

Coordination of Work: Towards a Typology

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Abstract: *Based on the study of different coordination theories and approaches and on the previous ethnographic case studies, authors identify certain types of coordination, which they introduce in this paper: time-based, product-based, process-based, and problem-based coordination. These types are instantiations of a coordination typology developed. The characteristics of these coordination types are shown, on the one hand, in terms of coordination work practices (relation between planning and execution, decision-making, distribution of work), impact factors (interdependencies, resources, output, flexibility, success criteria), and coordination mechanisms (protocols and artifacts), and on the other hand, by illustrating the analysis of a time-based coordinated work environment by applying this typology.*

Key words: *Coordination, CSCW, ethnography.*

INTRODUCTION

Cooperative work needs to be coordinated to succeed. "Coordination is managing dependencies between activities. ... if there is no interdependence, there is nothing to coordinate" [3, p.90]. To coordinate processes of complex systems coordination mechanisms are investigated for several years. Some studies provided theories to coordination in parallel and distributed computer systems, some others to coordination in human systems and a lot of them to coordination in complex systems that include both humans and computers. In computer science, the coordination theory is studied in two main research areas: in the field of Computer Supported Cooperative Work (CSCW) and in coordination programming. In CSCW, the core problem setting was to find out how computer systems can support coordination activities. To design and implement computer based coordination systems, methodologies and frameworks are needed [1]. There are studies about cooperative processes [15], methodologies to design coordination in a cooperative work environment [14], and about systems implementing coordination mechanisms [13].

However, besides the few definitions of coordination as an integrated process to project management, or identification and description of artifacts or processes building up a coordination mechanism when interrelated, there is no systematic description of coordination, no models and, definitely, no typologies of coordination so far, which can be used as an underlying framework for studies of coordination issues in collaborative work environments. Additionally, there is no research work done to evaluate a coordination concept or typology with real work environments.

To find out "how coordination can occur in diverse kinds of systems" [3, p.88] work practices can be investigated by means of ethnographic studies, which was and is a very important methodology applied in CSCW research. At the same time, we need to ask the question how information and communication technologies change the ways we work together. If we want to design systems to support cooperative practices we need to understand what work groups do and why they do certain things in a certain way.

This paper builds on the one hand upon coordination theories and approaches [12], and on the other hand on the empirical evidence of the last 10 years. It tries to systemize and analyze different coordination types, based on previous ethnographic studies. The goal is to develop a typology of coordination, which enables to understand work settings easily to design IT systems to support collaboration and coordination.

In the next section some relevant coordination theories and approaches are described. Afterwards a typology of coordination is introduced and described by showing relevant categories for analysis and components of the typology with their properties. As an example, time-based coordination is illustrated in a case study, before concluding the paper.

COORDINATION THEORIES AND APPROACHES

If more than one actor is involved in an activity, it is necessary to divide it and then manage *interdependencies* among the emerged activities [3] [2]. There are several kinds of interdependencies [3, p.91]: To manage *shared resources* an allocation process is needed. This is well studied in computer science and organization theory. *Producer/consumer relationships* occur when one activity produces something that is used by another. If multiple activities need to occur at the same time, they must be executed simultaneously. To manage *simultaneity constraints* synchronization processes can be applied. Finally, there are *task/subtask* dependencies that occur when a group of activities want to achieve an overall goal. First, individuals need to choose a goal (goal selection) and then they decompose this goal into activities or sub-goals (task decomposition) [3, p.96]. Sometimes it is a problem to break goals into activities that can be performed separately.

Schmidt and Simone introduced the concept of *coordination mechanisms* [4] [5] [6] -- as a "generalization of phenomena described in empirical investigations of the use of artifacts for the purpose of coordinating cooperative activities in different work domains" [7, p.155]. Their theory is mainly based on the use of artifacts for coordination purposes. A coordination mechanism is "a protocol that, by encompassing a set of explicit conventions and prescribed procedures and supported by a symbolic artifact with a standardized format, stipulates and mediates the articulation of distributed activities so as to reduce the complexity of articulating distributed activities of large cooperative ensembles" [7].

By means of ethnographic field studies Schmidt and Simone tried to understand how cooperating actors apply *coordinative constructs* in their work, what these constructs are and how such constructs are supported by artifacts. Articulation means the coordination, scheduling, aligning, meshing, integrating, etc. of individual and yet interdependent activities. To articulate distributed activities *specialized artifacts* are needed [7, p.162], like timetables, schedules, catalogs, classification schemes for large repositories, etc. They help reducing the complexity of articulation work and alleviating the need for ad hoc deliberation and negotiation. Schmidt and Simone called these specialized artifacts, the mentioned conventions and procedures *coordination mechanisms*. A coordination mechanism consists of a coordinative protocol and an artifact [7]. A *coordinative protocol* is a set of conventions and procedures that stipulate the articulation of interdependent distributed activities. It is a resource for situated action. It provides a precomputation of task interdependencies and through this it reduces the complexity of articulation work. Actors rely on these precomputations and their options for coordinative actions are limited in any given situation. "Plans are resources for situated action, but do not in any strong sense determine its course" [11, p.52].

Formal organizational constructs, as Schmidt defined, are, i.e., procedures, workflows, and process models. Their representation helps regulate routine coordinative activities in an organization and enable performing more reliably and efficiently. Formal constructs can be introduced to deal with increased complexity of work that normally occurs when the scale of cooperative work is increased [5]. Schmidt and Simone noticed that the role of coordinative protocols varies from situation to situation [7, p.174]. They can be used as weak stipulations like *maps* or as strong stipulations as *scripts*. This depends on the level of power of the precomputation of task interdependencies, which is represented by the protocol. Schmidt and Wagner studied architectural practices and analyzed common artifacts architects used to coordinate their design work [8]. The so-called *ordering systems* consist of several *coordinative artifacts* and are implicitly and explicitly used to systemize and categorize the common artifacts [9].

A TYPOLOGY OF COORDINATION

Based on the theories and approaches to coordination, as described in the previous section, combined with the analysis in the scope of our ethnographic research carried out for last 10 years in several application areas, we can identify following concepts and terms that help to systemize coordination environments (Figure 1).

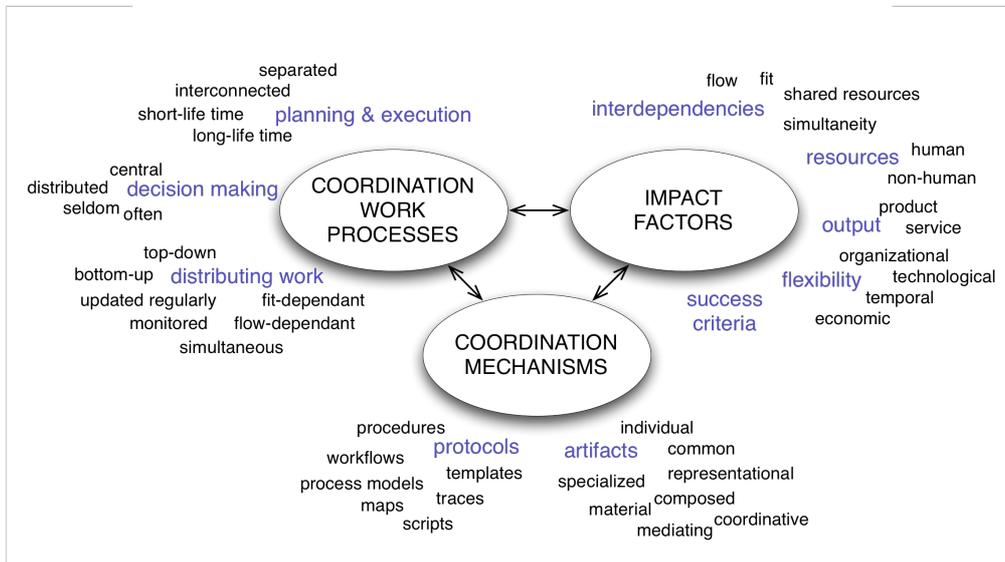


Figure 1. A typology of coordination with three central components and several subcomponents structuring properties of the typology.

To analyze the *coordination work processes* we have mainly to look at the relation between planning and execution practices, at the structure and type of decision making in the group, and at the ways of distributing work in a group. Following questions are useful to determine the properties of coordination work processes: What is the role of plans during the execution of project steps? Are plans used during the project as active documents? Are they updated regularly and referred to during the coordination of processes? How and how often are decisions made? Who is involved in the decision-making processes? What types of artifacts are used to support decision-making process? How is work distributed organizationally, temporally, and logically within the work groups? Who decides on what base to assign persons to tasks? How are dependencies between works of project members defined and monitored? Are meetings used to discuss the work progress and (re)distribution of work in ongoing projects? How is the distributed work integrated? How are interfaces between tasks defined?

Impact factors need to be understood to focus on specific coordination setting. The main impact factors regarding coordination activities are interdependencies. Are there known interdependencies between tasks, product parts or allocation of human and non-human resources for the project? Are there resources shared between groups or individuals? Are there producer/consumer relationships where prerequisite constraints, transfer or usability of outputs must be considered? Are there activities, which must be executed simultaneously? Are there tasks, which are divided into subtasks having sub-goals? How can task decomposition be done in such task/subtask dependencies? Another important factor is the definition of success. How is the success of the teamwork measured? What are the criteria for determining the success of the work group?

Work groups use of course certain *coordination mechanisms* they establish in their collaborative projects. To determine what type of coordination mechanisms is most suitable for a certain work environment, it is important to answer the following questions by considering the impact factors already defined: What is the coordinative protocol in the group? Which set of conventions and procedures are established in the cooperative work

environment? How is coordination carried out during the project? Are there differences between coordination practices of routine and non-routine work? Who is in charge for coordination in different phases of the project? What type of coordinative artifacts is used for coordination purposes, by whom? More systematic questions like, is standardization, direct supervision or mutual adjustment necessary or applicable for coordination purposes? What type of specialized artifacts is used to support coordination? Are coordinative constructs formalized, and do they have impact on organizational structure? What ordering systems in use can be identified?

Investigating these questions in real work environments in the scope of previous ethnographic research ended up in the following first set of different coordination types:

Time-based coordination

Deadlines drive the projects. At the beginning of a project, deadlines and other temporal conditions are defined and agreed on between participating stakeholders. Interdependencies are defined by temporal conditions. In a commercial project, these agreements are usually signed by customers, suppliers, and designers before starting the project. Project managers use a time-based approach to create a project plan, starting from the end delivery date by calculating the time periods backwards in which certain activities must be carried out. If possible, buffer time is calculated to provide a space for improvisation in case of unexpected contingencies. Simultaneity is common and coordinated between the persons directly involved. Decisions are mainly made distributed, because the timely definition of project work has impact on everyone's work, and in case of decisions everyone is interested to participate. Meetings are used to up-to-date the project progress and, in case of troubles, to reallocate resources to fit the current requirements. Besides the time-based project plan, regular meetings are the main components of coordination mechanisms. With a to-do-list as a coordinative artifact, the status quo of project progress can be captured and modified if needed. No additional coordinative constructs are needed. Success is measured mainly if deadlines are met, and of course, if expected results are delivered.

Product-based coordination

A complex product is divided into sub-parts, which are assigned to different persons or work groups. Interfaces between the sub-parts are defined. Interdependencies between sub-parts determine the coordination of work in the whole project. On the one hand, the implementation of the interfaces agreed on, on the other hand, the timeliness in delivering the planned parts in planned quality and quantity is main issues contained in coordination protocols. Project managers deal with these interface definitions and dependencies between the productions of sub-parts. They create a plan mapping the product structure and assign groups to the sub-parts. They monitor the progress of work on sub-parts, intervene in case of problems, and reallocate resources, if necessary, depending on the availability. Problems occurring between sub-groups can be of different types, personal, technical, commercial, complexity-related or strategic. Regular meetings can be very useful to bring different groups together to exchange their work progress and other issues relevant to all. Configuration management tools or other central common information spaces are used as coordinative artifacts enabling standardization of protocols. Decisions are made centrally involving the responsible persons for the sub-parts letting them to negotiate their open issues. Success is measured in the quality of the product, in its integrity, completeness and unity.

Process-based coordination

Processes are predefined, well structured and in most parts routine. Several groups are assigned to parts of the processes. A workflow or likely system is used to model the processes and to monitor them in real time. It is the only coordinative construct and defines the coordinative protocols. If there are deadlocks or problems in carrying out certain tasks in the workflow, project managers intervene and reallocate resources or

reassign people to tasks. In a supply chain or customer relationship, coordination of work goes further to externals like customers, suppliers, distributed teams from other locations, etc. The system used is the coordination mechanism. It enforces people to do certain things in a certain order. To skip or postpone a task is almost not possible. Modifications of workflow can be done in some cases, but normally not in an ad-hoc manner. Improvisations are difficult or impossible. Meetings can be useful to work around the system, or for reallocation of resources. Often, the cooperative work is also coordinated directly by people involved. This type of coordination is not coupled to the system used. Decisions are made centrally which may then modify the workflow system. People carrying out the work are not included in decision processes. Success is measured in the workflow system. A project of this kind is successful if work processes are carried out according the workflow in an efficient way.

Problem-based coordination

An occurrence of a problem triggers a chain of action. The problem can be related to a product, a process or a person. Depending on that, coordination is needed between involved people responsible for the product or its sub-parts, for a certain process or for a certain person or group. If a problem occurs, project manager is in charge to identify the right people to involve, in an ad-hoc manner. First of all, information about the problem and its circumstances must be captured. Then, a meeting must be scheduled between involved parties to clarify open issues and work on possible solutions. Coordination mechanisms like systems for bug tracking or configuration management, and coordinative artifacts like issue lists can help to coordinate the problem solution, especially if more than one person or group is involved. Success is measured in terms of fast reaction to problem occurred including the organizational flexibility and sustainable solutions delivered.

APPLICATION OF THE TIME-BASED COORDINATION TYPOLOGY IN A REAL ENVIRONMENT

In this section we want to apply the (time-based) coordination typology to illustrate how it is used for analysis of the ethnographic material gathered in a small team of a telecommunication company, called Mobile in this paper. Mobile consists of four people working on new applications for mobile devices, which must be presented in a trade fair event. There are detailed descriptions of their work practices and artifacts they used in other publications [16]. The main constraint in their project was the date of the trade show. It is an annual event and all mobile communication companies need to join the trade with their brand new products or services. This is always the main step to be present in the current market. If they miss one year they have problems in acquiring customers during the whole next year. Being aware of this strong constraint, Mobile tries to design new products and services within a relatively short period of time.

The distribution of work is done by the competencies of the group members. In emergencies the whole group acts together, to solve a problem or to distribute the unexpected additional work in the group. Improvisations are usual.

Decisions are made mainly cooperatively, because the time-dependant definition of project work has impact on everyone's work. Short regular meetings are the place of decision-making. Overhead in staff effort like writing down the work hours, minutes of the meetings, documenting design decisions, commenting the code etc. is kept very small. If it is necessary, quick and dirty solutions are common to overcome difficulties in the production.

Success is measured in meeting the deadlines by expected results. Of course, it is crucial to come up with new ideas, new features and attractive services at the trade. The output is measured by its quality and by the interest visitors of the trade event show. Still, everything must be ready to show at the trade, the point of time is the most important requirement to the process.

Coordination is carried out in an ad-hoc matter. If a decision has to be made, e.g. regarding the technology used, features planned, problems occurred in work processes or in cooperation with suppliers, the small team come together, no matter what the single members are doing at the moment, to discuss the emerged issues. They do not stop until they decide how to deal with the situation and what to do next. So, they coordinate their work situated [11], even sometimes they rearrange everything they planned to do beforehand. This flexibility is only possible, because the team is a very small team, team members know each other very well, they trust each other, and they help each other. They also know that they are dependant on each other.

CONCLUSIONS

In this paper, we presented our research on coordination. Based on our long-term ethnographic studies at different sites, like in manufacturing, system design, multimedia production, hospital work, etc. we were able to analyze our findings in the scope of these notions and concepts. The result is a list of concepts and questions that we used to identify differences in coordination work in different types of projects, which ended up in a first version of a typology for coordination work, instantiating four types of coordination: time-based, product-based, process-based and problem-based coordination. This list is not a final list. For instance, resource-based coordination could be added to it, as suggested by one reviewer. Additionally, there is still synthesis work to do, mainly by analyzing the rich empirical material, which can impact the current version of the typology.

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