Improving Remote Collaborative Process Modelling using Embodiment in 3D Virtual Environments

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Abstract

Identifying, modelling and documenting business processes usually require the collaboration of many stakeholders that may be spread across companies in inter-organizational settings. While modern process modelling technologies are starting to provide a number of features to support remote collaboration, they lack support for visual cues that are present in co-located collaboration. In this paper, we examine the importance of visual cues for collaboration tasks in collaborative process modelling from distributed remote locations. Based on this analysis, we present a prototype 3D virtual world process modelling tool that supports a number of visual cues to facilitate remote collaborative process model creation and validation. We report on a preliminary analysis of the technology and also describe the future direction of our research with regards to the theoretical contributions expected from the evaluation of the tool.

Keywords: Virtual Environments, Avatars, Collaboration, Business Process Modelling

1 Introduction

Business process modelling is a key practice in business process management (van der Aalst et al. 2003), which has been a top priority in many enterprises for a number of years now (Gartner Inc. 2010) as they invest in efforts to (re-) design organizational or technological systems.
Process modelling is concerned with graphically describing the business processes of an organization (Indulska et al. 2009). To create process models, modelling experts have to extract and consolidate the domain knowledge that is distributed among all the people involved in the business process (Dean et al. 2000). This happens in the form of communication between the modelling expert(s) and the domain experts in group workshops or individual interviews (S. Hoppenbrouwers et al. 2005).

Tool support for process modelling has been shown to affect the perceptions (Recker 2012) of stakeholders as well as to increase the participation in process improvement projects (Kock 2001). This is especially so when domain experts are scattered across multiple locations in a large multinational company or in global projects, when technology is a required mechanism to facilitate communication and collaboration. Technology that supports synchronous communication such as audio or video conferencing is broadly available today. This technology, however, does not support a number of visual cues that are often used for efficient collaboration on artefacts.

In this paper, we report on research that specifically explores technology support for visual cues in synchronous communication to aid the process of collaborative process modelling in distributed settings. Based on this research we hypothesise that the use of avatars in a virtual environment will facilitate remote collaborative process model creation and validation, by providing visual cues that are critical for efficient collaboration. To that end, we report on the development of a prototype solution based on 3D virtual world technology and outline our research plan that will examine the impact of such communication features on collaborative model validation and correction tasks.

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2 Background

Our research builds on, and integrates, three streams of literature: First, we need to understand how process modelling is conducted, and how this process changes when relevant stakeholders need to collaborate remotely. Second, we need to understand how technology can be used to facilitate communication in remote collaborative tasks. Finally, we need to specifically understand how visual cuing can be used to alleviate communication problems in remote collaborations. We discuss these issues, in turn.

2.1 The Process of Process Modelling

Process modelling transforms knowledge about the processes of a business into accurate models (Scholz-Reiter & Stickel 1996). These models are governed by process modelling grammars or languages, which provide a set of constructs and rules about how these constructs can be used to represent real-world phenomena (Wand & Weber 2002).

The knowledge required for this transformation is usually distributed across a range of people internal and sometimes external to a business. Each of these stakeholders has a mental model of the process. Through collaboration, these models are adjusted iteratively until every participant has the same mental model (S. Hoppenbrouwers et al. 2005). Accordingly, process modelling can be described as a process of converging on a shared view (J. Hoppenbrouwers et al. 2005) that is

	Participants Heads and Faces	Participants Bodies and Actions	Task Objects	Work Context
Monitor task status	**A1** - Facial expression can be used to identify how close to agreement the team is at any stage.	**A2** - Inferences about intended changes to task objects can be made from body position and actions.	**A3** - Changes to task objects can be directly observed	**A4** - Activities and objects in the environment that may affect task status can be observed
Monitor participants' actions	**B1** - Gaze direction can be used to infer intended actions	**B2** - Body position and actions can be directly observed	**B3** - Changes to task objects can be used to infer what others have done	**B4** - Traces of others' actions may be present in the environment
Establish joint focus of attention	**C1** – Eye-gaze and head position can be used to establish others' general area of attention	**C2** - Body position and activities can be used to establish others' general area of attention	**C3** - Constrain possible foci of attention	**C4** - Constrain possible foci of attention; disambiguate off-task attention (e.g. disruptions)
Create efficient messages	**D1** - Gaze can be used as a pointing gesture	**D2** - Gestures can be used to illustrate and refer to task objects.	**D3** - Pronouns can be used to refer to visually shared task objects	**D4** - Environment can help constrain domain of conversation.
Monitor comprehension	**E1** - Facial expressions and nonverbal behaviours can be used to infer level of comprehension	**E2** - Appropriateness of actions can be used to infer comprehension and clarify misunderstandings	**E3** - Appropriateness of actions can be used to infer comprehension and clarify misunderstandings	**E4** - Appropriateness of actions can be used to infer comprehension and clarify misunderstandings

Table 1: Visual cues for coordination and common ground. Adapted from Kraut et al. (2003)

iterative and highly dependent on communication.

Therefore, in a setting where these stakeholders are distributed across multiple, geographically distant sites, communication in task settings such as process modelling requires the use of technology.

2.2 Communication

Much research has been conducted to describe the processes and cognitive costs of communication. Clark & Brennan (1991) argued that communication is not only about a communicator sending a message to one or many receivers, but also about gathering evidence that the intended audience actually received and understood the message. They call this process "grounding of communication". For this communication process, fast and efficient feedback is important. Such feedback can take a number of forms including verbal acknowledgement, back-channel feedback and situated actions.

Kraut et al. (2003) identify how visual cues can be used in remote collaboration task settings to facilitate communication and feedback. Table 1 provides a summary. They suggest that common ground is facilitated by visual cues provided by the participants' faces, body posture, shared objects and work context. They say that these are used to monitor the status of the collaborative task, the participants' actions and comprehension, to direct and identify the focus of attention and create efficient messages. These effects have been demonstrated in a number of experiments. Specifically, full gaze-awareness (Monk & Gale 2002), situated actions (Gergle et al. 2004) and gesturing (Dodds et al. 2011) have all been shown to positively impact communication efficiency.

In summary, when communicating, people can make use of visual cues provided by head, body and shared objects to provide efficient feedback. This facilitates coordination and a common ground in collaboration. These visual cues are especially relevant in remote collaboration tasks involving the design and use of artefacts. We now review how visual cues relate to the process of process modelling specifically.

2.3 Visual Cues in Collaborative Process Modelling

Co-located process modelling is often conducted in workshops where several stakeholders are situated around a process model in form of a print-out or projection. The physical co-presence in the workshop setting facilitates the process of grounding communication between participants because the shared visual space supports a variety of visual cues. For example, the bodies of every workshop participant improve situational awareness by providing an indication of a) who is present, b) who is working together with whom and c) who is working on which part of the model. They therefore support awareness of the part of the process currently being discussed. Fig. 1 provides an example.

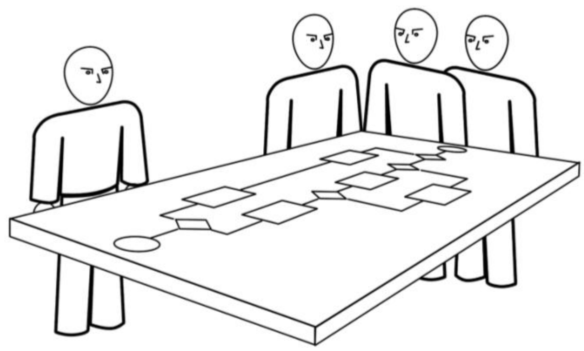

Fig. 1: Awareness and spatial context in collaborative process modelling.

The body can also be used for non-verbal communication (Fig. 2). Through gesturing and gaze the discussion can be regulated, structured and illustrated. For example, nodding to demonstrate agreement or understanding can provide efficient feedback to the speaker without interrupting. Pointing directs a joint focus of attention and therefore allows for efficient referencing of model parts and locations.

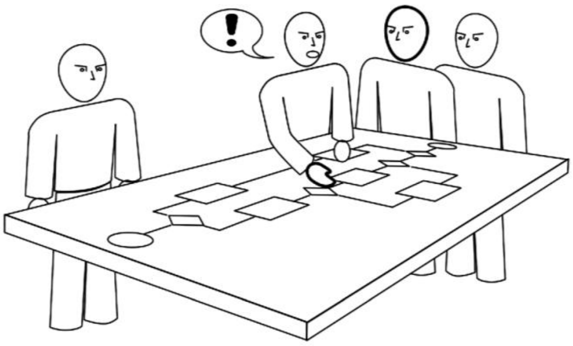

Fig. 2: Synchronous verbal and non-verbal communication in collaborative process model modelling

Furthermore, some non-verbal cues, such as facial expressions and body posture, can be without communicative intent of participants, as shown in Fig. 3. For example, gazing away indicates a decline in interest, which in turn impacts consensus-building and group decision-making processes in relation to the modeling artefact.

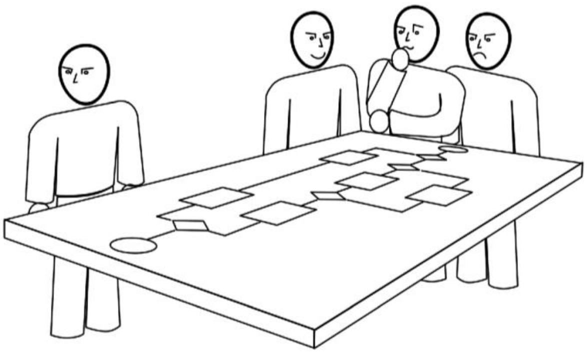

Fig. 3: Unintentional non-verbal communication in collaborative process modelling

In summary, communication in process modelling tasks can be facilitated by a number of visual cues when a visual space is shared by participants, for example due to physical co-presence. We now examine how much support is offered by current technology in remote settings where physical co-presence is limited.

2.4 Tool Support for Collaborative Process Modelling

When co-presence in a shared physical space is not possible or not efficient, communication needs to be supported by technology in order to allow for collaboration.

While verbal communication can be easily supported by phones or VOIP applications, shared visual features and spaces are more difficult to support. Video conferencing supports some visual features, such as facial expression and body posture, but literature shows that it has several limitations (Gaver 1992). The limited and stationary view into the other person's immediate environment makes it hard to see at what location the person is looking or pointing. Hindmarsh (2000) concludes that most synchronous communication systems fail to accommodate the processes people use to establish mutual orientation when collaborating on artefacts at a co-located site. Process modelling technologies have started to address the problem of collaboration in process modelling. Commonly used generic drawing tools such as Microsoft Visio do not support collaboration explicitly. Users have to save models to files and send these via email, separate repositories or other collaborative systems. BizAgi (2012) provides a locking mechanism to signal individual edits to a model, but no functionality to share models. Signavio (2009) solves this problem by storing models in a centralized repository. However, Signavio does not provide support for synchronous communication. Hahn et al. (2010) found that there is little support for synchronous collaboration in most process modelling tools they examined. Mendling et al. (2012) similarly observed that some aspects of awareness and communication are poorly supported by current process modelling tools. More recently, however, tools have started to implement synchronous collaboration features such as chat functions and synchronous model viewing and editing. IBM Blueworks Live (IBM 2010) and SAP StreamWork (SAP 2010) provide synchronous communication tools in the form of text chat. ARIS Business Architect and ProcessWave support audio and video chat.

These tools, therefore, provide support for the use of shared artefacts for coordination and common ground, but not for any of the cues that require an explicit embodiment in the modelling space. To support this argument, we have studied a focussed collection of tools, as well as any available documentation and publications relating to them, to analyse the functional support of any of the visual cues listed in Table 1. Table 2 shows the visual cues supported by each of the tools mentioned above, compared to the proposed prototype tool. Cues are listed as 'fully supported' when the behaviour described for the cues can be reproduced with the software. They are marked as 'partially supported' when meaningful parts of this behaviour can be reproduced using the tool. Otherwise, they are marked as 'not supported'. As can be seen, visual cues that use the body and actions of participants are not supported by any of the tools. Even though some tools show an image of the participant, it is never used in relation to the process model. We now discuss technology that can support these kinds of visual cues.

Tool vs Feature	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4	E1	E2	E3	E4	#
Microsoft Visio	×	×	×	×	×	×	(✓)	×	×	×	✓	×	×	×	×	×	×	×	×	×	**1**
BizAgi	×	×	×	×	×	×	✓	×	×	×	✓	×	×	×	×	×	×	×	×	×	**2**
Signavio	×	×	×	×	×	×	✓	×	×	×	✓	×	×	×	×	×	×	×	×	×	**2**
IBM Blueworks	×	×	✓	×	×	×	✓	×	×	×	✓	×	×	×	×	×	×	×	✓	×	**4**
SAP StreamWork	×	×	✓	×	×	×	✓	×	×	×	✓	×	×	×	×	×	×	×	✓	×	**4**
ARIS Business Architect	✓	×	✓	(✓)	×	×	✓	(✓)	×	×	✓	(✓)	×	(✓)	(✓)	(✓)	✓	×	✓	(✓)	**6**
ProcessWave	✓	×	✓	(✓)	×	×	✓	(✓)	×	×	✓	(✓)	×	(✓)	(✓)	(✓)	✓	×	✓	(✓)	**6**
West et. Al Prototype	×	✓	✓	×	(✓)	✓	✓	×	(✓)	✓	✓	×	×	(✓)	✓	×	×	✓	✓	×	**9**
Research prototype	✓	✓	✓	×	✓	✓	✓	×	✓	✓	✓	×	(✓)	✓	✓	×	✓	✓	✓	×	**14**

Table 2: Visual Cues supported by tool (✓– fully supported, (✓) – partially supported, × – not supported)

2.5 Collaborative Virtual Environments

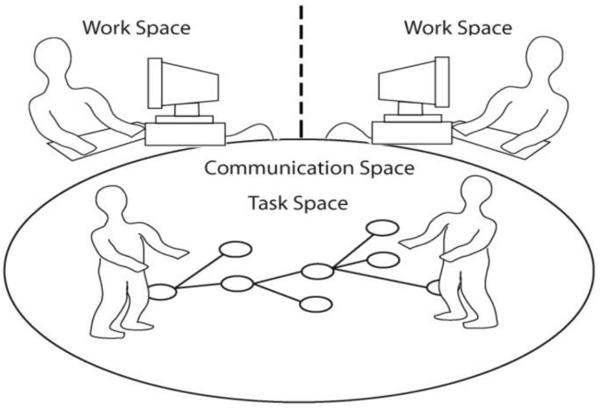

Fig. 4: Desktop-based virtual environments

One way to support visual features in collaborative work environments is to use 3D virtual environments with avatars. Embodiment in virtual environments reduces referential ambiguity (Ott & Dillenbourg 2002), allows the use of deixis (referencing something through context, e.g. "the window here"), pointing (Hindmarsh et al. 2000) and the use of face-to-face communication patterns (Herring & Borner 2003). While the intense computation required to display virtual worlds has limited their applications in the past, a rapid increase of the processing performance of devices has enabled the use of technologically advanced virtual environments, even on smart phones (Epic Games 2010). Similarly, the additional skills required by users to navigate virtual environments effectively, are to date mostly existent in significant share of people due to the popularity of video games (Entertainment Software Association 2012) and other visual applications in society today, and so the skills required for such environments should not be a significant impediment anymore. Desktop-based virtual environments, however, still have a number of limitations associated with visual interface technology. Keyboard and mouse controls do not limit the users expressiveness when using the avatar (Mazalek et al. 2011) and do not support unintentional non-verbal communication, such as facial expression or body posture. Furthermore, the use of a monitor as a window into the virtual world results in a limited field-of-view that can make it difficult to see both the origin and target of a pointing gesture (Hindmarsh et al. 1998). Reviews of technology supporting remote collaboration (Otto et al. 2006; Wolff et al. 2007) suggest that immersive interfaces can overcome these limitations. Recently, Dodds et al (2011) demonstrated that using a virtual world with fully animated avatars increased the speed of convergence to a mutual understanding between two people in a word guessing game. Traditionally, technology used for immersive interfaces was not feasible on a consumer level, however, more recently more cost-effective availability of large stereoscopic displays, head-mounted displays and motion sensing input devices have made them attainable to consumers even with a limited budget.

In summary, collaborative virtual environments with immersive interfaces can support visual features that are not well supported by other technologies.

3 Collaborative Virtual Environments for Process Modelling

In our previous work we have explored the use of 3D virtual worlds to support collaborative process modelling (West et al. 2010; Brown 2010). We have shown how the SecondLife platform can be used for collaborative process modelling. Participants responded positively to the modelling environment, although the measurements and participant numbers are not rigorous enough to be seen as strong evidence. Our findings to date do, however, motivate more rigorous investigation of the application and effects of such virtual environments on the practice of collaborative process modelling.

Fig. 5: Collaborative process modelling tool prototype

In addition, the modelling environment developed in SecondLife had a number of technical limitations (Poppe et al. 2012). The usage of SecondLife required the use of scripts and specific chat commands to interact with the process modelling tool. The fixed grid layout of the process model made it difficult to add elements, since the limited space often required moving other model elements out of the way first.

Furthermore, while the SecondLife client can be modified, modifications that require interaction with the server usually require complex workarounds. An example of such functionality is the use of motion capture to animate avatars. Since SecondLife was developed to use predefined animations it does not synchronise the skeletons used for character animation over the network. This makes addition of such features unnecessarily complex.

It was therefore decided to develop a dedicated prototype tool instead, in which model representation and interactions, as well as the user interface, can be designed specifically for the task of process modelling.

4 Prototype Process Modelling Tool

We developed a prototype business process modelling tool (Fig. 5) to support collaborative process modelling with avatars in a 3D virtual environment.

4.1 Implementation

One major requirement guided the development: since we want to investigate the effect of visual cues in process modelling we wanted the tool to be similar to current process modelling tools in all other regards. For this reason we use the BPMN grammar for the process model. We have implemented 64 process model elements from the BPMN standard, including swim lanes, all activities, events, gateways and three types of sequence flow.

We also decided to represent the process model in a 2D plane, so that users can interact with the model in the same way they would normally interact with process models in present 2D tools. Having all model elements on a flat plane also ensures that there are fewer issues with occlusion caused by the overlaying of objects viewed from a particular point of view, which can be a problem for 3D data representations (Tominski et al. 2005). Furthermore, we implemented a graphical drag & drop interface (see Fig. 6) similar to commonly used modelling tools such as the Signavio Process Editor (Signavio 2009).

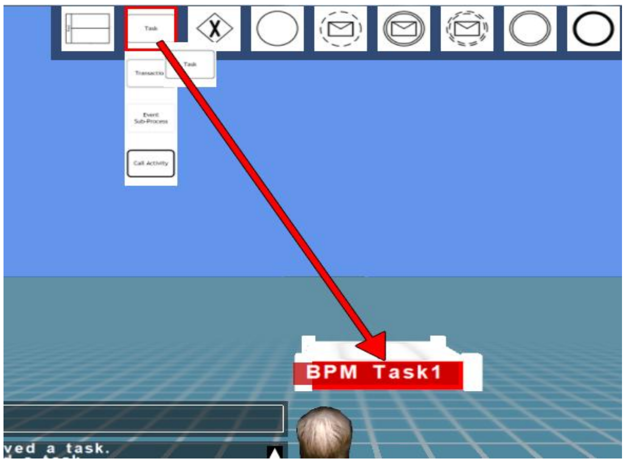

Fig. 6: Illustration of the Drag & Drop user interface

Users can create model elements by dragging the image of the required element from a bar at the top of the screen into the 3D space. They can move and scale elements by dragging markers on their corners (see Fig. 7). Even though the process model is two dimensional it is placed in a three dimensional virtual environment and the user can look at it from different angles. From some of these viewing angles, text can be difficult to read. We therefore implemented floating labels that turn towards the camera, so that they are always visible to the reader and an algorithm that can move them within local boundaries to minimize occlusion.

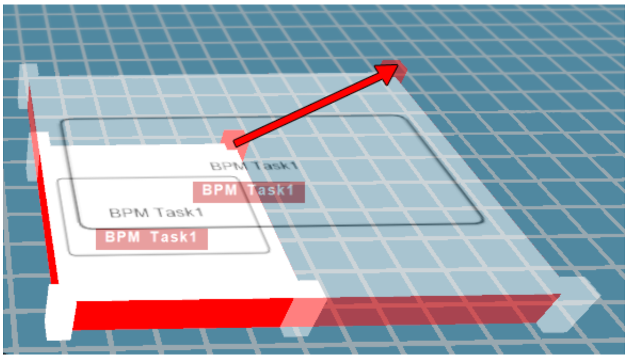

Fig. 7: Scaling model elements via grabbing corner elements.

Since the tool is primarily built to support collaborative process modelling, it provides a number of features for collaboration. First of all, it allows users to host a server or connect to a server. This server synchronises all actions between the different clients. Connected users can then create, view and edit process models in a shared virtual space. All participants can see these changes in real-time to allow for communication and coordination by actions.

For purposes of communication the tool supports voice-over-IP (VOIP) and text chat. Furthermore, each user is embodied in this space with an avatar, therefore allowing referential shortcuts such as "the gateway over here".

We have also implemented functionality to animate the avatars to support visual cues that depend on gesturing. This is used in three ways. First, avatars are automatically animated while the user interacts with the tool, e.g. a typing animation is played while the user enters text. Users can also choose specific predefined animations such as a head nod or waving an arm from a menu. Finally, we provide a procedural pointing animation, which users can execute by clicking on a model element while holding the Ctrl-key. This makes the avatar point at a selected element.

Furthermore, a command history gathers all the changes made to the model and changes can be undone by any of the participants. The history also contains an "awareness" display that shows what participants are currently doing (e.g. "User X is typing") to allow for better coordination of both communication and editing.

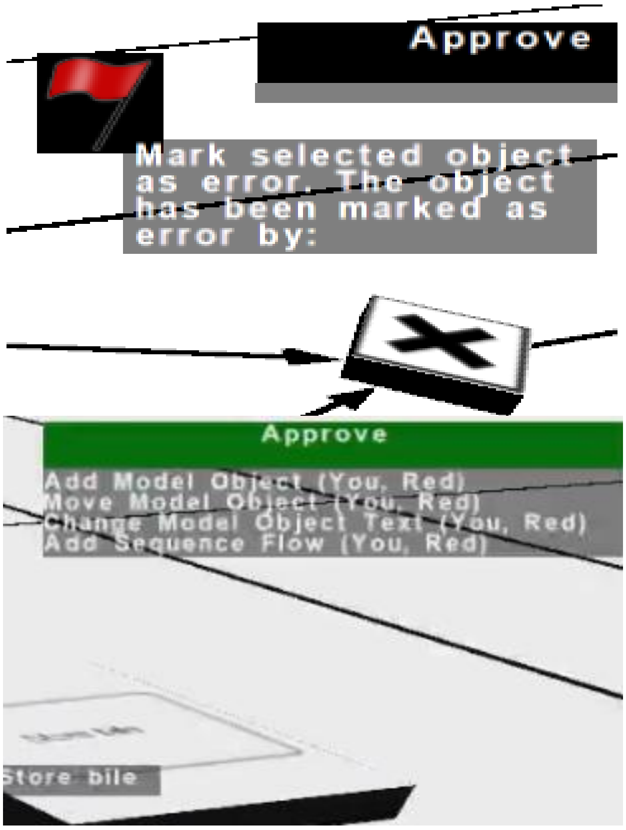

Fig. 8: Consensus mechanisms (top – error marking, bottom – change approval)

Due to the nature of the process modelling task, we have also implemented two consensus mechanisms (see Fig. 8). The process model can be locked for validation. In this mode changes to the model cannot be done until every participant has marked a model element as error. Thereby, participants have to reach consensus before editing the model. Once a model element has been marked as an error, changes to the element can be applied. These changes are gathered in a changes list per element. Before these changes are made persistent each participant has to approve the list of changes. This feature requires participants to come to an agreement that the proposed solution is an appropriate solution to the observed modelling problem. Note that the consensus mechanism also allows different solutions to a modelling error to be accepted, if all participants agree on the proposed solution.

Since the virtual environment is not bound by the physics of the real world, people can edit the model from any distance and can teleport instantly to locations to minimize time spent traversing the 3D space.

In the final phase we will use the Microsoft Kinect as an immersive interface to automatically capture the body posture and motion as well as the facial expression of the user and display them in real-time on the avatar.

The prototype process modelling tool described provides the required functionality for remotely located users to collaboratively model business processes. In addition, the representation of users via avatars enables the use of visual cues for efficient communication. We now analyse in detail which visual cues are supported by each of the prototype's features.

4.2 Feature analysis

In the following we show how the various features of the prototype tool described above translate into support for visual cues that facilitate collaborative process modelling as per Table 1.

The first group of cues rely on the use of shared task objects in communication. The prototype tool supports these by synchronising changes to the process model in real-time between all participants. This provides support for a number of visual cues:

- **A3 - Changes to task objects can be directly observed**
  Visible modifications to model elements allow participants to see whether somebody has implemented changes they discussed or is in the process of implementing them.
- **B3 - Changes to task objects can be used to infer what others have done**
  Visible modifications to model elements allow participants to infer that one person has implemented the discussed changes.
- **C3 - Constrain possible foci of attention**
  Since all the participants will be able to see the same elements, the focus of their discussion can be limited to these elements.
- **D3 - Pronouns can be used to refer to visually shared task objects**
  Participants can refer to model elements using pronouns. For example a participant might ask "Are you talking about **this** gateway?" moving the element back and forth to draw the attention of the other participants.
- **E3 - Appropriateness of actions can be used to infer comprehension and clarify misunderstandings**
  Participants can infer comprehension from changes made to model elements. For example, people can see someone has not understood which element they wanted to change as soon as the wrong element starts being moved.

Shared task objects are already supported by some of the current process modelling tools. However, a large number of visual cues require the use of an embodiment in a shared space with the process model. The prototype tool supports those by representing each user with an avatar in the modelling space. Specifically, the visual cues listed below are supported by the user embodiment in the space of the process model.

- **B1 - Gaze direction can be used to infer intended actions**
  The rotation of the avatar and avatar head shows which model elements are in the view of each user and thus can be interacted with.
- **C1 - Eye-gaze and head position can be used to establish others' general area of attention**
  The rotation of avatars and avatar heads can be used to infer the current centre of attention for each participant.
- **A2 - Inferences about intended changes to task objects can be made from body position and actions.**
  The position of an avatar can show whether a participant is about to make the changes requested to the diagram.
- **B2 - Body position and actions can be directly observed**
  The position of the avatar can serve as an anchor in the diagram.
- **C2 - Body position and activities can be used to establish others' general area of attention**
  The position of the avatars floating over the diagram can show which part of the model a participant is currently looking at.
- **D2 - Gestures can be used to illustrate and refer to task objects.**
  Because a user is embodied in the space of the diagram he can use deixis for efficient communication of references. He can say "Come over here, I found a problem in the model." and other users will understand the meaning attached to the word "here" based on the position of his avatar.
- **E2 - Appropriateness of actions can be used to infer comprehension and clarify misunderstandings**
  A user can monitor whether the other participants understood him, by monitoring whether their avatars move towards his position as requested or look around the diagram trying to identify the target location.

Additional visual cues are supported via animation of the body. Automatically animating the body depending on the actions the user is performing on the process model improves awareness and support for the following visual cue:

- **B2 - Body position and actions can be directly observed**
  Animations on the avatar can show current activities of the user, e.g. a typing animation of an avatar that is hovering above a specific task in the model can show that the user is currently changing the label of the task.

Enabling users to animate the avatar and point at model elements with key-presses enables the use of non-verbal communication behaviours and improve support for the following visual cue:

- **D2 - Gestures can be used to illustrate and refer to task objects.**
  The users will be able to use gestures to communicate. Animations on the avatar can be used for pointing gestures since they are in one continuous space with the diagram and other users can see both the gesturing of the avatar as well as the relation of the gesture to the model or other participants.

The deliberate use of non-verbal communication, however, does not provide collaborators with information that is communicated unintentionally via body posture and facial expressions. The use of the Microsoft Kinect as an immersive interface to automatically animate the avatars enables further visual cues that allow for such communication:

- **A1 - Facial expression can be used to identify how close to agreement the team is**
  The automatic animation of the avatars face will allow users to see how many participants are in agreement.

- **E1 - Facial expressions and nonverbal behaviours can be used to infer level of comprehension**
  The automatic animation of the avatars face will give other users the opportunity to infer the state of a user and react to it, for example to clarify a point just made, when a user looks confused.

- **D2 - Gestures can be used to illustrate and refer to task objects.**
  Animations on the avatar can be used for illustrating gestures and other users can see both the gesturing of the avatar as well as the relation of the gesture to the model or other participants. The automatic animation should make timing of back-channel feedback, such as head nods, much more effective as the user does not require time to select an animation anymore.

- **E2 - Appropriateness of actions can be used to infer comprehension and clarify misunderstandings**
  The body posture of the avatar can be used to infer confusion.

As can be seen, by the end of the final phase, the tool will provide support for all head and body visual cues that have been identified by Kraut et al. (2003). In turn, the tool will extend the range of current process modelling tools and research prototypes indicated in Table 2 with sets of extended visual cue support. However, definitive evidence of the benefits of these features for collaborative process modelling has to be gathered empirically. We, therefore, describe an experimental design to evaluate the prototype tool in the next section.

5 Outlook: Empirical Evaluation

For an empirical evaluation of this prototype tool we will measure the impact of visual cues on key tasks in the collaborative process modelling process. In order to isolate this effect we will use an experimental setting that allows for control over other influences. As our primary interest, at this stage, is in the impact of embodiment, we plan to compare the performance of the prototype with and without this feature (as opposed to comparing the prototype to other process modelling tools). In order to evaluate the prototype tool we will use an experimental between-groups design to measure changes in team performance brought about by the addition of visual cues. This approach should ensure high internal validity, although at the expense of ecological validity.

For the experiments, we will use business process modelling students as proxies for novice process modellers. We will have groups of three process modellers use the prototype tool remotely and collaboratively for two specific process modelling tasks, that is, model validation and model correction. The process model chosen is that of a human digestive process, because we can assume this process to be reasonably difficult for participants to understand, in turn increasing the need for communication and collaboration. We have modified an expert validated base model to add 3 syntactic and 3 semantic errors for the experiments. The diagram consists of 164 elements. This makes purely individual search difficult, the complexity of reference high, and therefore should emphasise the effects we expect to find (Gergle et al. 2004). Furthermore, most participants in our study will have incomplete knowledge of this process, which we believe will motivate collaboration with other participants to reduce uncertainty.

The groups of participants will be asked to find and correct the errors in the diagram. We will assign each group to either the “with avatars” or the “without avatars” condition and will measure the number of errors found and fixed by the group, as well as the time taken to do so. This will then give us a performance measure to compare the average performance of groups using avatars and groups not using avatars.

To avoid any confounding influences brought into the experiment by the participants, prior modelling knowledge, domain knowledge and experience with virtual environments of each participant are measured using a questionnaire.

In addition we will measure factors that are a result of our experiment setup. The novelty of the tool may influence the participants’ enjoyment and affect their performance. We will therefore use the cognitive absorption measure used by Agarwal and Karahanna (Agarwal & Karahanna 2000) to measure such an influence. Furthermore, the 2D representation of the process model in a 3D space could make the model so difficult to read that the task performance of the users is affected. We will therefore use an ease of model interpretation measure from Burton-Jones and Meso (Burton-Jones & Meso 2008) to measure whether the ease of understanding the model representation affects the performance of the participants. Finally, we will measure whether participants found the experimental task difficult or the tool difficult to use and how that affected their performance. We will measure this using a subjective cognitive load measure (Paas et al. 2003).

The execution of this research design will allow us to test whether adding embodiments to support visual cues in a shared visual modelling space decreases the time required for collaborative process modelling.

6 Limitations

Within the scope of this research, it is difficult to fully replicate the feature sets of 2D professional tools. Therefore any comparison with a 2D tool developed by the team would be biased by definition, as the developed 2D modelling tool will be inferior to use, and so confound the experimental results in the comparison. We therefore focus in this project on developing best practice approaches and tools for 3D virtual world modelling systems alone.

A limitation of this study resulting from this is the ecological validity of the experiments. We are not experimentally comparing the prototype tool to currently available process modelling tools and we are not evaluating them with professional process modellers. We can therefore not measure at this point in time, whether an increased overhead from having to navigate a 3D space as opposed to a 2D diagram would nullify any benefits gained from the additional visual cues.

7 Conclusions and Future work

In this paper we have shown how visual cues facilitate collaborative process modelling. We have found that current process modelling tools do not support these visual cues well and have identified technologies that can support them. We have furthermore proposed a modelling tool that uses these technologies to support these visual cues and have presented the first version of this tool. We then presented a research design to test the impact support for visual cues has on collaborative process modelling.

In the future, additional experimentation should evaluate the prototype in direct comparison with current process modelling tools, to supplement the high internal validity of our current investigation with greater ecological validity. However, as stated, this will require a mature, well-tested 3D tool to be developed first.

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9 References

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