

# Modeling Complex Work Systems - Method meets Reality

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## ABSTRACT

Modeling an existing task situation is often a first phase in the (re)design of information systems. For complex systems design, this model should consider both the people and the organization involved, the work, and situational aspects. Groupware Task Analysis (GTA) as part of a method for the design of complex systems, has been applied in a situation of redesign of a Dutch public administration system. The most feasible method to collect information in this case was ethnography, the resulting task model needed the GTA formalism to be adjusted to situational aspects of the work. The study shows that GTA as an approach is feasible in complex design cases, and that the formalism allows adjustment to cover situational aspects, while still keeping its cognitive ergonomic value for design.

## Keywords

Ethnography, Groupware, GTA, Task analysis

## INTRODUCTION

Various design approaches currently exist in Cognitive Ergonomics. The common characteristic is attention to users and user relevant aspects of the system to be developed. The implementation of this attention, however, is very diverse. In this introductory section we will briefly mention some viewpoints. In current user interface design practice, different viewpoints and approaches are often combined or integrated.

First of all, some approaches are based on user participation (Mumford, 1987). Attention to the user and his task situation is not based on systematic analysis and representation of task knowledge, but on the availability of the users during the design process. These methods allow users, who are not professional designers, to influence design decisions in a very direct and explicit way.

A different viewpoint can be found in design methods that stress the importance of systematic knowledge of existing task situations. Many approaches are based on cognitive psychological theory. TKS (Johnson, 1989), the Hierarchical Planning method (Sebillotte, 1988), and MAD (Scapin & Pierret-Golbreich 1989) present a method where design starts mainly with investigating current task knowledge. Methods of this type apply a conceptual framework that is derived from psychological notions on human memory and human planning. The prospective system users provide the knowledge that is subsequently represented in task models that feature as the main source for subsequent design activities. The design requirements and decisions are strongly based on these task models, where the (professional) users only indirectly contribute to this.

Again, a different perspective may be found in the

mainstream of CSCW design methods. Here, again, the existing task situation is the primary source for design. However, not the psychological basis of expert knowledge is considered, but the task-knowledge that can be experienced in current work situations and in "communities of practice". Activity Theory (Nardi, 1995) and ethnographic approaches (Jordan, 1996) are the main theoretical foundations for methods that aim at acquiring insight in current situated task domains. Design is based on this insight. Different from the previous type of approaches, however, the analysis of the current task situation is not guided by an a priori conceptual framework, nor is it followed by a formal representation of the task structure.

Many approaches (though mainly the knowledge oriented views) apply representation-techniques, conceptual frameworks or models to accommodate user-oriented viewpoints: CLG (Moran, 1981), GOMS (Card, Moran & Newell, 1983), CCT (Kieras & Polson, 1985), TAG (Payne & Green, 1986) and ETAG (Tauber, 1990) each provide methods to explicitly consider user related characteristics in design, mostly based on cognitive psychological theories. In these types of approaches, it is the designer who evaluates human aspects as part of design specifications, systematically considered with the help of the model or framework, in order to optimize the design. The framework provides a model of cognitive aspects of the user, in the form of a competence model or a performance model (de Haan, van der Veer & van Vliet, 1991).

The approach that we will present in this contribution is an attempt to integrate several viewpoints: we start our design by investigating knowledge of the current task situation. We apply different methods for this, related to the complexity of the human-machine system to be designed - both knowledge elicitation and ethnographic methods may be needed depending on the current task situation. We apply a conceptual framework that is based on a priori notions of human cognition and on our vision on situated tasks, as well as on our vision of the further design of complex systems. Finally, we apply a formal modeling approach. In this way we interpret and model the task world, as far as it is relevant for the designer, NOT as a complete account of the world as it exists for the people living in it.

Part of our approach will be illustrated in this paper. Our complete view on design considers several phases of design decisions, guided by explicit design rationale, which will not be discussed in detail (Van der Veer, van Vliet and Lenting, 1995). In the next section we elaborate our task analysis method GTA, which may be considered the first phase of design in this view (other

phases regard technology specification, early evaluation, and implementation - which will in practice be elaborated in an iterative structure of design activities). The remaining sections will provide a brief account of an actual design situation, regarding the reorganization of the Dutch social security system. We will illustrate our approach in this case and provide an account of what happens when applying GTA in a real life situation. This lead us to reconsider the conceptual formalism of GTA, though the conceptual framework as such is still feasible.

### **GTA - MODELING COMPLEXITY**

Groupware task analysis (van der Veer, Lenting, and Bergevoet, 1996) is an eclectic method. Analysis of the task situation may consist of (a) collecting information on current task situations; (b) modeling the current task situation including conflicts, problems, and needs of prospective users; (c) negotiation with the client of design on requirements; (d) investigating physical and technological possibilities and constraints; and (e) specification of the prospective task situation, based on b, c, and d, and often including the redesign of organizational and procedural aspects of the task situation. At this stage there will often be a need for early evaluation, even though no actual artifact has been specified in any detail.

It should be noticed that not all types of methods will always be feasible. E.g., sometimes, the actual design situation may prohibit activity a (the users may be unknown, the task situation may be inaccessible because of military strategic rules), or the current task situation may already be completely modeled, and the design may be restricted to system details that are supposed or required not to influence the task situation at all, in which case the whole set of task analysis activities will be superfluous.

We will provide a detailed account of some methods from categories a and b. For an account of the whole structure of methods in our view on task analysis, see van der Veer, Lenting & Bergevoet (1996).

The intended end-product of GTA is a formal task model that specifies the intended task situation, intended to be the input for the specification of technology details. This model (generally referred to as "Task Model 2") is build only after the current task situation is sufficiently investigated. The current task situation, modeled in "Task Model 1", may be based on knowledge acquisition methods like the ones proposed by Sebilotte (1988) or Johnson (1989). These methods apply mainly as far as relevant task knowledge is explicitly available from "professionals". In many cases this is partly true. Professionals, however, sometimes apply implicit knowledge (especially in cases where their task activities are triggered by situational aspects like the presence and state of certain task relevant objects - e.g., driving in a well known town).

Another aspect of task knowledge seems to be available mainly in the form of "group-knowledge" (Jordan, 1996), where anecdotes sometimes turn out to be vehicles of relevant strategies, or where teams are able to

provide information for performance only by combining role specific elements from different perspectives. Group knowledge may also be only implicitly available, in which case only trained ethnographers may detect relevant aspects of task behavior, about which none of the players in the situation seems to be aware.

In complex task domains, many different methods may be needed to collect all relevant information, from knowledge acquisition through interviews and psychological elicitation techniques, via behavior observations in situation, via study of documents, to ethnographic methods. GTA proposes to combine these methods, listing them mainly in two categories: collecting information that is of a cognitive nature (explicit knowledge from professionals and from documents), and information that stems from (mostly participatory) observation and registration in situ, which requires hermeneutic interpretation, like ethnographic interaction analysis.

In our practical experience with the GTA method we found these sources to be highly complementary. Information collected with the various methods turned not to be contradictory most of the time, or the contradictions could readily be interpreted (documents loose their validity over time, knowledge is role-specific and different roles may relate to conflicting goals). Conflict in this sense should not be removed but should be represented in the task model, as an important aspect of the current task situation.

The core of GTA is a conceptual framework that serves two purposes: to be some guideline for the original collection of information on the current task situation, and to be the base for modeling both the old and the new task situation. Although for the knowledge elicitation type of data collection a framework is quit common, for the ethnographic approach this is not obvious. The framework we apply is based on analysis of ethnographic methods in many design cases, and has up to now shown to be applicable, though we certainly have no theoretical proof for its validity.

The GTA framework consists of three viewpoints: people, work, and situation. Mainly the second viewpoint is quit common in the knowledge elicitation type of task analysis approaches, and the first is sometimes present as well (Johnson, 1989). All three seem to be valid in the ethnographic examples we have been able to analyze.

#### **People**

This viewpoint focuses on human actors, both as individuals and in groups. In GTA we consider the following concepts: (a) actors as individual persons. Important is mainly to collect information about relevant characteristics and about variability of these, e.g. typing skills or education; (b) roles as a categorization of people that perform certain sets of tasks; and (c) organization of people, revealing how and in what time structure roles are allocated to actors.

## Work

Work refers to structures of tasks and activities. At least we need to collect information on (a) tasks, indicating meaningful packages of work that intend to fulfill a certain goal; (b) task structures; (c) actions, defined as simple activities that do not have an individual goal but derive their meaning from the task as performed in a certain situation; (d) protocols and (e) strategies, which indicate structures of tasks that are commonly performed in certain situations, in general resp. in the case of experts.

## Situation

Analyzing a task world from the viewpoint of the situation means detecting and describing (a) the environment as a structure of physical, conceptual, and social relations as well as the relevant history of these relations; (b) describing the relevant things (we hesitate to coin these "objects" which might cause confusion with our object oriented formalism for other concepts in GTA), where things may be physical as well as conceptual, like passwords or messages; and (c) object structures, referring to semantic relations between objects, which may indicate type relations ("is a") as well as relations of other semantic character ("contains", "part of").

In performing data collection in GTA we try to apply all three viewpoints and collect information of all concepts from these viewpoints as well as the relation each has to other concepts (e.g. roles are described in terms of tasks that belong to the role, in terms of history of the situation in relation to the allocation of the role, as well as in terms of characteristics of the individuals that may take the role, and in terms of the rights that the role allows towards relevant objects).

In representing task knowledge in a task model, GTA proposes three different types of representation: object structures, relational graphs, and structural graphs.

### Object structures

For some concept in GTA it may be useful to define an object class, where the instances of that type are characterized by relations to objects of the same and other types. Thus far we regularly use object classes for roles, for tasks and for things, but we experimented with other classes as well (actors). Each object class is characterized by the above mentioned relevant relations.

### Relational graphs

Relations between objects of the same class are represented in the object structure, e.g., see the subordinate and superordinate slots and the themes and places slots in figure 1. For purposes of design decisions, however, a graphic representation will provide a more easy overview. We will benefit from a tree representation of type-hierarchy, as well as from a graphic representation of the themes-places relation where themes are objects that may find place in or on the current object, and the places are other objects that have the current object as a theme. In the same way relational graphs may show the semantic relation between roles and between tasks.

<b>Object:</b> timeslot	
<b>superordinate:</b> memo	<b>subordinate:</b> day_slot hour_slot quarter_hour_slot
<b>themes:</b> meeting holiday business travel	
<b>places:</b> month calendar week calendar day calendar	
<b>relevant tasks:</b> cancel meeting initiate meeting postpone meeting receive meeting cancellation forward meeting cancellation	
<b>actors/roles; competence</b> meeting participant; initiate cancellation meeting initiator; prohibit cancellation	
<b>passive/active:</b> passive	
<b>attributes:</b> time, date	

Figure 1. Object structure of thing object.

Figure 1 presents an example of a thing object for a calendar situation.

### Structural graphs

A last graphical representation that we found beneficial for representation of the task structure refers to relations between objects of different classes. E.g. we regularly will need to represent the relation between task structures and roles over time for which a certain kind of workflow diagram may be suitable. Likewise the relation between task structures and things is often needed to be represented.

## THE SOCIAL SECURITY CASE

GTA has been applied mainly to design exercises that were explored in the course of educational activities. Though the task analyses considered actual work in real life situations, the scope of the designs were tuned to the amount of time available in the design classes (ranging from 1000 to 3000 person-hours). The current example stems from a much larger design enterprise, where many person-years were spend on the specification phase alone. Our report considers the first phase of task analysis only, from initial inventarisation and collection of information to the formal representation of the resulting task model of the current situation, task model 1.

The Dutch social security system provides a large number of support facilities for citizens in divers situations of financial and other needs. In part of these cases the main reason for applying for support is a situation of very low or no income. Reasons may vary from loss of job to situations of divorce or loss of family member, forced change of housing situation, to other types of personal disasters.

A special type of tasks that is frequently performed by the social security systems in Dutch municipalities is the settlement of requests for support of primary subsistence. This task requires several levels of information collection and subsequent decisions.

The Dutch social security system as a whole is currently in a transition from very traditional office organization supported mainly by some database facilities and much stand alone simple personal computing facilities to a work structure that should be much more efficient, well structured, and requiring less overhead. Integrated implementation of workflow management tools and other forms of cooperation technology are being considered. Some prototyping systems are being constructed and installed in certain offices. Some divisions of the Amsterdam branche have been appointed as test bed for certain aspects of the new development. In this situation, one of the authors was contracted to perform a task analysis with the aim to describe the current situation, as a start for a systematic design effort. A period of 6 months full time could be devoted to this goal.

Colleagues had already studied other parts of the situation, and an overall sketch of the office structure and a collection of characteristics of the actors in relation to the identified roles was available.

### A METHOD MEETS REALITY

At the start of our task analysis of the handling of requests for primary support of subsistence in the social security case we profited from the fact that a group of our colleagues already had been working in the same offices. A detailed analysis was available of the characteristics of actors and regular roles, and, on the other hand, the office workers were aware of the status and possible obtrusive presence of ergonomic analysts.

Our main data collection started with some interviews of the type proposed by Sebilotte (1988). One of the first parts of our task model 1 was a structural graph of the process, of which figure 2 shows only the general structure.

During the phase of knowledge elicitation, however, we found out that an enormous variety of strategies existed and that workers evidently were unable to provide a generic account of the details of their work.

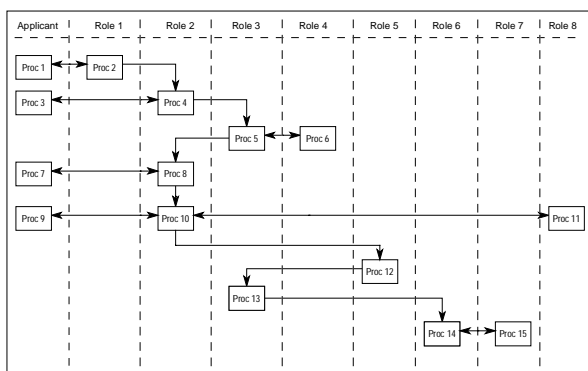


Figure 2. Process structure of work flow.

### Ethnography: Hanging Around

We decided to embark on an ethnographic study. One of the authors spend 2 months in the office, "hanging around" in order to get a feeling of what was going on in the complex process, and, on the other hand, to make her

role clear to the people. All employees knew that the whole social security system was being redesigned, and that the researchers were participating in this process as part of an outside consulting project. During these first months the employees learned to trust the analyst in relation of what would not be communicated to (other) staff members, and the analyst learned to identify the "hot spots", instances of events and interactions that seemed relevant for systematic analysis.

The analyst also learned to present herself to the applicants for financial support, which were the clients of the service. These people are often trying different ways to "earn" as much support as possible from the system by presenting their case in a way they consider most promising for this. The analyst learned how to communicate with these applicants, in order to establish a relation of trust in this case as well, meaning that she will not be, and will not be considered, a possible source of information or influence in any direction.

### Participant observation

This development of a basis of trust turns out to be very important in order to be allowed witness to important aspects of interactions. It needs to be established by a strong commitment of not involvement with the process. On the other hand, this commitment could not always been kept: e.g., the analyst was present at a certain moment when a document was placed in the pigeon hole of a worker who was not expected to be present for the next 4 weeks. She was convinced that this would seriously affect the applicant's expected financial conditions for the next period, so she decided to interfere with the event (and make a record of this action). In the light of the commitment to all actors involved, not reacting to this type of observation would not have been appropriate. However, the analyst performed no action that violated any commitment on which the trust was based, i.e., that was perceived not to be in the interest of any actor that had allowed the analyst to participate in private and personal aspects of the situation.

### Interaction Analysis

After 2 months the analyst felt to have acquired enough insight in the situation to be able to identify "hot spots". In addition, the analyst increased insight in the character of the roles in this organization, both by collecting a more complete overview of the task structures related to the roles that were already identified, and by establishing the notion of some additional roles in certain situation, where a second person was needed to conform important decisions. This second person normally performed identical roles, but was in this case chosen because there was no relation to the applicant concerned. Hence, in the actual situation of a certain request this person acted in a different role.

In order to systematically collect information, we choose to apply interaction analysis (Jordan, 1996), which consists of recording instances of hot spots on video, transcribing these into content logs, interpreting them, and combining interpretations of equivalent hot spots into general descriptions. Jordan proposes different possible views for orientation. We decided, based on an

analysis of the situation (including relevance of locations, differences between actors, complexity of the process, etc.) to collect both setting-oriented records for those settings, where the internal structure seemed to be situation and actor dependent, and process-oriented records for the total complex process.

For setting oriented records, the analyst collaborated with several employees in identical roles, who were willing to cooperate, and who differed on relevant aspects of their strategies in the setting concerned or on their views on the roles involved. For the process-oriented records, we asked collaboration of actors who were participating in the very first parts of the complicated process, in order to acquire approval from a set of applicants to videotape and analyze the complete process of their case. At the start it was, of course, unpredictable in which direction cases would develop. We had to discard certain parts of cases after it turned out the continuation developed into a different process in the service. Each relevant record was transcribed into a content log.

After collecting a sufficient number of records for the relevant subprocesses and complete process records, the tapes and the content logs were interpreted. In this activity we asked the participation of some of our colleagues, who were at that time also working in the same offices in the course of different design cases, as part of the same external consultancy project. The records were interpreted in terms of the conceptual framework.

### GTA FORMALISM REVISED

Although the interpretation of the records in terms of the GTA conceptual framework was relatively straightforward, serious problems arose when trying to construct models from different accounts of the same event, both when combining observations from different actors in the same role, and from combining observations from a single actor for different occurrences of the event. This is in contrast with the situation that is normally reported from task modeling approaches of the knowledge type (MAD, GTA), where professionals are found to be consistent and in agreement between each other relating the task structure. The behavior in the case of our complex system turned out to be strongly influenced by situational factors as well as by attributes of the partners in the interaction.

The first addition we had to make to the GTA formalism concerned the way to represent the structure of a certain task. In the past, we used constructors in the sense of Scapin and Pierret-Golbreich (1989), where notations like LOOP, PAR, OPT, indicated that certain subtasks are performed in a loop, in parallel, or optional, though we normally adjusted the actual set to the actors' perception of the task domain. Constructors are used both in the representation of task object structures, and in representations of relational graphs that show task decompositions. In the current case, however, we needed several much more elaborate constructors, especially in cases where an employee was interacting with the applicant for support:

CHOICE (<LIST>) and OPT (<LIST>),

where LIST can be any ordered subset of A, Cb, Cs, S. CHOICE indicates that one of the subtasks is chosen based on a condition that is a function of the elements of the list, evaluated in the order stated, OPT indicates that the following task is optional, based on the evaluation of the ordered list. See figure 3, for part of a task relational graph.

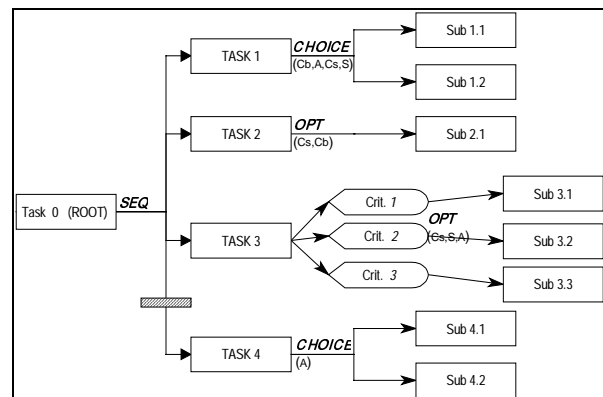


Figure 3. Relational task graph with new constructors, interrupted sequence and multiple criteria.

In this process the elements of the list were: preference/strategy of the individual actor (A), behavior of the client (Cb), situation of the client (Cs), other situational aspects (S).

Moreover, in the formal representation we still found the need to frequently add notes to certain constructors where a single verbal label was insufficient to make the formal representation interpretable for members of the design team.

Another addition we needed to define for the task relational graphs indicated the (frequently occurring) interruption of a sequence of related tasks by periods of events that were unrelated to the current process.

A last addition to the task graph concerns the frequent situation where a task is decomposed into a set of subtasks, each of which is only performed based on a criterion that is valid for that subtask only. In order to provide a readable and valid representation, we had to explicitly introduce this set of combined criteria and subtasks as part of the task hierarchy.

### CONCLUSIONS

The GTA framework showed to be valid even for the highly complex and highly situated type of process that analyzed. The methods of data collection in this case were mainly of ethnographic nature, where a long informal introduction and subsequent interaction analysis turned out to be feasible. The GTA formalism needed to be adjusted to allow a representation of situated and person-dependent substructures of tasks and events.

The task analysis as a whole was in fact checked for validity by the subsequent phases of design. Based on the model of the current task situation (task model 1) an analysis of the detected conflicts and problems, a new

task structure of the process was specified. This specification was formalized with the same extended GTA formalism, which allowed the development of scenarios for the process and especially for the subprocesses that were proposed to be redesigned. The scenarios were implemented by developing video fragments via role-playing. Both the original task model 1 and the scenarios that represented the proposed redesign were judged by the workers as realistic descriptions, resp., sensible proposals to solve the conflicts and problems. The GTA method seems to abstract the rich task insight that the analyst acquired via ethnography in such a way that the important aspects were saved, and thus were available for systematic redesign.

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