A Method of Analysis to Uncover Artefact-Communication Relationships

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Abstract

This paper introduces a method of analysis to uncover artefact communication relationships in real world settings. This method is based on learning and communication theory, together with situated cognition. It was developed in the context of agile software development practice. Using this method, we found evidence that physical artefacts help team members to define contexts within their practice, which in turn become part of their contingency plan for communicating during specific contexts of communication. A contingency plan is a set of communicative actions that members take in future events that are possible but not intended, including the unanticipated.

Introduction

Since the late 1980s and the 1990s there has been an interest in cognition to consider agents as situated in their specific context as it was realized that people are strongly affected by, and possibly dependent on their environment (Susi & Ziemke, 2001). With this shift of focus, new interactive theories of cognition have emerged. These interactive theories such as activity theory (Leont'ev, 1978), situated action (Suchman, 1987), and distributed cognition (Hutchins, 1999), are noted for their emphasis on the relationship between artefact and cognition. Activity theory emphasizes the relation between externalization and internalization: internal and external activities are always mediated by the use of artefacts, and external activities can become internal, or internal activities can become external. The aim is to understand the unity of consciousness and activity. In this approach, the unit of analysis is the human activity. Situated action (Suchman, 1987) emphasizes the relation between knowledge and action in context. The context of the action is extremely important and artefacts must therefore be considered to have an important role in any action, being part of the environmental conditions. The aim of situated action research is to explore the relation between knowledge and action, and the particular circumstances in which these occur. The unit of analysis is the individual and the environment in which the individual is taking actions. Distributed cognition seeks to understand the organization of cognitive systems (Hutchins, 1995). It looks into a broader class of cognitive events by considering how the information to be processed is arranged in the material and social world, and to consider the cognitive roles of the social and material world as well. The theory considers agents and artefacts as part of a complex cognitive system, which is regarded as the proper unit of analysis. Despite the emergence of these theories, to date there has not been much emphasis on the relation between artefacts and communication process with the aim to understand how artefacts influence the construction of communications during collaboration.

Our inquiry is motivated by theory and practice. The former is influenced by the work on memory and text comprehension (Ericsson et al, 1980), whereas the latter comes from Agile practice (Agile, 2001) in a real-world setting. Our initial aim is to develop a method of analysis that uncovers artefact-communication relationships, and the focus of this paper is to introduce this method. The paper is organized as follows. We give the background of the method, followed by an introduction to the method of analysis. Then we show an example of how the method is applied, followed by findings, and discussion.

Background to the method

In a real-world setting, the primary challenge is to make sense of the many possible stimuli in a stimulus and response pattern, e.g., is individual A's utterance at this time a response to the utterance of individual B at a previous time or both to individual B's utterance and the physical artefact[1], or it may be A's response to some previous behavior of his own? Therefore we need a method of analysis that can guide us as to how to identify the relationship between stimulus and response while also capturing any explicit or implicit reference to the physical artefacts in the stimulus and response. As a start, we use the communication model by Binti Abdullah & Honiden (2007). The model was developed for analyzing chat dialogs on the mediated Web, with the aim of defining the communication patterns that

[1] We use physical artefact and artefact interchangeably throughout the paper.

constitute contexts, e.g., debugging a computer program, through inferring stimulus and response. We give a brief background to the theories used in the communication model followed by an introduction to the model and then how it has been adapted for our purpose.

Hierarchy of learning and communication

The hierarchy of learning and communication by Bateson (1972) is a communication theory that emphasizes the notion of *context* in communications and its relationship to changes in levels of learning (Bateson, 1972, pg 283). Bateson defined contexts as a pattern taken by a series of events, knowledge of which can help inform one of future events. Hence in his communication theory, he defined that stimulus is an elementary signal internal or external, where internal stimulus could be beliefs. Context of stimulus is a meta-message that classifies the elementary signals. This leads to the abstraction of communication exchanges: $a_1b_1a_2b_2$.., where 'a's refer to items of A's behavior, and the 'b's to items of B's behavior. It follows that a_i may be stimulus for B or it may be A's response to B, or it may be A's reinforcement of B. This general ambiguity means that the ongoing sequence of interchange between two persons is structured only by the person's own perception of the sequence as a series of contexts, each context leading to the next.

Situated cognition

Situated cognition defines that every human thought and action is adapted to the environment as perceived and conceived by the action in the moment. The central thesis of situated cognition by Clancey (1997) is focused at relating perception to memory to explain what takes place during the action of perceiving (e.g., I am reading the story card 'user account') and the formulation of conception or meaning. According to a situated perspective, the process of perceiving a message and interpreting it is a construction of coupled perception-interpretation on the spot, where realization comes into our mind, like an idea. It is dynamic and influenced by possible meanings: data are construed as present while understanding is developing. The perceptual-conceptual construction of interpreting is not merely fitting a context to a message. The context must be considered in interpreting the message, and the meaning is contextual. The process of interpreting occurs within us, as part of the ongoing process of constructing what the current activities are (Clancey, 1997, pg 204).

The communication model

Figure 3 shows the communication model from Binti Abdullah & Honiden (2007, p100), which has been slightly adapted for this paper. Referring to Figure 1 we give a simple interpretation of the model by relating the main ideas from the two theories, and then we explain how it was used for our study. The arrows denoted by numbers 1 to 5 represent the flow of information from the external world to the inner world of individual R while contextualizing his activity in his situated environment.

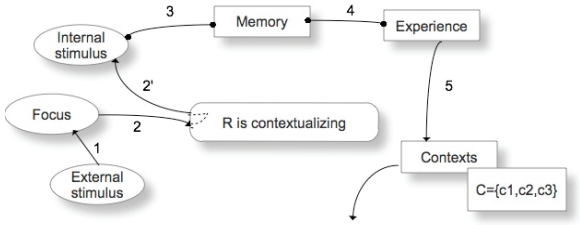

Figure 1. Communication model.

External stimulus, internal stimulus, and context refer to Bateson's communication theory whereas focus, memory, and experience refer to ideas from situated cognition (Clancey, 1997). External stimulus as defined by Bateson is the information coming from the environment that may be one of many signals, whereas an internal stimulus is a belief. In this model, intentions and predefined goals are regarded as internal stimuli. The flows number 1 to 2 represent the action of individual R perceiving, in which some information from the environment may become an external stimulus for him, and in turn may trigger him to focus on specific details, invoked from his internal stimulus. The association of focus and internal stimulus represented by arrows 2 and 2' is to show that the association process may occur in parallel, as viewed from the theory of situated cognition (Clancey, 1997). Arrows 3 and 4 represent that this invocation of internal stimulus is part of the memory, which holds experiences. This whole process occurs while individual R is contextualizing, allowing the individual to respond appropriately, represented by arrow 5. Here, contexts, $C = \{C_1, C_2, C_3\}$, follows Bateson's theory on context and redundancy of patterns. For example if we find that there is a repeated response of an individual during a specific time, within a particular setting, then we can infer that these redundant patterns make up context, C_1 as the context of coordinating a meeting, perceived from individual R. Hence C_1, C_2, C_3 are generalizations of redundancy of communication patterns, in which these patterns define what a particular context is for individual R (Bateson, 1978). Readers must take note that the model does not attempt to theorize how communications take place, rather to systematically identify stimulus and response for defining contexts. For our purpose we define external and internal stimulus, and focus as below:

External stimulus We refer to specific details from the environment (including artefacts) that may have caused the individual to react in such a way at the present moment, as external stimulus. There can be several external stimuli at any one time.

Internal stimulus We refer to dialog contents or thoughts associated to external stimulus, which can be inferred as recalling or remembering as internal stimulus.

Focus is used to delimit the beginning and end of a set of utterances that are about the same issue.

The method of analysis

Although the communication model is useful for the identification of stimulus and response, it requires *a priori* an understanding of what an utterance of a speaker is about. Thus we devised the following:

(i) Transcribe the collected data with transcription symbols (Atkinson et al, 1984).

(ii) Analyse communication with pragmatics and discourse analysis (Levinson, 1983) using a situated approach, which employs a moment-by-moment analysis. This approach captures how utterances unfold in time.

(iii) Extract sets of {internal stimulus, external stimulus, focus} from the analyzed communications (see detailed description in the next section). Each set is called a 'feature'.

(iv) Identify whether any relationship to a physical artefact exists in any of the features. We refer to records of video, photographs, and field notes to identify whether there is any overlapping of the features with the speaker's actions that refers to the physical artefact.

(v) Associate each set with its context. For example, "*are we gonna integrate it into tins at the moment?*" is defined as context user requirements[2] (see detailed description in the next section)

(vi) Find correlation patterns between the features where physical artefact is identified. A correlation pattern is identified in our work where there is a repeated occurrence of the physical artefact-communication link to the action of an individual during specific contexts.

An example of an application

In this section we discuss an example of a real-world setting application, Agile Requirements Engineering where our method of analysis has been derived, and applied. We firstly introduce Requirements Engineering (RE) followed by Agile practice and then a step by step demonstration of the application of the method.

RE is a branch of software engineering that is concerned with the process of *discovering* and *knowing* what to build in a software project. A requirement is formally stated as a user need or a necessary feature of a system that can be detected from a position external to that system (Davis, 1993). The early stage of RE is known as the activity of gathering requirements. During this activity, the needs of customers are discovered through using group communications techniques such as creative meeting (Goguen & Linde, 1993) supported by analysis tools such as use-cases[3] (Sendall, 2003). The goal of the activity is to achieve an agreement among customers and developers of the system's requirements specification.

[2] The contexts emerged from the data and the authors agreed together which defined context was related to which utterance.

[3] Use cases are descriptions of a system's behavior that specify "who" can do "what" with the system in question.

Agile practice is a software development process that favors communication over formal tools (Agile, 2001). The approach emphasizes communication and collaboration and de-emphasises the role of tool-analysis. It has been reported that two simple physical artefacts (i.e., story cards and the wall), used in a particular and disciplined manner, and supported by appropriate social activity, are key to the success of co-located agile teams (Sharp et al, 2009). Story card(s) (see Figure 2) are index cards used to capture a *user story*. A user story captures a requirement for the customers, and some of the details of the requirements for both the customers and developers as a collaborating team. Usually the customer writes the story but because the story card is small, it can only capture an abstraction of what is required. Hence for example, 'As a jobseeker I want to post my resume to the jobs website so that I am more likely to secure new employment', is a user story. However 'Post Resume' may be the only abstraction captured on the story card. Furthermore, developers and customer need to discuss and refine the user story before it can be implemented fully.

Figure 2. Story cards

Figure 3. The wall

Figure 2 shows one variation of how story cards may be created and displayed. Here what is written on the story card is a 'short story' of what needs to be developed, and one example, it says: 'USER ACCOUNTS'. A face photo and a name written next to the face photo are glued on top of the story card. This is to show who is working on which story card for that day. In this example the story cards are displayed under 'LIVE STORIES', this means that story cards under this group will be the story cards developed for that day.

The wall is where story cards are organized and displayed on a vertical space, e.g. filing cabinet (see Figure 3). These physical artefacts are used continuously during Agile practice, until software is turned into a product. A standard day starts with a stand up meeting, and is followed by pair-programming. 'Stand-up meeting' refers to the fact that the agile team stands up during the meeting, this meeting is held every morning next to the wall, and generally last no more than 15 minutes. Pair-programming is a very intensive collaboration session (Sharp & Robinson, 2008), where developers collaborate to produce the code necessary to fulfill the story cards that they have agreed on.

To date there has not been much reported on how these physical artefacts support Agile practice during the activity of gathering requirements. In order to gain insights into the relationship of the physical artefacts and Agile practice of RE, we conducted an observation study on an agile development team following an ethnographically-informed approach (Robinson et al, 2007). In particular, this approach aims to study practice without interference, and asks 'how' and 'why' questions where the observer does not start with a

hypothesis in mind. The team was based in a large telecommunications company in the UK; the observation lasted for four days in March 2009. The team consisted of 5 developers and 2 customers. All the studies were conducted at the agile development team's office. The data gathered from the observations consisted of field notes, informal interviews, audio recordings of every meeting (about 3 hours in total), together with short video recordings of the group interaction in front of the wall during those meetings. The data also includes audio records of four pairing sessions (about 7 hours in total), of different pairs of each day observations together with short video recordings of the pairs' interactions with each other and in front of the wall. Then one author did the transcription to selected data on a stand-up meeting, of second day observation. The transcription (about 1,550 lines of dialogs) was aligned with field notes, photographs, and video interactions. The whole process took about twice as long as discourse analysis. We demonstrate a small example of how it is applied in the next section.

Results

In this section we will demonstrate how the method of analysis is applied to an excerpt of whiteboard meeting, for steps (i) till (v) only (refer to section on method of analysis).

Step (i) Apply transcription symbols. See Appendix A for the transcription symbols.

Event 1: Excerpted from recorded audio, 24th March 2009.

Ln 1: J: what is it we are trying to get here (0.3) I mean this how this log in stuff gonna work (.) ((*J is drawing on the whiteboard and looking at the wall*)) I mean you've got bunch of static (0.2) (…) are we gonna integrate it into tins at the moment? ((*J is looking at the drawing and at the wall*))

Ln 2 M: yes (.) it's static (.) (…)

Ln 4: J: right (.) ((*J looks at the drawing while looking at M and others*)) and that's (0.1) ((*J looks at the board and the wall*)) our registration story which is (0.1) ((*J appears to be recalling while looking at the wall and the board*)) registration number (…)

Ln 15: A: so uhm (0.2) ((*A looks at the board and the wall*)) is that all there is on the portal? ((*A looks at others*))

Ln 16: M: (…) that's all there is. ((*M looks at everyone*))

In the above, J is the facilitator, A is the developer, and M is the customer. In the following, we show the result of analysis when applied to Ln-1.

Step (ii) Analyse communication with pragmatics (Levinson, 1983) and discourse analysis (Wood, 2000). For pragmatics analysis we make particular references to:

Time deixis. Makes ultimate reference to participant-role. For example words such as *now* used in the utterance 'Pull the trigger now!' can be glossed as 'the time at which the speaker is producing the utterance containing now'.

Place or space deixis. Concerns the specification of locations relative to anchorage points. We specifically refer to pure place-deictic words such as *here*, and *there*, and *this* and *that*.

Pragmatics markers. This is a non-propositional part of a sentence meaning that can be analyzed into different types of signals, which correspond to different types of potential direct messages a sentence may convey. Specifically we refer to inferential markers, elaborative markers, focusing markers, topic change markers (Fraser, 1996).

Presupposition. Referring phrases and temporal clauses (for example) carry presuppositions to the effect that they do in fact refer, it is an implicit assumption about the world or background belief relating to an utterance whose truth is taken for granted in discourse.

The combination of linguistic analysis helps us to understand whether an utterance is referring to existing concepts of requirements, and whether that reference was a response to the physical artefacts. This step is applied in parallel with step (iii), shown in the following.

Step (iii) Extract sets of {internal stimulus, external stimulus, focus}. At this step, we apply the communication model (refer to section on the communication model).

Ln-1: J: what is it we are trying to get here (0.3) I mean this how this log-in stuff gonna work (.) ((*J is drawing on the whiteboard and looking at the wall*)) I mean you've got bunch of static (0.2) (…) are we gonna integrate it into tins at the moment? ((*J is looking at the drawing and at the wall*))

a. "What is it that we are trying to get here (0.3)."

'What' denotes the 'representation' of a goal from the facilitator's J's point of view, and since the customer is there it denotes that the goal of the meeting is to get requirements from the customer, thus the external stimulus is the 'customer'. 'Here' represents the place of their meeting, which may encompass the setting of the meeting (wall and whiteboard). The time interval (0.3) may indicate a recall of 'what' to do in association to the place and time (Schilperoord, 2002). Hence 'here' is inferred as internal stimulus.

b. "*I mean this how this log-in stuff gonna work (.) ((J is drawing on the whiteboard and looking at the wall))*"

'I mean' which overlaps with the action of Facilitator J drawing on the whiteboard, may denote a mark of clarification (elaborative pragmatic marker). 'this' referred by Facilitator J through pointing to the drawing on the whiteboard may indicate that 'this' refers to 'log-in stuff'. 'this' and 'log-in' were both emphasized. Thus we infer external stimulus to be 'this' and internal stimulus to be 'log-in stuff', since 'log-in stuff' appears to be a recall from 'this'.

c. "I mean you've got bunch of static (0.2)"

Speaker clarifies 'log-in stuff gonna work' from preceding utterance by stating 'I mean' and making reference to it as 'bunch of static'. Thus we infer at this moment that the external stimulus is 'log-in stuff', and the internal stimulus is 'static'. Since 'static' appears to be a recall of 'log-in stuff' inferred by how the words were emphasized followed by time interval.

d. "Are we gonna integrate it into tins at the moment? ((*J is looking at the drawing and at the wall*))"

'Are we gonna integrate it' denotes that Facilitator J presupposes that everyone is aware that there will be a task. 'at the moment' indicates time and place deixis that may represent time afterwards, or anytime during the week. Since 'it' refers to the drawing of 'static', and the utterance of 'tins', which is emphasized overlapped with J looking at the drawing of 'it' and the wall (where the word 'tins' exists on one of the story cards) thus we identify the external stimulus as 'it' and 'tins'. As for the internal stimulus, we infer it as 'integrate it into tins' since it appears to be a recall of a goal. Thus we have a set of external and internal stimuli at each utterance.

Table 1: The detailed identification of stimuli.

J's utterance	External Stimulus	Internal Stimulus
a.	Customer M	here
b.	this	Log in stuff
c.	Log in stuff	Static
d.	it, tins	Integrate it into tins

We eliminate those features, which are redundant, because we are only interested in the initial stimuli (limited to time and space of observation) of an individual's utterances at a moment-by-moment. Refer to table 1, column external stimulus. As example, since 'log-in stuff' is the reference/recall to 'this', thus we can eliminate to consider 'log-in stuff' as part of the initial external stimuli of J's response. We obtained the following.

Table 2: The composed stimuli.

Complete utterances of facilitator J	External stimulus	Internal stimulus
a. d.	Customer M, this, tins	Log in stuff, static, integrate it into tins

For identifying the focus (i.e., issue), we deduce it as 'log-in' since 'log-in' can be considered as a general concept that has properties of static page, and that has to be integrated into tins. The utterances are in general about issues related to log-in. Therefore we have below.

Table 3: The identified focus.

Utterance J	External stimulus	Internal stimulus	Focus
a. d.	Customer M, this, tins	Log in stuff, static, integrate it into tins	Log in

(iv) Identify whether any relationship to physical artefact exists in any of the features. At this step, we check through the previously analyzed data, and recorded data of videos, photographs, and field notes that demonstrates overlapping of utterances to actions of looking at the wall, and then checking if any of the utterances are in part referred to words existing on the story cards (limited to time and space). Based on this heuristic rule, we obtain the following, **words in bold** indicate the correspondence between words and the physical artefact.

Table 4. The identified physical arterfacts.

Utterance J	External stimulus	Internal stimulus	Focus
a. d.	Customer M,	**Log-in** stuff**,** static,	**Log-in**
	this, **tins**	integrate it into tins	

Step (v). Associate each set with an RE activity 'context'. Since the utterances of J are a question directed to the customer about a new requirement thus we label it as the context of gathering requirements. Thus we have Table 5 below.

Table 5. The identified set of features and context.

Ln-n	External Stimulus	Internal Stimulus	Focus	Context
1	Customer M, this, **tins**	**Log in** stuff**,** static, integrate it into tins	**Log in**	Gathering requirements

Findings

We use our findings (e.g., Table 5), and relate it specifically to Agile practice by interpreting the artefact-relationship in its situated contexts within the different practices of Agile (i.e., stand up/whiteboard meeting, pair-programming sessions). This is done in the following way. Firstly we looked into all identified contexts of gathering requirements during meetings and pair-programming sessions. Then we marked the start and the end of the contexts. Next we looked into the repeated artefact-communication relationships that occurred during these contexts. Then we compared the repeated relationships of gathering requirements during whiteboard meeting to stand up meeting and pair-programming. This was done in order to have a meaningful interpretation of how the artefact constructs part of the member's communication process during Agile practice.

We found that during whiteboard meeting the start of the context of gathering requirement is when physical artefact was present in external stimulus (see section results, on the excerpt of the meeting at Ln-4). It is used to initiate the context of gathering requirements. When this takes place, communication about this context continues which brings another artefact to be recalled from memory. Then this artefact becomes the focus of the communication, and the same context still continues after some time. The end of context is when a new artefact associated to the existing artefact is created and categorized, or when everyone agrees that there are no more modifications or clarifications needed to the existing artefact (see section results, on the excerpt of the meeting at Ln-15). The analysis of the physical artefact-communication relationships revealed that the artefact helped the team members to define boundaries of the context of gathering requirements implicitly as a group. This is observed in the way that the team members rely on the artefacts to plan and anticipate their communicative actions, because gathering requirements is influenced by their Agile practice setting and purposes: during whiteboard and stand-up meetings, and pair-programming sessions. The artefacts become a part of the contingency plan for an individual or as a group for communicating. A contingency plan is a set of communicative actions that members take in future events that are possible but not intended, including the unanticipated.

Discussions and Future Work

Our method of analysis attempts to relate artefacts and communications in the complex nature of everyday work practice, with a long term goal to understand how short text comprehension (concepts) on physical artefacts influence the construction of communications during collaboration. As a start, we have developed a method of analysis that uncovers physical artefact-communication relationships. The strength of the method is that it attempts to start from two beginnings. The first is to develop a method of analysis that is based on observations and data of the real-world setting. The second is that it attempts to transcend the application of theoretical foundations, and linguistic analysis into the method of analysis. Hence the method can be viewed as a result of inquiries of specific phenomena that have occurred repeatedly. The method would be useful in the future in studying collaborative real-world settings such as the classroom, and design collaboration. The preliminary findings obtained from applying the method in the real-world setting of Agile Requirements Engineering allowed us to gain insights that the physical artefact is part of what defines the boundaries of contexts. Hence the physical artefacts become part of the team members' contingency plan for communicating during specific contexts of communication. Our future work will be twofold: (i) to refine the concepts used in our method of analysis and; (ii) to relate our study to recent research on thought, and gestures (Nathan, 2008). Understanding artefacts form part of communication during collaboration can contribute to designing an AI tool that guides people in formulating actions when they are incapacitated by their environment.

Appendix A

Transcription symbols	**Definition**
(0.3)	indicates measure of pauses in seconds (e.g., three tenths of seconds)
(.)	A micro pause, hearable but too short to measure
Underlining	signals emphasis
((*text*))	Additional comments from the transcriber

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