Association for Information Systems
AIS Electronic Library (AISeL)

ACIS 2009 Proceedings | Australasian (ACIS)

12-2009

A Framework For Modelling and Understanding Human Behaviours in Small Team Interactions

Terence Blackburn
School of Computer and Information Science, University of South Australia, terence.blackburn@unisa.edu.au

A Framework For Modelling and Understanding Human Behaviours in Small Team Interactions

Terence Blackburn
Paul Swatman
School of Computer and Information Science
University of South Australia
South Australia
Email: terence.blackburn@unisa.edu.au
paul.swatman@unisa.edu.au

Abstract

This paper describes work in progress to automate (where possible) computer support for colocated, synchronous, small team meetings. Researchers have made progress providing support for groups in different places and times but there are few face to face support applications. We claim that the behaviours in human interactions are too hard to predict and, consequently, using an algorithmic approach for designing support has been neglected. Current approaches are too prescriptive with their support for "declared" processes when humans are so variable in the way they carry out their duties or their "enacted" processes. We propose that the low level human actions and behaviours must be observed, identified and supported dynamically from a toolset. In this manner, computer interventions can be provided in real time. The main contribution of this paper is an extensible framework called RES, which helps researchers to understand the problem before considering a solution. The framework is informed by established theories of human behaviour. Concepts within these theories are paired with observed behaviours and these pairs tell small stories about the interaction. Aggregating small stories may then describe observable activities in a meeting.

Keywords

Behaviour, modelling, interaction, small teams, meetings.

INTRODUCTION

There is a general lack of focus (Shumarova and Swatman, 2008b) on computer support for *people interacting directly with other people* in high importance, face to face teams; the type that that deal with planning for emergencies such as forest fires, rescue missions and military operations; where team collaboration is usually intense and time sensitive. Activities include planning, analysis and decision making and they rely on information and knowledge, which has to be created, retrieved, displayed, manipulated and stored.

Research that has aimed at developing this type of computer support or "collaborative information technologies" (CITs), including work from domains such as Group Support Systems (GSS), Computer Supported Cooperative Work (CSCW) and Groupware, has seen much progress over recent decades. However, most of this success has occurred in asynchronous and/or distributed collaboration. Of note is that there have been few effective results in the area supporting face to face, colocated (dynamic) team work; in other words meetings. In reality, there are almost no well known applications that support the inherently social nature of group work. Over recent years, much of this research has focused on web mediated collaboration (Shumarova and Swatman, 2008b) but prior to that many laboratory experiments examined technological support for small groups[1]. It seems that, rather than making further progress, the focus has been on solving the same problems that have already been "solved" (applying the same solutions) in this new research context.

The idea that there may be problems in this area of research is not a new one. In a recent citation analysis of CSCW literature (Jacovi et al., 2006) the second most cited article was Grudin's (1988) "Why CSCW applications fail: problems in the design and evaluation of organization of organizational interfaces". Many people seem to be interested in finding out where the problems are.

Computers can usually manage structured processes better than humans. On the other hand, people manage contingent, emergent processes better than computers. Unfortunately, CIT's impose a process, they are prescriptive, they can only operate within a defined structure and they have a limited universe of discourse (Wegner and Godin, 1999). Even though designers try and accommodate the variability, flexibility and change

[1] Small teams, in this work, consist of 5-6 people.

that humans deal with constantly, applications are essentially "hardwired". In reality, people in small teams do not follow predefined processes. They largely ignore prescriptive direction, have an unlimited universe of discourse and are not predisposed to adopt structure. People's actions are "highly flexible, nuanced, and contextualised" (Ackerman, 2000) and the path they follow through tasks is emergent and contingent, in line with Suchman's (1987) concept of Situated Action (SA). Ackerman (2000) sums up the problem succinctly when he says there is a "divide between what we know we must support socially and what we can support technically". The applications we design to support collaboration (the technical aspect) do not stay in step with the realities of how people actually collaborate - the social aspect.

The technical aspects of collaborative applications are based on two main foundations. First, theories of rational action - or rational choice - (Heckathorn, 1997, Scott, 2000) assume that people will make the best choices according to the constraints in any given circumstances. This concept is encapsulated in program design because designers cannot predict users' choices in the deployment domain. They are forced to make assumptions. The second main input for CIT development is derived from theories of cognitive science, which reduce reasoning, planning, learning and communication to the level of symbols and mathematical models and this approach matches the processing style of computers.

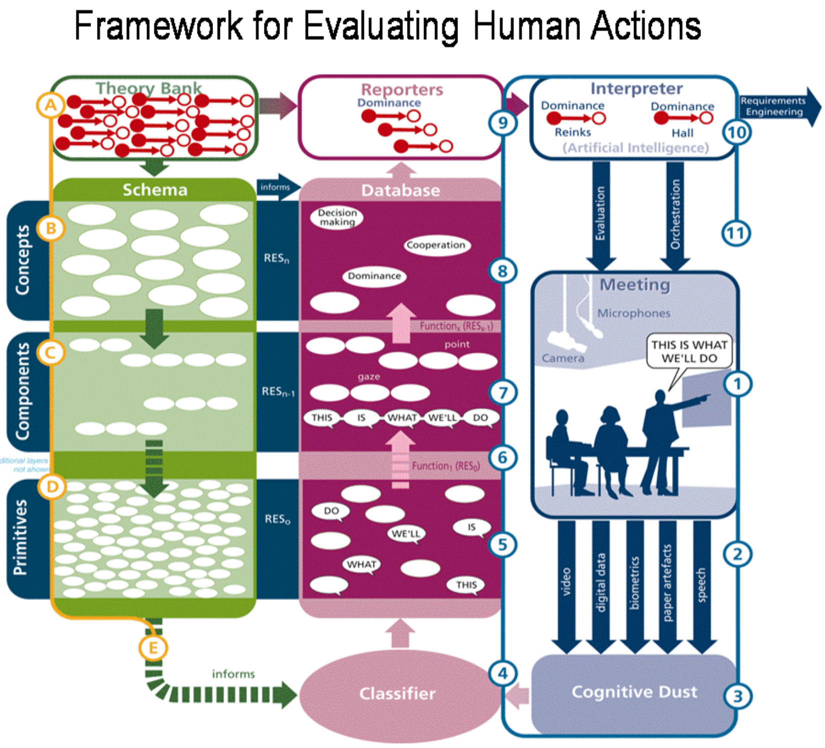

Figure 1. The framework for analysing and modelling traces of observed human actions

The social aspects of the problem can be described by theories of unplanned or contingent behaviours such as Activity Theory (Bertelsen and Bodker, 2003), Situated Action (Suchman, 1987) and Distributed Cognition (Hutchins, 1995). These three theories are prevalent in the CSCW literature and are regularly used to characterise human behaviours, actions or systems in various ways. However, these theories are descriptive rather than predictive and cannot directly motivate or inform the design of supportive software. Our work focuses on "better understanding the practically desired or required". Using a multi modal infrastructure, we directly observe teams and use people's actions and behaviours as the inputs to our computation models rather than cognitive constructs.

The main contributions of this article are: a new lens through which computers can observe, understand and support human interactions and the articulation and the population of a Real time Ethnographic (data) Store called RES (Blackburn and Swatman, 2007). RES (see Figure 1), which is described in more detail elsewhere (Blackburn and Swatman, 2007), creates a link between observed instances of human actions and theories of human behaviour. The theory bank describes human behaviour that occurs in small groups and it allows researchers to replace algorithms with behaviours as the motivators for support applications.

The rest of the paper is comprised of the following. The background section provides some context to the problem of supporting small teams of colocated workers. This is followed by a broad description of some of the behavioural theories and then the concept of Cognitive Dust (our data) is explored. We present the framework for storing and modelling the data before recounting a small case study. We then draw all of the material together by describing some of the small stories that can be identified in the data. We conclude and provide details of future work.

BACKGROUND

Computer support for dynamic face to face team work, the type described earlier, has had almost no impact within enterprises and organisations (Shumarova and Swatman, 2008a). One possible explanation is that it is difficult to predict and develop software that will fit into organisational work practices which evolve over time (Pinelle, 2000). Others have suggested that lack of commercial support might deter managers from purchasing group support applications. There are a number of reasons why CSCW applications have failed to live up to expectations (Grudin, 1988) including the difficulty of being able to properly evaluate group applications (Pinelle, 2000, Neale et al., 2004) but there might be another reason.

The applications and tools that represent research outcomes over the last twenty years have not been based on any theories of what people *actually* do while involved in face to face team work. These applications are not based on real world empirical evidence. They are usually based on algorithms, theories of Rational Choice or post hoc rationalisations and evaluations which depict what people *think* they do or have done. If an arbitrary task was to be executed more than once, it would be done so in a slightly different manner each time (Suchman, 1987) and may require slightly different support. This makes prescriptive support approaches only partially useful and not consistent enough to be deployed with confidence. This work takes a different approach. We configure support for the task dynamically as it is being executed. Our approach is observational, real time and driven by the actions of people involved in the task. We suggest that work processes that are not (formally) structured are either semi structured or ill structured and "structure" refers to one or a set of processes that have been predefined. There is a recognition that the path that people choose to navigate through their tasks is emergent (Suchman, 1987).

Our focus is on intervening in group activities by providing timely and contextually relevant support technologies. Examples of support for personal activities might include: collecting, filtering and sharing information; suggesting relevant actions; and assisting the human in any suitable manner (Myers and Yorke-Smith, 2007). We extend this to include tasks that would assist in a technologically rich workspace such as: automatically reconfiguring a workspace, as determined by current activities; recognising when and how to reform sub groups into one main group to discuss an important issue; and prefetching information for display on public screens.

Having described examples of support, we need to identify the level at which we will intervene. Our work model consists of a taxonomy of processes, activities and actions. *Processes*, at the top of the taxonomy, are repeatable and coarse grained such as the agenda for a meeting. *Activities* can feature anywhere in the processes and include discussing ideas, brainstorming and making choices. (This is at the level where support interventions could be applied.) *Actions* are the communication primitives within activities and include speaking, listening, gesturing and gazing.

BEHAVIOURAL THEORIES

Concepts in behavioural theories include domination, conflict, task oriented work, negotiation, non verbal behaviour, norming and many others. Theories may focus on one or more concepts, which are described, analysed and sometimes used in empirical studies. To be suitable for empirical work, concepts need to be decomposed into their component parts to expose their variables. For example, the concept of *negotiation* can be broken down to include *discussion, agreement, disagreement, goals and plans*. These can be middle level structures in our model and may also be decomposed into smaller elements such as speaking and listening. These represent the data primitives in the theories.

To understand this picture of team interaction, it is useful to categorise these behaviours. Our set of components is based on previous work (Pinelle et al., 2002, Hare et al., 1994) but extended to encompass all aspects of communication, cognitive representations, artefacts, entities and relationships that might be represented within team interaction and its associated context. The set is comprised of: the physical setting; artefacts and resources; personality, processes, structure, communications, performance, people and power.

Examples of some of the theories in these categories include:

- the physical setting – the invasion of personal space, where one person sits too close to a second person, can have differing effects on the second person. Close interpersonal distances may result in increased levels of arousal such as high blood pressure, high heart rate (D'Atri, 1975)

- structure – when the group size equals five, the communication style could be interaction but if it increases to around ten people, the communication style becomes a monolog (Fay et al., 2000).
- communications – the communicative acts expressed through the eyes are used to confirm other communication channels in use. This may be why people look at each other when they converse and use the eye expressions both as a confirmatory back channel as well as a source of reinforcement for speech (Grumet, 1983a)
- performance – group hierarchies tend to form based on *participation* and often only a few people do most of the talking and take significant places in the hierarchies (Karp and Yoels, 1976)
- people and power – interrupting others is a form of dominance that is more likely to be undertaken by people who are self-confident and not afraid of negative evaluation (Ferguson, 1977).

We need to decompose these theories into their constituent parts and we use Reporters to match these parts with data from the data store. Reporters (see 9 in Figure 1), small software applications, are each responsible for specific theories that make well defined claims about some aspect of group interaction. As an example, Rienks and Heylen (2006) discuss aspects of dominance such as, people who speak the most may be trying to be dominant. Theories in this format allow us to expose production rules that can be used to generate stories in much the same way as humans generate stories to explain situations. In this case, the Reporter responsible for the concept *dominant speaking* is looking for word counts in the data to populate a "fuzzy" production rule such as:

> if person 1 is consistently speaking more than person 2, then person 1 may be exhibiting dominant behaviour relative to person 2 (and this is evident by the number of words each speaks)

This example is one of many that exist in theories. At any time, many production rules may be populated from the database with the result that small scraps of stories are generated; some of which will be wrong and some are going to be contradictory. This raises an important point.

While a causal relationship articulated in any arbitrary theory can be described as a production rule, in reality, these rules are not necessarily formal or correct. For example, while one person is exhibiting dominant behaviour, it does not mean that the person is more dominant. They may be *trying* to be dominant without success or they may be dominant for a period of time before surrendering their position in the hierarchy. Due to these types of issues, we cannot mathematically or formally state that "if A then B" is either true or false. Both values may be valid at different times hence we may think of "fuzzy" production rules. These concepts can be accommodated by a machine in the same manner that humans incorporate these changes and adapt their view of the world. This creates a problem for a computer application because we need to provide an interpretation mechanism which works with data that may be incomplete, or complete but inconclusive. Prior to this, however, we need to consider how the data is generated.

COGNITIVE DUST

Most of what is observable in group interactions are traces of communicative acts. These acts represent attempts to transfer internal cognitions from one person to another or to a group of people. They are external manifestations of peoples' thoughts and they are mediated primarily through speech as well as other secondary modes. This suggests further links with the theoretical literature; External Cognition (Scaife and Rogers, 1996) and Distributed Cognition (Hutchins, 1995).

External and Distributed Cognition

If teamwork is viewed from the perspective of external cognition, the physically observable, persistent cognitive representations are considered to be a mechanism for "computational offloading". External Cognition describes how people use their environment to reduce the cognitive effort required in work activities. For example, writing notes on a white board substitutes as a mental persistence mechanism and using a calculator substitutes for mental processing. This is similar to the model of Distributed Cognition (DC), which adopts a view where all of the relevant nodes in a system are linked. DC is comprised of a set of cognitive representations and it models the creation, representation, mediation and propagation of these cognitive artefacts in the environment (Hutchins, 1995). People are regarded as nodes in this system at the same level as keyboards or computer displays.

We were influenced by these concepts in earlier work (Blackburn, Swatman et al., 2007) but we have since extended this view. We claim that all artefacts are (ultimately) generated by people and that people are special, rather than being considered as just another *passive* node.

An alternative Distributed Cognition model

We are not satisfied that these theories we have examined adequately support the interpretation of the *complete* set of entities, artefacts, representations and *behaviours* that exist in a small group workspace due to reasons such as cognitive "noise". While the theories of External and Distributed Cognition provide a conceptual framework for our work, we need to drill down to a finer level of granularity. We need a more encompassing yet focused approach, which is able to adequately include workspace artefacts, "computer observable" phenomena (such as biometric data), observable human actions and even entities that may not seem to be a part of the immediate system.

The problem of identifying and interpreting the range of cognitions in a workspace with human observers might be tractable if a group consisted of only two or three people, but if teams are as large as five to ten people, and these people can break into subgroups and subsequently reform into the large group, the problem becomes acute. In these cases, separate, complete cognitive systems are created and monitoring them all is beyond the abilities of any one individual person or even a small team. (This will not represent a problem for multi modal infrastructures.) We need to be exhaustive in our approach because we don't know in advance which data will be useful and which data can be ignored. We have labelled this extensive and exhaustive set of representations, actions, artefacts and phenomena as "Cognitive Dust" (Blackburn et al., 2007).

Distributed Cognition to Cognitive Dust

This "dust" includes all of the cognitive representations in a workspace. If we accept that the communication strategies used between people are usually successful, we hypothesise that, if a technological infrastructure could observe enough speech and body language and "interpret" this data, it could decipher a person's intention to act.

Cognitive Dust allows us the more encompassing model of workspace interaction that we need. Non verbal behaviour (NVB), for example, is an important communication channel for establishing power, dominance and leadership in a group. This is important for deciding which people to support in times of confusion or contention for attention. For example, if two of the people in a sidebar conversation are conversing, using the same keywords, their rate of utterances and volume of speech has increased and progress in the sidebar group has halted (along with other indicators), then a level of conflict might exist that could require an intervention. This links our theories with observed behaviour. There is, however, a large conceptual gap between observing human behaviour and triggering a supportive intervention. We need to build links between these concepts and this is our framework; RES.

THE "RES" FRAMEWORK

The bank of theories has two roles in this work. In the first instance, it provides some indication about what the observed behaviours might mean; and it also allows us to recursively decompose the theories into sub components/concepts until the actions or primitives within the behaviours are exposed. This set of subcomponents informs the design of our framework we use to store the data the traces of actions.

Our collection of theories is stored in the Theory Bank (A in Figure 1) and it is the *concepts* in these theories that inform the design of our schema, which is constructed in a top down fashion where the concepts represent the highest layer (B in the Figure 1). Concepts are decomposed into their component parts (C in Figure 1) and some concepts such as dominance, status or power can be manifested and described in a number of ways. Theories tell us that people who speak more (Rienks and Heylen, 2006) or smile less (Hall, Coats et al., 2005) may be exhibiting signs of dominance in the group. Components in these concepts could be: a count of each speaker's words and a count of each person's smiles. The components in these simple examples are also our primitives in the schema (D in Figure 1) so no further decomposition is required. The set of primitives (D through to E in Figure 1) comprises the categories of dust for the Classifier to refer to when receiving the Cognitive Dust from the workspace (Blackburn et al., 2007). The dust components at this lowest level have been either inferred or defined by the theories through the schema and can be used to classify the dust. The Classifier's job is to identify, classify and persist the Cognitive Dust into RES at the lowest level in its various native formats (4 in Figure 1).

RES is a multi-layered repository for Cognitive Dust in unmodified (5 in Figure 1) and abstracted forms (7 & 8 in Figure 1). Each level in the schema is represented at a corresponding level in RES by concrete instances of data. At the lowest level, RES_0, data formats include: MPEG files for video, MP3 for audio, textual representations, speech transcripts, electronic files and biometric data (initially encountered at 2 in Figure 1 and stored at the lowest level in RES at 5). Functions are used to abstract or transform this raw dust into representations with higher (or clearer) levels of semantic meaning (6 in Figure 1). Words, for example, can be aggregated and processed to form sentences. The sentences are then stored at a higher level in RES_{0+m} (where "m" equals 1..n as levels in RES can be bypassed). Ultimately, at layer RES_n, the Cognitive Dust has been processed and abstracted into concepts (8 in Figure 1), many of which are found in the theory bank.

It is at this level, RES_n, that people reason about other's activities. They can tell who has been accepted as the leader in the group, who has superior work skills, who feels comfortable taking minutes and who sometimes likes to act like a clown. At a semi conscious level they may infer succeeding actions from a series of current and previous actions and states and this is what we seek to express (ultimately) in machine language.

A CASE STUDY

The scenario is a video of a group of five people interacting during a series of competitions where groups compete against other groups. In this extract, which is about 52 seconds long, Tim has just left his previous group to join the current one. This appears to be the first meeting of the "new" group and everyone is seated and talking at a table. The other members of the group are Bim, Lim, Tim and two unnamed women. They are seated around a rectangular table and Tim is located at the head of the table. He is the only person wearing a formal suit and tie while the others are wearing casual clothes. As the scene starts, he is talking and a sequence from the scene is recorded in Table 1

Table 1. Selections of audio and video from the scenario

Time		Audio	Video
1:29	Tim	You know when I came over here, I, you know the reason I told you guys the reason …	Scene starts with a shot of the swimming pool outside house and switches to the large table in a room inside the house
1:33		… like I thought there was a lot of talent here, you know,	Camera on Bim. He is sitting back in his chair, stares at Tim, mouth open, eyebrows raised. He chews gum, looks away, looks back at Tim.
1:36		… like, that's a very smart group and a very passionate group…and so like I said... uncomfortable. I'm going to...	Camera back to Tim who still talks at the group. Lim sits with his left arm over his chair and his body turned away from the speaker. He looks down and away
1:45	Tim	The moment I was in there and I was listening to the other team and I was kinda like...	Camera goes to Tim who is smiling and looking from left to right (at other members of the team?)
1:47		All of that, like I couldn't have made a bet…	Camera goes to Tim with Lim and Bim in background both looking at him
1:50	Bim	It…	
1:51	Tim	It was clearly such a great move.	Camera goes to Tim, Lim & Bim in background, both look at him. Lim has arm over the chair and Bim sits back and chews gum. Tim is using his hands.
1:54	Bim	Let me ask you…	Tim leans forward and towards Bim. Lim looks at Tim but his head is leaning to the left.
1:55	Tim	So I just wanted to say like I am so happy I'm in that group…	Bim looks away and Tim looks back to the other members of the group
1:57	Bim	Would you…	Bim is cut off
2:25	Tim	Like you guys are great	Video shot to the side of Tim and behind so that Lim and Bim are still in the picture
2:26		You are all so smart, you're all so…	Close up on Bim who is staring down in front of him still sitting back in his chair
(the table is left incomplete due to space restrictions)			

TELLING STORIES FROM COGNITIVE DUST

We examine one view abstracted from instances of observed actions and another that is theoretically derived. Then we establish links between the two views with the goal of trying to tell small stories.

Views of the Data and Data Types

The two main classes of Cognitive Dust are speech and body movements. Captured through microphones and cameras, they provide the bulk of the dust normally observable by humans. Dealing with the audio track is not so difficult at one level as Tim does most of the talking. However, he moves from one incomplete sentence to another and this exacerbates the already difficult task of deciding where a sentence starts and stops.

> 2:26: "You are all so smart, you're all so….
> 2:28: Everybody brings something different to the table
> 2:30 Lim, I see you very similar to me…"

In about four seconds Tim utters three contiguous, incomplete sentences. The connections between them are weak and the meanings could be hidden in some cases, such as, "bringing something to the table" which means "contributing something". We need to consider how fast Tim talks – this is not evident in the table – and the low level of clarity. The data types extracted from the speech, along with their qualifying factors are:

1. Words (speed, clarity, meaning, quantity, volume);
2. Sentences (completeness, idiomatic meaning); and
3. Pauses (existence, duration, quantity).

Many of these entities can be readily processed but it is a little harder for video records.

The video evidence is richer than the audio track and it is easier to identify multiple communication channels in the group, although many are mediated non verbally. In the opening scene, Tim is seated at the head of a rectangular table with the other members sitting along the sides. A variety of seating poses can be observed; some people sit forward in their chairs, some sit back and, on one occasion, a person has their legs crossed away from the speaker. While people are sit in their chairs we can observe the direction of their gaze. This was sometimes focused on the speaker or towards the floor.

We are able to observe closeup images of people's faces. This revealed: raised eyebrows, eyes open wider than normal or closed, mouths held open, Bim chewing gum, smiling, as well as expressions that could only be described as "blank". Various other observations include: Bim laughing in a clearly irritated manner as he walks away from the table; a person sitting with their elbows resting on the table and the synchronised actions of Lim and Bim at various times.

The data types in the video footage are composite structures that can be observed over several video frames, such as the sequence of coordinated head hand and arm movements when someone puts their head in their hands. This is too fine grained for our analysis as we observe at the level where people are more aware of composite actions, along with their qualifying factors. For example:

- Body actions: chewing gum, direction of gaze, linking gaze to speech, moving hands while talking (height of hands), covering the mouth with a hand
- Body postures: leaning back in chair, putting an arm over the back of chair, leaning the head or resting it in the hand, legs crossed, head dipped, two people synchronising their movements
- Facial expressions: eyebrows raised, mouth open, smiles, eyes closed or open, an exasperated grin
- Seating arrangements: sitting at the head of table, sitting on the long side of the table
- Group size: in this case, six people

Each of these data types, where appropriate, is associated with a specific instance of RES for each person and this allows the data store to eventually build a composite picture of what each person says and does during the interaction. However, all of this data has almost no meaning on its own; it needs the explanatory power of theories to provide semantic richness.

Data Types and Theoretic Concepts

After identifying data types, we need to identify theories that discuss these data types in their rhetoric, descriptive or predictive discourse. We identified eight different types that are either primitive or composite. These are: body actions, body postures, facial expressions, seating arrangements, clothing, words, pauses and sentences. Examples of data types and qualifiers are described in Table 2.

Table 2. Examples of data types and their qualifiers with explanations below

Body actions	interrupt others [22]	gaze direction [11]
Body postures	lean back in chair [17]	synchronised movements [18]
Facial expressions	smiling [15]	raised eyebrows
Seat position	head of table [3]	interpersonal distance [2]
Words	quantity [20, 21]	speed
Sentences	completeness	idiomatic meaning
Pauses	quantity [21]	duration
Miscellaneous	group size [8]	group development [19]

The data modelled from our observations is matched with the theories from the theory bank to tell scraps of stories. Explanations for Table 2, linked by the numbers, follow.

[2] People have lots of space at the table. They are relaxed with a normal heart rate (D'Atri, 1975).

[3] Tim is sitting in the dominant position (Lecuyer, 1976), and may want to be perceived as the leader (Lecuyer, 1976). He is in a good position to dominate (Greenberg, 1976), can make more eye contact with people, who may see him as leader (Greenberg, 1976), he can participate more by catching people's attention (Lecuyer, 1976), talks more (Reynolds, 1984) and talks to the group (Goetsch and McFarland, 1980). He is at the hub of the group (Jolley, 1973), this promotes bonding and friendship (Greenberg, 1976). He is persuasive, happy to share information (Weinberg , Smotroff et al., 1978), dominant, friendly (Hare, 1994) but he is coercive (Podsakoff and Schriescheim, 1985)

[8] Group size is six, this may be close to an ideal number (Yetton and Bottger, 1983) but the communication style is not as interactive as it should be (Fay et al., 2000)

[11] Listeners gaze towards or away from the speaker and the speaker looks at the person being spoken to. This is provides or denies a back channel, or reinforces the speaker's (Grumet, 1983)

[15] Lim smiles when Tim flatters him (Ekman, 1982) but he may be smiling to appease Tim (Goldenthal, Johnston et al., 1981)

[17] Bim leans back in his chair and not engaged with Tim's dialog (Bond and Shiraishi, 1974)

[18] Lim and Bim are subconsciously mirroring each other and it might be Lim who leads. They are mentally in step (LaFrance, 1979) such as when they both look down together.

[19] Tim is trying to get commitment to his viewpoint. This behaviour is evident in new groups when they are still forming relationships (Tuckman, 1965)

[20] Tim is doing all of the participation in the group and preventing the others from engaging and he hopes this will ensure his place at the top of the power hierarchy (Karp and Yoels, 1976)

[21] Tim is not producing any pauses in an effort to be dominant (Rienks and Heylen, 2006)

[22] Bim unsuccessfully tries to interrupt Tim, who, in turn, is successful at interrupting Bim. This is dominating and shows that both men have self confidence (Kennedy and Camden, 1983)

This has provided examples of how the data can be matched to appropriate theories of behaviour to tell small scraps of stories, which can be aggregated to create rich pictures of human behaviour. The most valuable scraps will often be the most recent. This is true, for example, when conversation becomes heated and the dominant participants in an argument react quickly to each others. This makes it hard to collect scraps and interpret them as stories in the way that humans interpret incomplete sets of dust either intuitively or by guesswork. They are not always correct in their interpretation but it serves as a signpost for where we should be focusing our support interventions.

CONCLUSIONS AND FUTURE WORK

Researchers have so far been unable to develop autonomic computer support applications to assist teams that are interacting face to face in meetings (rather than communicating through electronic media). These applications need to be sensor driven and examples in different domains include heart monitors and various environmental alarms. (The current sensors in our work – and we use them regularly – are cameras and microphones.) These programs have the ability to trigger various actions without human intervention. Our goal is to build a similar class of support applications for colocated, synchronous teams who would benefit from cognitive offloading.

Suggesting possible uses for this type of computer support is problematic as there currently seem to be no technologically rich workspaces in which to experiment. However, examples of autonomic support activities for teams (in these rich workspaces) might include: finding, filtering and sharing information; suggesting relevant actions; automatically reconfiguring a workspace (as determined by current activities); recognising when and how to reform sub groups into one main group to discuss an important issue; and prefetching information for display on public screens. Support applications we design will need to make decisions based on a combination of observed data and a theoretical knowledge base of behaviours. The knowledge base acts as a substitute for human experience and it provides causal mechanisms that may allow a machine to correctly infer what is happening from the observed human actions.

We have demonstrated that it is possible to build a semantic picture from observations of human interaction but, while our proof of concept seems to be sensible, we have no proof that it will work. Evaluation might also be a challenge if people resist continuous monitoring and recording. This has not been a problem in our lab, though, as our members quickly became used to wearing headset microphones etc and eventually ignored them. Our level of confidence has increased, however, to the point where we are developing a prototype.

We expect to have challenges in future work such as the transformation functions that abstract data to higher levels in our model. Hopefully this work is tractable– even if it is difficult. Research in this area already exists, particularly in mathematics, but many problems have not been solved yet. For example, while we might recognise a set of words that can be turned into a sentence, it is harder to extract meaning from vague or incomplete sentences (and this represents real conversation as opposed to dictation). Abductive logic may be useful is this situation.

In the future, applications based on observed, real time behaviours may have wider uses such as in robotics. In this field, robots (other than industrial robots) that interact with people could benefit and improve the quality of interaction based on dynamic feedback from humans. In other areas where direct observation of people is critical, such as when individuals are at risk of self harm, our approach may have application. In some cases, human observation of these people is fallible but an application, trained to recognise the precursors to a self harm episode, may provide adequate warning to trigger a successful human intervention. Other creative people will find more uses for our methodology but, ultimately, we hope our approach can support small collocated teams

REFERENCES

Ackerman, M. (2000) Intellectual challenge of CSCW: The gap between social requirements and technical feasibility. *Human-Computer Interaction,* (15:2-3)**,** pp 179-203.

Bertelsen, O. & Bodker, S. (2003) Activity theory. In Carroll, J. (Ed.) *HCI models theories, and frameworks: Toward a multidisciplinary science*. San Francisco, Morgan Kaufmann.

Blackburn, T., Swatman, P. & Vernik, R. (2007) Cognitive dust: A framework that builds from CSCW concepts to provide situated support for small group work. *Lecture Notes in Computer Science,* 4402.

Blackburn, T. & Swatman, P. A. (2007) Modelling human actions in small group meetings, In Prodeedings of *18th Australasian Conference on Information Systems*, Toowoomba, Qld, Australia.

Bond, M. & Shiraishi, D. (1974) The effect of body lean and status of an interviewer on the non-verbal behaviour of Japanese interviewees. *International Journal of Psychology,* (9), pp 117-128.

D'atri, D. (1975) Psychophysiological responses to crowding. *Environment and Behavior,* (7), pp 237-252.

Ekman, P. (1982) *Emotion in the human face*, 2nd Cambridge, England, Cambridge University Press.

Fay, N., Garrod, S. & Carletta, J. (2000) Group discussion as interactive dialog or as serial monologue: The influence of group size. *Psychological Science,* (11:6)**,** pp 481-7.

Ferguson, N. (1977) Simultaneous speech, interruptions, and dominance. *British Journal of Social and Clinical Psychology,* (16) pp 295-302.

Goetsch, G. & Mcfarland, D. (1980) Models of the distribution of acts in small discussion groups. *Social Psychology Quarterly,* (43:2)**,** pp 173-183.

Goldenthal, P., Johnston, R. & Kraut, R. (1981) Smiling, appeasement, and the silent bared-teeth display. *Ethology and Sociobiology,* (2), pp 127-133.

Greenberg, J. (1976) The role of seating position in group interaction: A review, with applications for group trainers. *Group & Organization Management,* (1:3)**,** pp 310-327.

Grudin, J. (1988) Why CSCW applications fail: Problems in the design and evaluation of organization of organizational interfaces, In Proceedings of *Computer Supported Cooperative Work*, Portland, Oregon, ACM Press.

Grumet, G. (1983b) Eye contact: The core of interpersonal relatedness. *Psychiatry,* (46:2), pp 172-180.

Hall, J., Coats, E. & Lebeau, L. (2005) Nonverbal behaviour and the vertical dimension of social relations: A meta-analysis. *Psychological Bulletin,* (131:6)**,** pp 898-924.

Hare, A. (1994) Types of roles in small groups. *Small Group Research,* (25:3)**,** pp 433-448.

Hare, A., Blumberg, H., Davies, M. & Kent, M. (1994) *Small group research: A handbook*, Ablex Publishing.

Heckathorn, D. (1997) The paradoxical relationship between sociology and rational choice. *The American Sociologist,* (28:2).

Hutchins, E. (1995) *Cognition in the wild*, Cambridge, Mass, MIT Press.

Jacovi, M., Soroka, V., Gilboa-Freedman, G., Ur, S., Shahar, E. & Marmasse, N. (2006) The chasms of CSCW: A citation graph analysis of the CSCW conference, In Proceedings of *20th anniversary conference on Computer Supported Cooperative Work*, Banff, Alberta, Canada, ACM Press. pp 289

Jolley, J. (1973) Leadership and task completion in wheel and circle configurations: A small group experiment. *Utah State University Journal of Sociology,* (4:1)**,** pp 35-44.

Karp, D. & Yoels, W. (1976) The college classroom: Some observations on the meanings of student participation. *Sociology and Social Research,* (60:4)**,** pp 421-439.

Kennedy, C. & Camden, C. (1983) Interruptions and nonverbal gender differences. *Journal of Nonverbal Behavior,* (8:2)**,** pp 91-108.

Lafrance, M. (1979) Nonverbal synchrony and rapport: Analysis by the cross-lag panel technique. *Social Psychology Quarterly,* (42:1)**,** pp 66-70.

Lecuyer, R. (1976) Social organization and spatial organization. *Human Relations,* (29:11)**,** pp 1045-1060.

Myers, K. & Yorke-Smith, N. (2007) Proactivity in an intentionally helpful personal assistive agent, In Proceedings of *AAAI Spring Symposium on Intentions in Intelligent Systems*, Stanford University, Ca.

Neale, D., Carroll, J. & Rosson, M. (2004) Evaluating Computer Supported Cooperative Work: Models and frameworks, In Proceedings of *CSCW*, ACM Press.

Pinelle, D. (2000) *A survey of groupware evaluations in CSCW*. Department of Computer Science., University of Saskatchewan. Saskatoon

Pinelle, D., Gutwin, C. & Greenberg, S. (2002) Task analysis for groupware usability evaluation:Modeling shared-workspace tasks with the mechanics of collaboration. *ACM Transactions on Computer-Human Interaction 10(4), 281-311*.

Podsakoff, P. & Schriescheim, C. (1985) Field studies of French and Raven's bases of power: Critique, reanalysis, and suggestions for future research. *Psychological Bulletin,* (97), pp 387-411.

Reynolds, P. (1984) Leaders never quit: Talking, silence, and influence in interpersonal groups. *Small Group Behavior,* (15:3)**,** pp 404-413.

Rienks, R. & Heylen, D. (2006) Dominance detection in meetings using easily obtainable features. *Lecture Notes in Computer Science,* (3869), pp 76-86.

Scaife, M. & Rogers, Y. (1996) External cognition: How do graphical representations work? *International Journal of Human-Computer Studies,* (45), pp 185-213.

Scott, J. (2000) Rational choice theory. In Browning, G., Halcli, A. & Webster, F. (Eds.) *Understanding contemporary society: Theories of the present*. Sage Publications.

Suchman, L. (1987) *Plans and situated actions*, Cambridge University Press.

Tuckman, B. (1965) Developmental sequences in small groups. *Psychological Bulletin,* (63), pp 384-399.

Wegner, P. & Godin, D. (1999) Interaction as a framework for modeling, In Proceedings of *Conceptual Modeling*, Los Angeles, CA, USA, Springer-Verlag.

Weinberg , S., Smotroff, L. & Pecka, J. (1978) Communication factors of group leadership. *Journal of Applied Communication Research,* (6:2)**,** pp 85-91.

Yetton, P. & Bottger, P. (1983) The relationships among group size, member ability, social decision schemes and performance. *Organization Behaviour and Human Performance,* (34), pp 145-159.

COPYRIGHT