueprint for the Creation of Group Interaction Patterns

Andreas Schmeil[1,*] and Martin J. Eppler[2]

[1] Faculty of Communication Sciences, University of Lugano (USI), Via Buffi 13, 6900 Lugano, Switzerland
andreas.schmeil@usi.ch

[2] mcm – Institute for Media and Communications Management, University of St. Gallen, Blumenbergplatz 9, 9000 St. Gallen, Switzerland
martin.eppler@unisg.ch

Abstract. Despite the fact that virtual worlds and other types of multi-user 3D collaboration spaces have long been subjects of research and of application experiences, it still remains unclear how to best benefit from meeting with colleagues and peers in a virtual environment with the aim of working together. Making use of the potential of virtual embodiment, i.e. being immersed in a space as a personal avatar, allows for innovative new forms of collaboration. In this paper, we present a framework that serves as a systematic formalization of collaboration elements in virtual environments. The framework is based on the semiotic distinctions among pragmatic, semantic and syntactic perspectives. It serves as a blueprint to guide users in designing, implementing, and executing virtual collaboration patterns tailored to their needs. We present two team and two community collaboration pattern examples as a result of the application of the framework: Virtual Meeting, Virtual Design Studio, Spatial Group Configuration, and Virtual Knowledge Fair. In conclusion, we also point out future research directions for this emerging domain.

Keywords: group interaction, patterns, embodied collaboration, presence, virtual worlds, MUVE, CSCW, blueprint, framework.

1 Introduxction

An ideal online, three-dimensional virtual environment would provide a space in which users can move freely, interact intuitively with all kinds of objects, recognize familiar people, and communicate in a natural manner with them – all in the most realistic look-and-feel setting, evoking a feeling of being part of the virtual world. In addition to that, it would allow displaying complex content or data in innovative and useful ways, neglecting the limitations imposed by physical reality. Such an environment holds the promise of moving remote collaboration and learning to another level of quality. But even if such platforms were available today (and they soon will be): without the right kind of dramaturgy, script or setup, users would not know how to best benefit from their infrastructure.

* Corresponding author.

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We believe that today's available online virtual environments are already capable of adding significant value to collaborative work and collaborative learning. However, companies, institutions as well as educators may not know how to utilize the spatial characteristics of these environments to the fullest. Moreover, many of the virtual environments that are currently (early 2009) being advertised as offering great productivity boosts for collaborative work emphasize on the collaborative editing of text documents, spreadsheets and presentation slides that are mounted on big walls – a method of working together that would work just as well (or better) without gathering in a three-dimensional virtual space.

Our premise, consequently, is that the main two features of 3D virtual environments, namely being embodied in an immersive environment, and the environment being configurable at will, allow for new, innovative, and valuable forms of working and learning together. With our research we aim at improving collaboration in these virtual environments or virtual worlds following these steps:

- systemizing and formalizing the necessary elements for visual collaboration
- developing and identifying novel and existing collaboration patterns, and describing them in the developed formalism
- evaluating their effectiveness experimentally and comparing them (in terms of added value) to other collaboration arrangements

In this paper, we focus on steps one and two and present a framework for embodied collaboration in online 3D virtual environments, based on semiotics theory, as well as an overview on virtual collaboration patterns. Our framework represents a blueprint of how collaborative group interaction patterns in virtual environments can be described or generated. We also present four examples of the application of the framework, resulting in four online collaboration patterns. We believe this framework to form a first important step in the process of formalizing collaboration in virtual environments – a task that is crucial in order to put forward the application of 3D virtual environments for serious and productive uses.

The remainder of this paper is structured as follows: First, we define online virtual environments and present their advantages for collaboration. In section 3, we then present a blueprint to formalize the design elements and necessary infrastructure of collaboration patterns in such environments. In section 4, we provide real usage examples of collaboration patterns based on virtual embodiment. In section 5 we highlight future research avenues for this domain. We conclude the article with a review of our main contribution and its limitations.

2 Online Multi-user Virtual Environments

Virtual environments in general attempt to provide an environment where the user or spectator feels fully immersed and present. This *presence* is a psychological phenomenon that has been defined as the sense of being there in an environment. *Immersion*, on the other hand, describes the technology of the virtual environment and its user interface that aims to lead to the sense of presence. It can be achieved to varying degrees, stimulating a variable number of human senses. However, the expression of feeling immersed is often also used for online, desktop-based, virtual environments that are controlled only by keyboard and mouse and address only two sensory channels: the visual and auditory one.

This kind of virtual environment, featuring multiple users to be in the same shared virtual space at the same time, has been named Online 3D Multi-User Virtual Environment, or MUVE for short. While formal definitions are generally rare in this area, a MUVE is agreed to be a special type of a Collaborative Virtual Environment (CVE). In the ongoing scientific discourse in the research community, a Virtual World, commonly understood as a special type of MUVE, has recently been defined as "a synchronous, persistent network of people, represented as avatars, facilitated by networked computers" [2]. Our research only regards MUVE and Virtual Worlds as opposed to locally installed multi-user VR systems, for the following two reasons: First, the major benefit of utilizing 3D virtual environments is widely believed to be the possibility to have instant team or group meetings without travel. Second, serious collaboration in and between companies is not likely to take place in Immersive Virtual Reality centers (due to availability, accessibility, costs, complexity, and constant need for technical staff).

To date, there is an abundance of MUVE and Virtual Worlds available, for all age groups and for many different areas of interest. The Virtual Worlds consultancy K Zero keeps informative graphs up-to-date on their company website[1]. While systems like Second Life, OpenSim and Activeworlds enable users to design their worlds and to create static and interactive content themselves, others like Sun's Wonderland and Qwaq Forums focus on productivity in conventional tasks like the editing of text documents, spreadsheets and presentation slides; only up-/download of documents and repositioning of furniture is possible in these latter worlds. Still others focus on providing training scenarios. New MUVE and Virtual Worlds are launched almost monthly, and it seems like each new one tries to fill another niche.

Nevertheless, for most application domains, it is still unclear what value MUVE might add to the existing modes of communication and collaboration, just as it remains unclear which features and enhancements are needed to maximize the benefit of using virtual worlds [1]. In a previous paper, we have discussed the advantages (and potential risks) that collaborative virtual worlds bring for knowledge work and education – which are by definition also valid for MUVE [17]. In this paper, we try to define more specifically how these advantages can come about.

3 A Blueprint for the Creation of Collaboration Patterns

As already stated as our premise, we believe that the fact of being embodied in a configurable three-dimensional virtual environment allows for innovative, valuable new forms of working and learning (and also playing) together. *Embodiment* terms the coalescence of recent trends that have emerged in the area of Human-Computer Interaction (HCI) and reflects both a physical presence in the environment and a social embedding in a web of practices and purposes [7]. It is in the same manner applicable to group interaction in MUVE, as users feel immersed in the virtual environment and present in the same setting with their colleagues or peers (co-presence). With *configurable* we mean the possibility of creating or uploading and editing or modifying interactive objects in the virtual environment.

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[1] http://www.kzero.co.uk [last access 11/02/2009]

While there has been research on the feasibility and usability of embodied conversational agents in Virtual Reality (VR) applications [15], and also on presence and co-presence in VR [19], it is yet to be investigated how embodiment in online virtual environments affects group interaction and collaborative tasks. Manninen states that "the successful application of a social theory framework as a tool to analyze interaction indicates the importance of joining the research effort of various disciplines in order to achieve better results in the area of networked virtual environment interactions." [12]. His work and results will be discussed in more detail in subsection 3.3.

The approach we are presenting in this paper is also of interdisciplinary nature – in particular, we combine communication theory and insights from the field of HCI. The resulting framework presents a systematic view on the field of Multi-User Virtual Environments (MUVE) and their utilization for collaborative tasks. As such it represents a blueprint on which diverse collaboration tasks, such as planning, evaluation, decision making or debriefing can be designed and executed. It is based on the underlying distinctions of semiotics and employs concepts from the HCI research field. We present it in detail and discuss its use in 3.5. In the following, we first describe the various steps that we have taken in developing the framework.

3.1 Using Patterns for the Description of Virtual Embodied Collaboration

We have realized the need for a solid formal framework that is capable of describing collaboration in MUVE in all its aspects while identifying group interaction patterns of collaborative work and learning in the virtual world Second Life [17]. The pattern approach is a useful and concise approach to classify and describe different forms of online collaboration. Manninen states that the utilization of real-world social patterns as basis for virtual environment interactions might result in usable and acceptable solutions [12].

An alternative approach to using patterns would be to describe collaborative situations as scenarios. A scenario is an "informal narrative description" [6]. However, comparing this with the definition of patterns, a "description of a solution to a specific type of problem" [9], reveals that the pattern concept has been contrived with more focus to solve a problem or to reach a goal. In addition to that, a look at the work of Smith and Willans, who implement the concept of scenarios for requirements analysis of virtual objects [21], makes it clear that the scenario-based approach is too fine-grained and at a too low, functional level to describe whole collaborative tasks in flexible multi-user settings.

Hence, we have decided to use the pattern approach. We adapt the collaboration pattern definition from [9] by adding the notions of tools and a shared meeting location, to give us the following definition: A collaboration pattern is *a set of tools, techniques, behaviors, and activities for people who meet at a place to work on a common goal, together in a group or community*. How exactly this definition fits with the resulting framework will be explained by means of an illustration in 3.5.

3.2 The Semiotic Triad as an Organizing Structure

From a theoretical point of view, one can conceive of collaboration activities as interpretive actions and of collaboration spaces as sign systems in need of joint interpretation. Visual on-screen events in virtual spaces have to be interpreted by users of

MUVE as relevant, meaningful, context-dependent signs that contribute towards joint sense-making and purposeful co-ordination. As in any sign interpretation system or (visual) language, semiotic theory informs us that three different levels can be fruitfully distinguished, namely the syntactic, semantic and pragmatic ones [8]. This threefold distinction has already been applied effectively to various forms of information systems or social online media (e.g. [18]). These three distinct interpretive layers can be applied as follows to immersive virtual worlds:

The *syntactic dimension* contains the main visible components of a collaboration pattern and its configuration possibilities. The syntactic dimension ensures the visibility and readability of a collaboration pattern. It provides the necessary elements as well mechanisms to use elements (digital artifacts and actions) in combination.

The *semantic dimension* refers to the acquired meaning of elements and to the conventions used in a collaboration pattern. It outlines which operations or artifacts assume which kind of meaning within a collaboration pattern. While the syntactic dimension tells the user how to use a collaboration pattern (and with which elements or actions), the semantic dimension aligns the available visual vocabulary to the desired objectives or contexts. In this sense the semantic level is a liaison layer between the virtual world and the participants' objectives.

The *pragmatic dimension* reflects the social context of the participants, and their practices, goals and expectations. It is these intentions that need to be supported through the dramaturgy (semantic dimension) and the infrastructure (syntactic dimension). This dimension clarifies in which situations which type of dramaturgy and infrastructure use makes sense.

3.3 Action and Interaction in 3D Virtual Environments

In our understanding, the support of action and interaction forms one major part of a virtual environment's infrastructure. It determines how users can act and affects their behavior in both lonely jaunts and in group settings. Moreover, the way users can control their avatars and perform actions heavily influences the level of satisfaction of the user and thus in the end determines whether or not collaborative work or other planned tasks in the virtual environment succeed or fail, continue or are abandoned.

We believe that a formalization of action and interaction in virtual environments on a high abstraction level is required. Manninen successfully applied a social theory framework to create a taxonomy of interaction, resulting in a classification of eight categories: Language-based Communication, Control & Coordination, Object-based Interactions, World Modifications, Autonomous Interactions, Gestures, Avatar Appearance, and Physical Contacts [12]. However, this classification is based on studies in multi-player online action and role-playing games, where different requirements regarding interaction must be assumed than for serious collaborative tasks. Also, the study might have focused too much on a language-centered perspective and neglected some of the genuinely visual aspects of virtual worlds.

In the field of Human Computer Interaction there is a generally accepted distinction among navigation and manipulation techniques. Navigation techniques comprise moving the position and changing the view. Manipulation techniques designate all interaction methods that select and manipulate objects in a virtual space. In some cases, the side category System Control is used, consisting of all actions that serve to change a mode and modify parameters, as well as other functions that alter the virtual experience itself. Bowman and colleagues refine this classification by adding a category Symbolic Input for the communication of symbolic information (text, numbers, and other symbols) to the system [5]. For our purpose of formalizing (inter)actions for collaboration, we build on this classification and make the following adjustments to align it with the requirements of the area of Online 3D MUVE:

The importance of communicating text, numbers, symbols, and nowadays also speech to the system (and thus to other avatars or users, interactive objects, or the environment itself) has increased significantly. We call this first category *Communicative Actions*. A sub-division differentiates between verbal (i.e., chatting) and non-verbal communication (i.e., waving).

Having both navigation techniques and methods for changing the view in one shared category, results from the fact that HCI and VR systems do not necessarily assume the existence of an avatar as a personalization device in the virtual environment; without this embodiment, navigating and changing the viewpoint can be considered as one and the same action. In our classification, changing one's view would fall into the communicative actions category, as a non-verbal form of letting others know where the user's current focus of attention is, or to communicate a point or object of interest to others in the virtual environment (the primary purpose of changing the view can be disregarded here, since it is only the actuating person who experiences the change). As a result, our second category, *Navigation*, comprises only walking, flying or swimming, and teleporting (in the nomenclature of Second Life).

We rename the manipulation techniques category as *Object-related Actions*. Actions referring to the creation or insertion of virtual objects also belong to this category, along with selection and modification techniques. By insertion we mean the result of uploading or purchasing virtual objects, for instance.

All system control actions are much less important in MUVE than they are in classic Virtual Reality systems. Due to the often customized or prototype forms of VR applications, system control is in many cases developed and tailored to only one application. In MUVE, by contrast, the viewer software (i.e. the client application to enter the virtual environment) is usually standardized and provides a predefined set of system control options. Hence, we dispense with a system control category.

If one were to put these actions on a continuous spectrum, they could also be distinguished in terms of their virtual world effects or level of invasiveness or (space) intrusion. Chatting or changing one's position, avatar appearance, or point of view is far less intruding than moving an object, triggering a rocket, or blocking a door.

Further, it has to be noted that these distinctions and the resulting classification do not include virtual objects. These, in our view, require a separate classification that takes their manifold types and functions into account. In the following subsection, we discuss this important element of virtual environments.

3.4 A Typology of Objects in Virtual Environments

In his successful book *The Design of Everyday Things*, Donald Norman postulates that people's actions and human behavior in general profits from everyday objects being designed as to provide affordances, i.e., they should communicate how they should be used [13]. He argues that less knowledge in the head is required (to perform well) when there is, what he calls, knowledge in the world. This insight can be fruitfully applied to virtual worlds by building on latent knowledge that users have and by providing cues that reuse appropriate representations [20]. This not only gives motivation for practitioners to utilize virtual environments for collaborative tasks, but implies that objects in virtual environments and their design are of great importance. Hence, we understand virtual objects as to form another major part of a virtual environment's infrastructure. Affordances can (and should) be used to signal users how to interact with a particular object, or how objects with built-in behaviors may act without any direct influence from the user's side.

Fact is, however, that for a long time researchers active in virtual environments have focused largely on graphical representation and rendering issues. With the launch (and most of all with the hype) of Second Life, a new era of accessible online virtual environments has begun. Following the trend of enabling users to create content (also a vital element of Web 2.0), users of many MUVE can now create and edit objects, and customize the appearance of their avatars. With the possibility of scripting objects, they have become a powerful instrument in designing memorable user experiences in MUVE. In fact, interactive virtual objects represent technology in virtual environments; without active and interactive objects, any virtual environment would be nothing more than a virtual version of a world without technology. This comparison might illustrate the need for a formalization regarding virtual objects.

In spite of their crucial functional importance, little research has been conducted on classifying virtual objects so far. More work has been done on the technical side; for instance, an approach of including detailed solutions for all possible interactions with an object into its definition has been proposed [11]. Another later presented framework takes up on this idea and adds inter-object interaction definitions [10]. Currently – to the authors' knowledge – at least the two MUVEs Second Life and OpenSim support defining avatar positions for interaction within an object definition, as well as inter-object communication. A first informal classification of virtual objects was proposed by Smith and Willans while investigating the requirements of virtual objects in relation to interaction needs: the authors state that the task requirements of the user define the behavioral requirements of any object. Consequently, they distinguish between background objects, which are not critical to the scenario, contextual objects, being part of the scenario but not in the focus, and task objects, which are central to the scenario and the actions of the user [21]. While this distinction may be useful for determining the level of importance of virtual objects, i.e. in requirements analysis phase, it does not distinguish objects based on their functional characteristics. Hence, we present a classification of virtual objects according to their activeness and their reaction to user actions:

Static Objects have one single state of existence; they do not follow any type of behavior and do not particularly respond to any of a user's actions. We distinguish among static objects that are in a fixed position, i.e. not movable and not to take away, and objects that are portable. These latter static objects can be visibly worn, carried or just repositioned, and thus have a distinct value for visual collaboration.

Automated Objects either execute animations repeatedly or by being triggered. Alternatively they follow a behavior (ranging from simple behaving schemes such as e.g. following an avatar, through highly complex autonomous, intelligent behaviors). We further separate the most rudimentary of all object behavior forms into an extra sub-category – the behavior of merely constantly updating its state or contents.

Interactive Objects represent generally the notion of a tool or instrument; either they produce an output as a response to a given input, or they execute actions on direct user commands (like e.g. a remote control), or they act as vehicles, meaning that the user directly controls their movement (with or without the user's avatar on it), using his primary navigation controls. The border between automated and interactive objects may seem fuzzy at first, but it is clearly delineated by the differentiation whether a user triggers an object to act deliberately or indirectly.

Considering alternative classification properties, for example the distinction of whether virtual objects are fixed in their position or not, whether they can be moved or deformed, or follow physical laws, e.g. move in the wind, is in our belief of secondary importance – especially for the use cases we try to support with our contribution (professional collaboration tasks).

3.5 A Blueprint for Embodied Virtual Collaboration

Figure 1 illustrates the framework for virtual collaboration based on the distinctions described in the previous sections. It is intended as a blueprint for virtual, embodied collaboration in virtual environments. As such, it can be used as a basis to develop or describe collaboration patterns in MUVE. Its three-tier architecture reflects the syntactic, semantic, and pragmatic levels of a collaboration medium, as discussed in 3.2. In the following, we explain the parts of the framework, in a top-down order.

Context and Goal. The context describes the application domain of a collaboration pattern, while the goal defines more specifically what kind of activity a pattern aims to support. A first category comprises patterns that aim for collaborative work in the traditional sense, i.e. having main goals such as to share information or knowledge, collaboratively design or create a draft, a product, or a plan, assess or evaluate data or options, or make decisions etc. Since these goals do not necessarily have to be associated with work in the narrow sense of the word, we label the first context category *Collaborate* (for a definition of collaboration see [16]). The category *Learn* frames the domain of education. We assigned six goals to it, selected according to Bloom's Taxonomy [3]. Bloom distinguishes different levels of learning goals starting with simple memorizing or recalling information, to the more difficult tasks of comprehending something, being able to apply it, analyze it, being able to synthesize it or even evaluate new knowledge regarding its limitations or risks. In the domain of *Play* we do not strive for mutually exclusive and collectively exhaustive categories and simply allude to such usual game oriented goals as feeling challenged by competition, distracting oneself (losing oneself in a game), or socializing with others in a playful manner. A collaboration pattern can also be aiming at several goals.

Dramaturgy. The term dramaturgy in this context designates the way in which the infrastructure in virtual world is used to reach a specific collaboration goal or in other words support a group task. While the goals and contexts specify the why of a

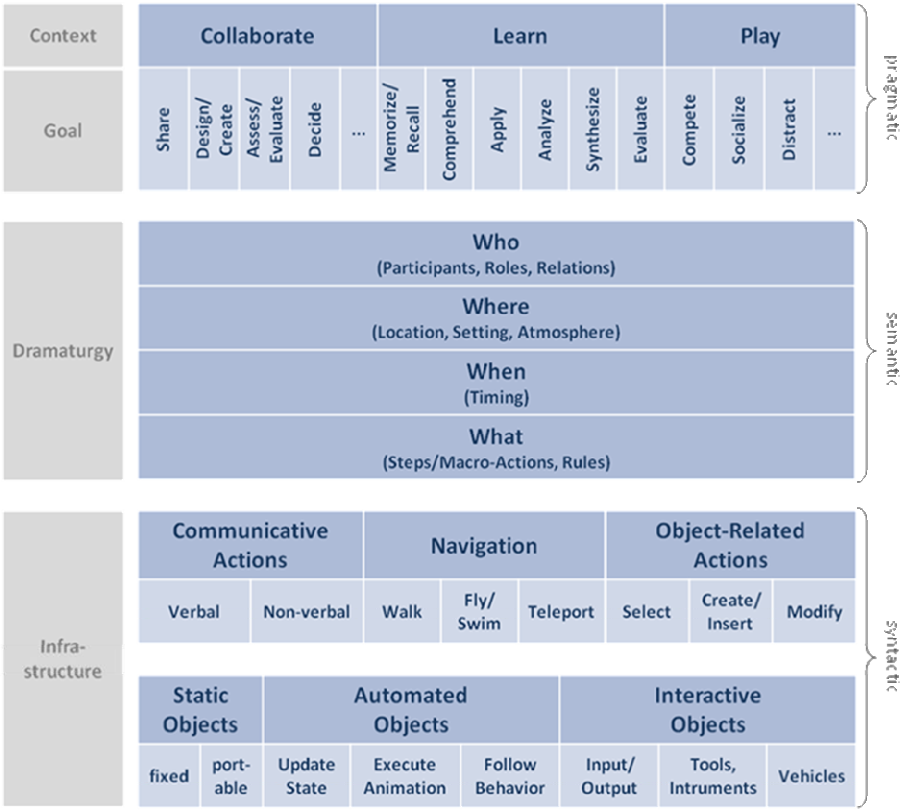


Fig. 1. A Blueprint for Embodied Virtual Collaboration

collaboration pattern, and the infrastructure (below) the how, the dramaturgy consists of the necessary participants and their roles and relations (the 'who'), their interaction spaces and repertoire (the 'where'), as well as the timing and sequencing of their interactions (the 'when'). The dramaturgy also specifies the actions (the 'what') taken by the participants and the social norms and rules they should follow within a given collaboration pattern. The dramaturgy defines in which ways the infrastructure of a virtual world can be used by the participants to achieve a common goal.

Infrastructure. The final, most basic level of the blueprint contains the previously discussed elements Actions and Objects. As explained in previous subsections, we think it is useful (for the design of patterns) to distinguish among communicative, navigational, and object-related actions and among static, automated, and interactive virtual objects.

We refined a definition of a collaboration pattern in subsection 3.1, as being *a set of tools, techniques, behaviors, and activities for people who meet at a place to work on a common goal, together in a group*. Using the wording of the framework, this would translate to *a set of objects, actions, rules, and steps for participants with roles who meet at a location to collaborate on a common goal in a given context*. A specific collaboration pattern is then an instance of the framework and can be defined using the parameters positioned within the framework.

There are two distinct ways in which the above blueprint can be used for practical and research purposes: It can be used in a top-down manner from goal to infrastructure in order to specify how a given goal can be achieved using an online 3D virtual environment. Alternatively, the blueprint can be used bottom-up in order to explore how the existing virtual world infrastructure can enable innovative dramaturgies that help achieve a certain collaboration (or learning) goal. In the next section, we are going to illustrate how the elements of the framework can help in the description of collaboration patterns. Some of these patterns have been developed using the framework in a top-down manner, while others were created from a bottom-up perspective.

4 Examples of Collaboration Patterns Based on the Blueprint

The theory of patterns, originally developed for architecture [14], but in practice more commonly used in software development, can be applied to the domains of collaboration, as outlined above. The documentation of collaboration patterns, however, needs to be adapted to the context of virtual environments. For this purpose, we have presented a collaboration framework in section 3 which we will now use to present a series of online collaboration patterns.

We have collected a number of virtual collaboration patterns and formalized them using the blueprint of section 3. The resulting patterns range from Virtual Team Meeting, Virtual Town Hall Q&A, Virtual Design Studio, Online Scavenger Hunt, Virtual Role Playing, Project Timeline Trail, Project Debriefing Path, Virtual Workplace, Virtual Knowledge Fair, to Spatial Group Configuration (for these and other patterns, see [17]). In figures 2 and 3, we provide four examples of collaboration patterns based on our framework. The first two patterns support teams in their collaboration, while the patterns documented in figure 3 can be used by larger groups. As the figures illustrate, a collaboration pattern (i.e. an instance of the framework) is comprised of one or several alternatively applicable contexts, several possible goals for the pattern, a full dramaturgy description, and avatar actions and virtual objects that are required. Hereby, actions and objects are ordered by relevance for the particular pattern (e.g. talk and chat can be useful for most patterns, although are not crucial in every case, thus not documented there).

These four examples illustrate that the framework presented can be used to analyze or document the core requirements for online, virtual embodied collaboration in the form of patterns (although a complete pattern description should also contain pointers to related patterns). The framework cannot, however, predict the actual value delivered by such collaboration patterns. We will address this important issue in section 5.

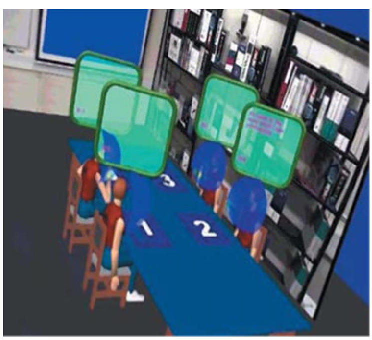
Name	Virtual Team Meeting	Virtual Design Studio
Context	**Collaborate** – project meeting, team meeting, management meeting, etc.	**Collaborate** – product development, design session, architectural review, etc.
Goal	**Share** – knowledge transfer **Decide** – decision making	**Design** – design of a physical or virtual object or building **Assess** – assess, annotate, modify drafts
Dramaturgy	**Who:** < 15 team members	**Who:** < 6 designers, product engineers, architects
	Where: virtual team or meeting room	**Where:** functional design room
	When: < approx. 1 hour (duration)	**When:** < approx. 4 hours (duration)
	What: define the agenda, discuss its items, screen options, reach decisions, document decisions and next steps, as well as responsibilities	**What:** prepare design room, agree on design scope, import drafts, edit and modify designs, try out design alternatives, export approved versions
Infra-structure	**Actions**	**Actions**
	Verbal – talk, chat **Non-Verbal**– show, affirm,decline, vote **Create/Insert** – upload documents **Modify** – co-edit documents	**Modify** – model, sketch, annotate **Create/Insert** – upload documents **Select** – select objects or parts **Non-Verbal** – point, show perspective
	Objects	**Objects**
	Fixed – places to sit **Interactive** – information screens **Automated** – statistics displays	**Interactive** – modeling tools, sketching tools, annotation tools **Fixed** – environment of the object
Screenshots		

Fig. 2. Two Collaboration Patterns for Virtual Teams in the Structure of the Blueprint

Name	Spatial Group Configuration	Virtual Knowledge Fair
Context	**Collaborate** – voting by position, division into groups, revealing similarities, etc.	**Collaborate** – internal knowledge sharing, dissemination, find partners, etc
Goal	**Decide** – vote **Share** – show preferences and opinions **Assess** – decide with moving cause	**Share** – exchange experiences and project information, present work or new products, advertise, network
Dramaturgy	**Who:** > 10 or > 30 individuals, depending on utilization	**Who:** > 30 specialists
	Where: vast field, either subdivided into areas or framed by symbols	**Where:** convention center, pavilions, show rooms, or other stands
	When: < 5 minutes (duration)	**When:** duration of up to an entire day (synchronous) or week (asynchronous)
	What: define the alternatives for voting/assessing, subdivide area and/or place symbols, let users position their avatars on the field, analyze result	**What:** prepare stands and hallways/ paths showing information and demos, run/execute scheduled lectures and presentations, look after visitors
Infra-structure	**Actions**	**Actions**
	Walk – position avatar on a field subdivision or close to a symbol, to communicate vote, decision or assessment answer	**Verbal** – chat, talk, present **Non-Verbal** – point, draw attention, demonstrate **Walk** – roam the fair, meet others
	Objects	**Objects**
	Fixed – symbols and/or field subdivision **Automated** – position interpreter for automated data analysis and statistics (optional)	**Interactive** – modeling tools, sketching tools, annotation tools **Fixed** – environment of the object
Screenshots		

Fig. 3. Two Collaboration Patterns for Virtual Communities, in the same Structure

5 Future Research Needs and Initiatives

Having established a systematic map of the elements required to devise and implement virtual, immersive and embodied collaboration patterns, the question nevertheless remains which of these patterns are the most effective ones in terms of their benefit in supporting collaboration tasks in groups (and what drawbacks or risks they may contain). To this end, we are currently devising experimental settings in order to compare virtual collaboration patterns with other collaboration settings. Our first experiment will take place in an especially prepared project setting implemented in an OpenSim environment. It will consist of a series of typical project management tasks, such as introducing project team members to each other, team building, conducting a stakeholder analysis, or agreeing on a joint timeline of project milestones. In a first set of experiments we will use students as participants, in a second round managers.

In addition to observing and recording the behavior and measuring the performance of the participants, we will also administer ex-post surveys on the participants' satisfaction with the task and communication support provided by the collaboration pattern and the virtual environment. This should give us additional insights into how the elements of a virtual collaboration pattern work together. While these experiments will yield relatively reliable data, they nevertheless lack the real-life context in which collaboration usually takes place. Consequently, a further area of research consists of participatory observation (or alternatively online ethnographies) in real-life collaboration settings that take place in virtual worlds. This will allow researchers to better assess the real advantages and disadvantages of this new form of working together. Additionally, in another related ongoing research project we are investigating communication and the use of tools in real-life design studios [4]. This work might give further insights on the infrastructural requirements (i.e. actions and objects, in our blueprint nomenclature) for patterns for collaborative design.

6 Conclusion

In this contribution, we have developed and presented a systematic framework that organizes the necessary elements for the design and implementation of collaboration patterns in virtual worlds. This framework is based on three levels, namely the pragmatic or contextual level, including the goals of an online interaction, the semantic or dramaturgic level that defines how elements and actions are used (and interpreted) in time to achieve the collaboration goal, and the syntactic or infrastructure level consisting of the actual objects and online actions that are combined to implement a collaboration dramaturgy. We have presented two team-based virtual collaboration patterns, and two community-based collaboration patterns to illustrate the use of the framework. In terms of limitations and future research needs, we have pointed out that our framework does not provide indications as to the value added of collaboration patterns. This is thus an area of future concern that we will examine through the use of controlled online experiments and in-situ participatory observation within organizations.

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