REINVENTING THE WHEEL: CONTROL TASK ANALYSIS FOR COLLABORATION

Maryam Ashoori, Catherine Burns
Advanced Interface Design Lab, University of Waterloo

Cognitive work analysis (CWA) is a relatively new human factors perspective for analyzing complex sociotechnical systems. However, it does not yet have specific tools and techniques that allow it to address teamwork explicitly enough to provide good guidance on how to support teams and collaboration. In this paper, Decision Wheels are introduced as an extension to the Decision Ladders for representing collaboration in teamwork environments. This extension would be a significant contribution to both CWA methodology and human factors methods for team situations. It would enable human factors practitioners to understand the cognitive work of teams better, and to design better collaborative systems for teamwork environments.

INTRODUCTION

In today's complex work environments, human error and poor situation management result in large financial losses, and loss of life, everyday. Many preventable human errors occur as information is passed between members of the team. When moving toward data driven services, people need to adapt to new expectations, new technologies, and an increasing demand for quality interactions across and within the team. However, teamwork often suffers from inadequate awareness of team goals; conflicts between team goals and individual goals; and process losses due to poor coordination among team members.

While there are reasonably good measures in the literature for evaluating team efficiency, very few studies have attempted to design proper technologies to improve team performance and collaboration. There are very few methods that explicitly derive team performance and collaboration requirements in a manner that could be used to design new systems.

Cognitive Work Analysis (CWA) is a relatively new human factors perspective for analyzing complex sociotechnical systems that has shown success in other industries such as military and industrial contexts. CWA emerged from the work of Rasmussen and his group (Rassmussen, Pejtersen, & Goodstein, 1994) from a project for the Danish government to introduce safe nuclear power to Denmark. Vicente (1999) further developed this framework to present it as a framework for designing safe, productive, and healthy computer-based work.

There has been an increasing interest in applying CWA models and techniques to many diverse human-technology systems. CWA has been explored for a broad range of applications such as aviation (e.g. air traffic control [Kilgore, St-Cyr, & Jamieson, 2009], cockpit display design [Flach & Amelink, 2003], collision detection [Ho & Burns, 2003], and airport collaborative decision making design [Groppe, Pagliari, & Harris, 2009]); military applications (e.g. maritime surveillance [Naikar, Drumm, Pearce, & Sanderson, 2000], and naval command and control [Burns, Bryant, & Chalmers 2000]); and health care applications (Burns, Enomoto, & Momtahan, 2009) to name a few.

These applications however, have focused on individual users and not on team applications. In fact, there have been few examples of CWA for collaboration and teamwork (for example see: Hajdukiewicz, 1998; Rasmussen, Pejtersen, & Schmidt, 1990; Burns & Vicente, 1995; Ashoori 2010; Naikar, Moylan, & Pearce, 2006; Jenkins, Stanton, Salmons, Walker, & young, 2008). CWA does not yet have specific tools and techniques that allow it to address teamwork explicitly enough to provide good guidance on how to support teams and collaboration.

CWA examines how people work with technology from an understanding of the technological system, the tasks that must be performed, the strategies to do so, and the influence of the organization and individual competencies on how people work (Vicente, 1999). A complete CWA includes a Work Domain Analysis, followed by the analysis of control tasks (Control Task Analysis), strategies (Strategies Analysis), social organization (Social Organization and Cooperation Analysis), and operator competencies (Worker Competencies Analysis). This paper mostly focuses on revamping the second phase of CWA for collaboration.

TOWARD A TEAM CONTROL TASK ANALYSIS

There have been very few attempts to extend Control Task analysis (ConTA) for establishing collaborative work requirements. When it comes to teamwork, a proposed framework should explicitly answer what control task constraints emerge where work flow and even cognitive tasks are shared among team members. Naikar et al. (2006) illustrate a new formative representation for ConTA called the Contextual Activity Template (CAT). They argue that control tasks can be identified in the context of work situations and/or work functions where the boundaries between the activities of actors might be different over various situations.

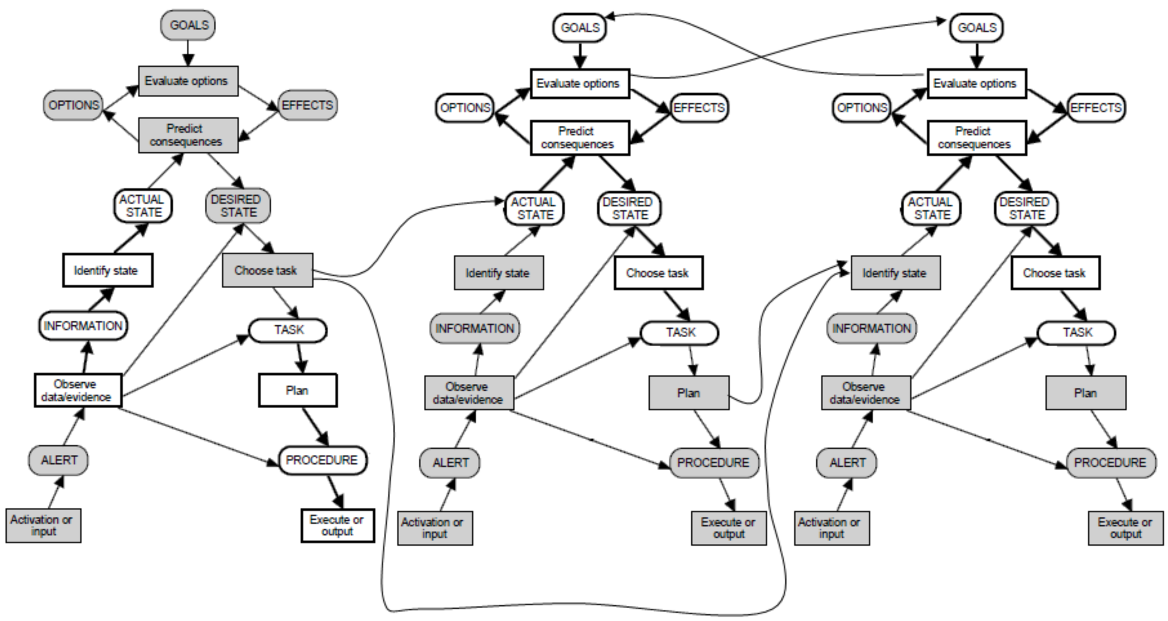

Figure 1. A chain of decision ladders in a sample teamwork scenario.

Naikar et al. (2000) extend the idea of CAT to design new teams and explore the feasibility of alternative team designs by summarizing patterns of activity and workload and estimating spare capacity for further work responsibilities. The CAT can be also color coded to show which actors can perform what functions in which situations (Jenkins et al., 2008). However, since each actor is represented with a single color, it might get complicated for larger groups.

Burns et al. (2009) discuss a chain of decision ladders where links between ladders demonstrate the collaboration points (e.g. Figure 1). This chain of decision ladders work well for three or four actors but becomes fairly complex for five or six actors. As they scale, there is no way to represent the links between the ladders. This paper extends the chain of decision ladders to the decision wheels to show interactions between teammates in larger teams and interactions between the team of teams, a view of teamwork that has not been clearly shown in these previous adaptations of the ConTA.

THE DECISION WHEELS

The decision ladder is the dominant modeling tool for ConTA. To show collaboration, decision ladders can be used to distribute control tasks across actors. Although there have been few works on allocating decision activities among different types of actors, interactions are not yet clearly addressed.

Figure 1 shows the chain of the decision ladders for a hypothetical collaboration scenario between three team members (A, B, C), a similar approach as in (Burns et al., 2009). Links between the ladders demonstrate the collaboration points between the team members. As mentioned before, this way of control task representation becomes fairly complex as it scales. Decision Wheels are proposed to decrease the complexity of representing relations between the decision ladders. Figure 2 illustrates a generic view of this idea. The decision wheel distributes the control tasks across actors with each actor comprising a portion of the wheel.

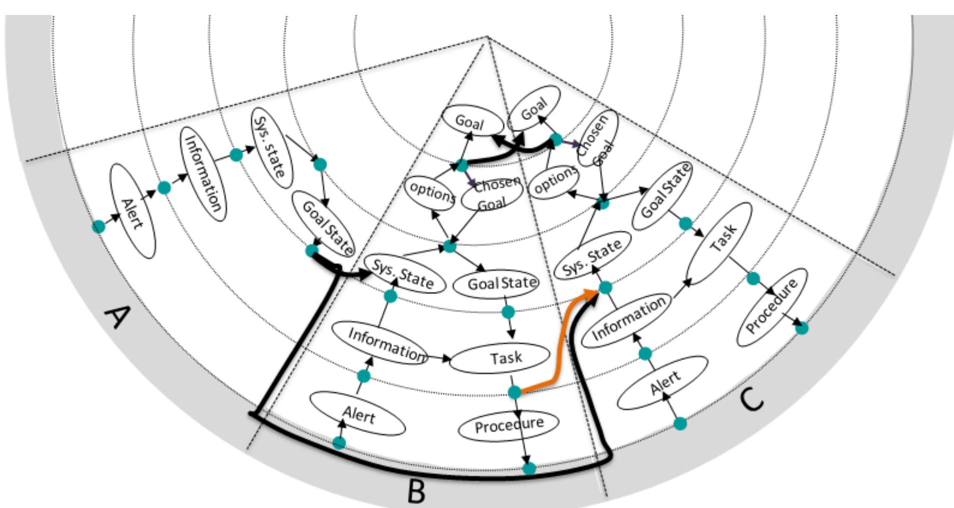

Figure 2. A sample decision wheel for the team members in Figure 1.

Slices of the wheel show the decision ladders of the team members. Interactions between actors are mapped onto the links between actor's decision ladders. Data processing activities are represented by a small circle while the ovals depict the cognitive states of knowledge resulting from the data processing activities. There is a color code to distinguish the synchronous and asynchronous activities. A Decision Wheel Table (DWT) describes further attributes of the links between actors of Figure 2. Each row of the table represents a single interaction link between two actors.

Table 1. DWTs for the hypothetical scenario.

Collabo-ation	Type	Boun-dary Objects	Scope	Media of Collaboration
A and B	Synchronous	B.O. 1	Intra-team	Face to face
A and C	Synchronous	B.O. 2	Intra-team	Phone
B and C	Asynchronous	B.O. 3	Intra-team	Shared dis-play
B and C	Synchronous	B.O. 4	Intra-team	phone
B and C	Synchronous	B.O. 5	Intra-team	Face to face

The type of the interaction (synchronous/asynchronous), scope of the interaction (within the team or outside the team), media of collaboration (e.g. face to face, on the phone, shared display, an alert, a message), and the boundary objects shared within the actors would be listed for each link.

Representing decision ladders within a wheel provides a clear way to show the links and interactions for a larger group.

Considering the scope of the interactions, it is very easy to represent the collaboration across various units of an organization at the same time. One wheel can be built for each team and then by connecting the wheels together, the collaboration across the teams can be shown. Figure 3 illustrates the collaboration for a team of two teams. As shown in the figure, there are two collaboration points between the teams. The first link between two teams (highlighted by *) indicates H from the second team triggers the work for C from the first team. The second interaction link shows B from the first team provides some information for F from the second team.

CASE STUDY: COLLABORATION SCENARIO IN A HEALTHCARE SETTING

For verification, this approach has been applied to establish the collaboration requirements for a sample collaboration scenario taken from the Ottawa Hospital. The scenario was developed by a subject matter expert to show a typical but complex collaboration situation. This particular scenario considers a patient who has entered the hospital to deliver a baby and develops a fairly straightforward complication, a headache. The actual scenario considers seven members and two units of the hospital.

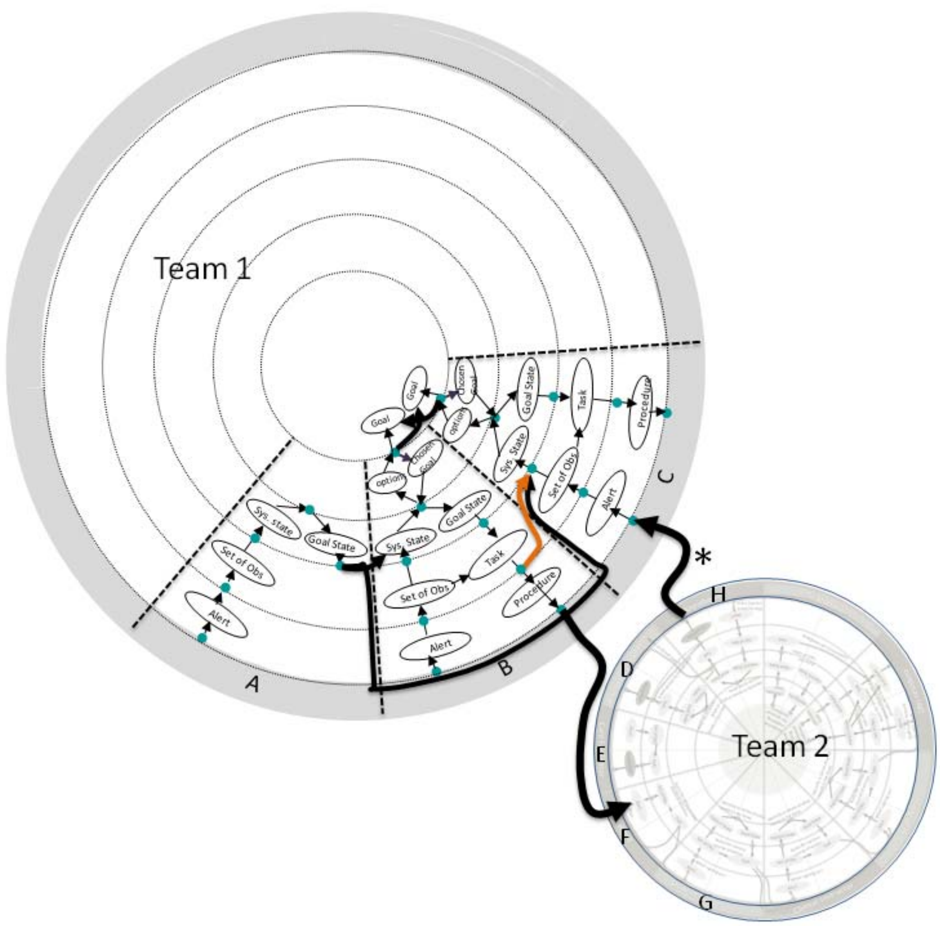

Figure 3. Decision Wheels representing the collaboration between two teams.

Scenario: The collaboration scenario starts with Mrs X as the patient. Mrs X has a vaginal delivery of a baby in the morning, requiring an epidural, and is now a patient of the mother baby unit. She has an assigned staff nurse to manage her care. Mrs. X develops a bad headache in the afternoon while walking. The staff nurse assesses the patient and determines that the patient needs to be assessed by the physician. The nurse talks to the obstetric resident available about Mrs X. The obstetric resident comes to the mother-baby unit to assess the patient who decides that the patient could benefit from an epidural blood patch (a simple surgical procedure that injects a sample of the patient's blood into their epidural space). He contacts the anesthesia resident to arrange for a blood patch to relieve the pain if Mrs. X agrees with this procedure. The anesthesia resident calls the care facilitator in the birthing unit to arrange for time for the blood patch. The care facilitator in the birthing unit identifies a primary nurse to do the blood patch with Mrs X. The care facilitator in the birthing unit calls the care facilitator in the mother baby unit to discuss time of blood patch. The patient is transferred to the birthing unit. The anesthesia resident is present to do the procedure. After the procedure the patient will recover and then would be ready to transfer back to the mother baby unit. The primary nurse updates the staff nurse about the patient state before transferring the patient.

Analysis: The scenario provides a wide variety of interactions between multiple team members and across teams. While Figure 4 represents these interactions, Table 2 identifies the attributes of each interaction.

Links are numbered to simplify the explanation. For each collaboration link, the type of collaboration (synchronous/asynchronous), boundary objects (the object shared within the link), the scope of the interaction (between units or intra-unit), and the form of collaboration are listed in Table 2.

The anesthetist and the primary nurse collaborate on the blood patch procedure which makes it a synchronous activity. Synchronous states and activities are shown with the solid boxes in this model.

Results: In comparison with a typical ConTA this model allows

- larger team and inter-team interactions to be shown
- synchronous and asynchronous interactions to be identified
- boundary objects passing between teams or team members to be identified.

In comparison with typical team work models, using the decision wheels allows

- team interactions to be identified at various cognitive states and cognitive processes
- shortcuts and shunts to be identified

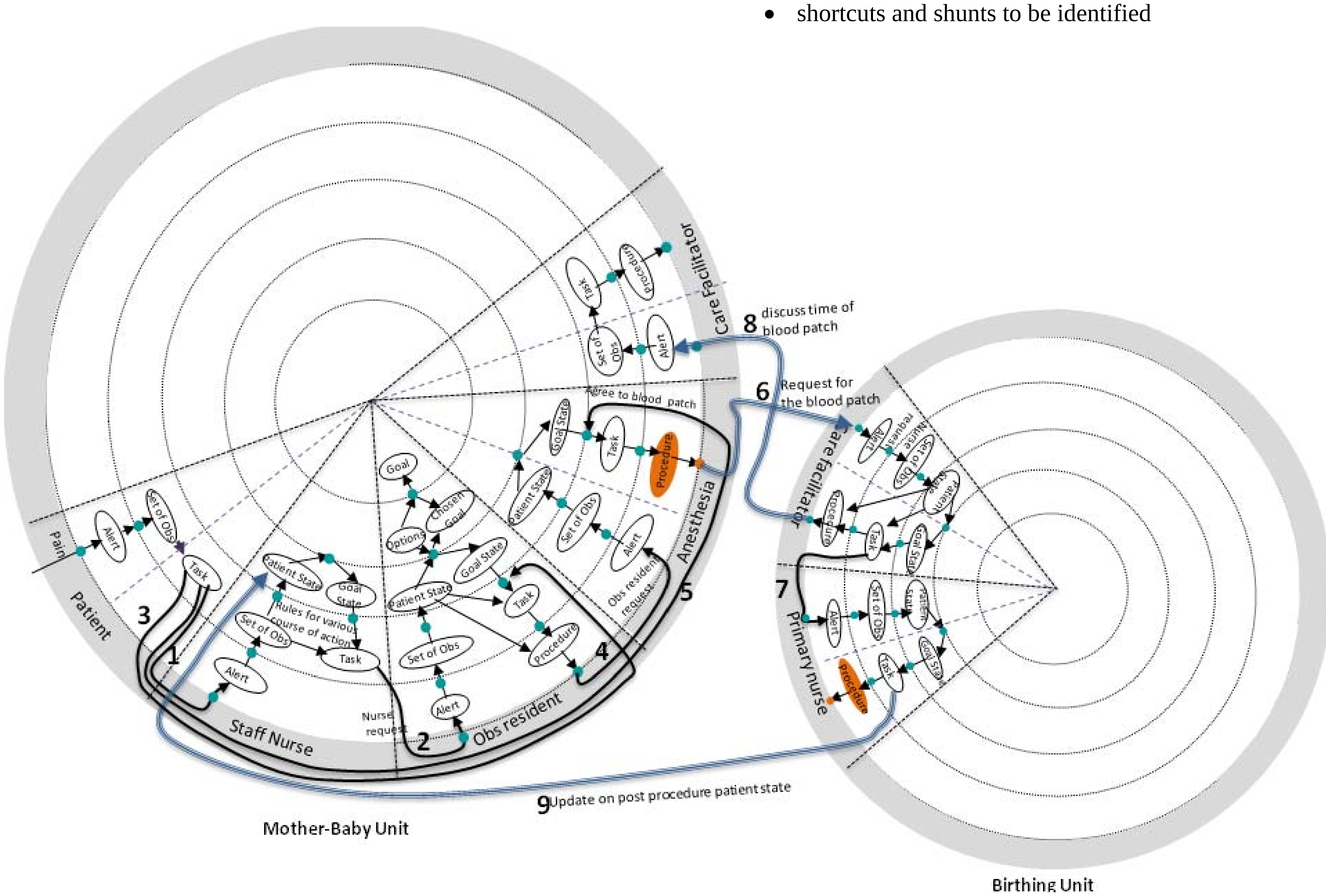

Figure 4. The Decision Wheel representing the sample collaboration scenario.

Table 2. DWTs for the sample collaboration scenario.

	Collaboration	Type	Boundary Objects	Scope	Media of Collaboration
1	Patient-Staff nurse	Sych.	-Patient record	Mother-Baby unit	Face-to-face
2	Staff nurse-Obs Resident	Sych.	-Patient ecord	Mother-Baby unit	Phone
3	Patient- Obs Resident	Sych.	-Patient -Patient ecord	Mother-Baby unit	Face-to-face
4	Obs Resident – Anesthesia	Sych.	-Patient ecord	Mother-Baby unit	Phone
5	Anesthesia-Patient	Sych.	- Patient -Patient ecord	other-Baby unit	Face-to-face
6	Anesthesia-Care facilitator	Sych.	-Patient ecord	etween units	Phone
7	Care facilitator-primary nurse	Sych.	-Patient ecord	irthing unit	Phone
8	Care facilitator-Care facilitator	Sych.	-Patient ecord	etween units	Phone
9	Primary nurse-Staff nurse	Sych.	-Patient ecord	etween units	Phone

Limitations: The decision wheel is a new adaptation of the decision ladder to look at larger team interactions. While this does allow larger teams to be analyzed, it still suffers from scaling issues such that extremely large teams could not be studied with this model. As well, certain teams may exhibit specific team based states and processes that differ from those modeled in the classic ConTA.

CONCLUSION

While CWA does not exclude the description of teamwork, ConTA is usually discussed in the context of a single operator. Adapting the ConTA to explicitly consider team activities, provides a stronger understanding of teamwork than existing methods, which would result in the ability to design dramatically better decision support systems for teams.

The Decision Wheels make a theoretical contribution by extending the ConTA framework to support teamwork and should make a practical contribution by demonstrating the usefulness of the framework in a real collaboration context. These developments should enable human factors practitioners to understand the cognitive work of teams better, and to design better collaborative systems for teamwork environments.

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