A Work Context Perspective on Mixed-Initiative Intelligent Systems

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Abstract

The issue of mixed-initiative intelligent systems has gained increasing interest in recent years. In particular, much attention has been paid on sharing the initiative between the user and the system on the tool level. In this paper, we are focusing on the problem of embedding the system into a workplace. We are proposing a framework for the analysis of how intelligent systems fit into a work context. We outline an approach with three different perspectives, focusing on the work process as a whole as well as human computer interaction on the interface and system level. The theoretical background consists of the Actor Network Theory, Semiotics, and the Activity Theory. We describe some challenges for the design of mixed initiative intelligent systems and outline how our framework might help to deal with these challenges.

1 Introduction

Case Based Reasoning (CBR) is a research area in the field of AI. Its aim is to understand and build systems which are able to use former experience in order to solve new problems. A CBR system is able to learn by taking care of experience in the form of so called cases, which describe problems and their solutions. When a new problem arises, one sufficiently similar previous problem has to be identified and the former solution has to be adapted to the new problem. The new solution might also be based on more than one previous case.

Being capable of learning during its use, CBR systems are one way to overcome the knowledge acquisition bottleneck. But it might be useful not to build the whole knowledge abductive, but to include given domain knowledge. The Division of Intelligent Systems in Trondheim is focusing on CBR systems which do not only learn from experience, but also incorporate given general domain knowledge to solve the problems (see e.g. [Aamodt, 1995]). This is referred to as knowledge-intensive CBR.

The group is aiming towards building a framework for such CBR systems. This involves identifying usable knowledge and reasoning structures as well as questioning how to embed the system in user tasks.

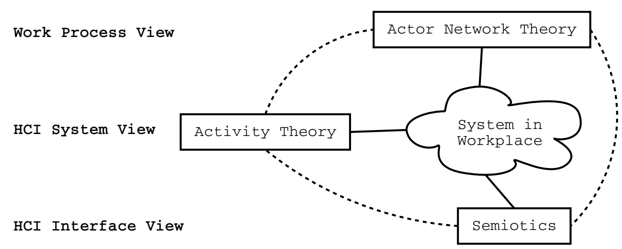

Figure 1: *Overview: Different views on the work context.*

When an AI system is considered not as a replacement of, but a supplement to human work, the question of an adequate form of interaction arises. An AI system is to a certain degree trespassing the boundary of viewing the computer system as a tool, and extending this to as to act as a partner in a work flow.

The notion of mixed initiative takes these role change into account. It is made explicit that both the human user and the machine can take the initiative in the interaction. The system might proactively request information from the user which is needed to solve a given problem. The control might either lie in the hands of the user when entering data, or the system can guide her through a dialogue.

In the light of this changes also the human computer interaction should be revisited. Traditional interface engineering methods focusing on the computer as a tool seem not to be appropriate to design intelligent systems. Further on, the integration of this kind of systems into work processes is likely to change.

This has in first sight the consequence that an AI systems must definitely be developed by taking the whole work situation into account. Traditional software engineering techniques, mainly focusing on the artifact itself, might possibly not give adequate results. Therefore, the software production process must integrate methodologies of work analysis.

In order to understand how the system fits into a work place situation, we propose a theoretical framework which is focussing on three different perspectives (see figure 1):

- Work process view: Actor Network Theory,
- HCI interface view: Semiotics,
- HCI system view: Activity Theory.

We are arguing that this theoretical framework is helpful for understanding how AI systems in general and especially CBR systems fit into a work process, and how they interact with the user.

1.1 Challenges

Mixed initiative intelligent systems face a couple of interesting challenges. We will shortly mention some of them:

- **The control issue:** How can we deal with the shift of initiative and control between different actors, both human and non-human?
- **The communication issue:** How can we facilitate the exchange of knowledge and information between actors involved?
- **The evolvement issue:** It is unlikely that the form of interaction remains unchanged over time. How can we assure a sufficient flexibility in communication abilities?

In order to illustrate how the different views in our framework can be used to cope with these challenges, we will now introduce a short example. We will later on look at some aspects of this system from our different viewpoints. The example is a diagnostic system in the oil drilling industries. It is used to monitor the drilling process in order to identify situations where the oil drill can get stuck. To this end, it collaborates with human users. The system is a a knowledge-intensive CBR system.

2 Work Process View: Actor Network Theory

We model the context in which the system is implemented with the help of the Actor Network Theory, ANT (see e.g. [Latour, 1991] and [Monteiro, 2000]). The basic idea here is fairly simple: whenever you do something, many influences on *how* you do it exist. For instance, if you visit this conference, it is likely that you stay at a hotel. How you behave at the hotel is influenced by your own previous experience with hotels, regulations for check-in and check-out, the capabilities the hotel offers you (breakfast room, elevators).

So, you are not performing from scratch, but are influenced by a wide range of factors. The aim of the ANT is to provide an unified view on these factors and your own acting. An actor network in this notion is 'the act linked together with all of its influencing factors (which again are linked), producing a network' (see [Monteiro, 2000, p. 4]).

In this network, you find both technical and non-technical elements. By this, the ANT avoids the trap of either overstating the role of technological artifacts in a socio-technological system or underestimating their normative power by applying the same framework to both human actors and technological artifacts. This makes it possible for us to understand how technological artifacts influence the doing of human actors in much the same way as other human actors.

Some key concepts of the theory are (compare e.g. [Monteiro, 2000]):

- **Actors:** Humans and technological artifacts,
- **Actor-network:** The totality of actors, interests, organizations, rules, standards, and their interaction,
- **Translation:** Actors interests translated into technical or social arrangements,
- **Inscription:** Result of the translation of one's interest into material form,
- **Subscription:** Acceptance of the inscribed interests by other actors.

In the ANT, technological artifacts can stand for human goals and praxis. Hotel keys, for example, are often not very handy, because the hotel owner has *inscribed* his intention (that the keys do not leave the hotel) into metal tags (which is why the guest *subscribe* to the owners intention: they do not want to carry this weight). A software system for workflow management is a representation of organizational standards in the company where it is used (and makes human users follow these standards).

One advantage of the ANT in the setting of intelligent systems is that it already comprises technical artifacts and humans in the same model. Humans and artifacts are exchangeable and can play the same role in the network. But in contrast to traditional artifacts, which are merely passive (black boxes in which human interests are subscribed) or which active role is restricted to translating intentions of the designer into changes of the praxis of the user, AI systems play a more active role: they have to *act-if* they had human capabilities.

In previous work in our group (see [Pieters, 2001]), we have argued that intelligent systems have to show certain capabilities usually ascribed to humans in order to interact with the user in a meaningfull way. On the other hand, since at least some of these capabilities rely on transcendental concepts, it is not possible to *design* machines which expose them.

In contrast to e.g. [Edmonds, 2000], who proposes a system which opens for the evolvement of certain properties, we use the notion of *as-if* in our approach: in roughly the same way as humans can never be sure that human counterparts have the capabilities they expect them to have, but ascribe it to them, our goal is to design intelligent systems which act in a way that makes humans ascribe human characteristics also to them. Also in [Pieters, 2001], it is argued that some properties of knowledge-intensive Case-Based Reasoning systems make them well suited for exposing this *as-if* capability. We will not focus on this.

2.1 Example

For the design of mixed-initiative systems, it is important to notice that the border between human and artifical actors is weakened in the Actor Network Theory. This makes it for example easier to include the notion of alternating the control between human and machine actors, thereby making the *control issue* explicit. By understanding how the initiative for a task is shared between different human actors, we get hints for how a technical artifact should behave in the same situation.

In our drilling problem example, we can with the help of the Actor Network Theory describe the organizational standards for dealing with critical conditions and identify situations where the diagnostic system should intervene.

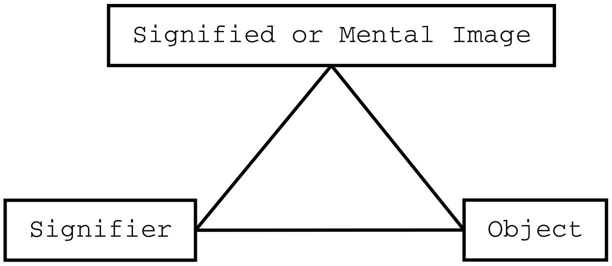

Figure 2: *The semiotic triangle.*

3 HCI Interface View: Semiotics

As seen in discussions between Ben Shneiderman, long time proponent of direct manipulation interfaces, and Pattie Maes, proponent of an agent oriented view of user interaction, at IUI-97 and CHI-97[1], the underlying metaphors for both views make a combination rather difficult.

Whereas Shneiderman strengthens the '[...] goal to create environments where users comprehend the display, where the system is predictable, and where they are willing to take responsibility for their actions'[Alty *et al.*, 1997, p. 44], Maes clarifies that giving up some control is very common in every day tasks, but that this does not mean that the overall process is not controlled at all [Alty *et al.*, 1997, p. 54].

It is very important to notice basic differences between direct manipulation and agent based interfaces as illustrated by this control example, which can be generalized for the whole interaction process of human and AI actors.

When focusing on the interaction of a particular user with the system, we use the semiotics approach (see e.g. [Nake, 1994] and [Andersen, 2001]) to understand the peculiarities of interaction with intelligent systems. The basic concept of the chosen interpretion of semiotics is the sign, a triadic relation of a signifier, a signified, and object (see figure 2). It is the process of sense-making, where a representation *(signifier)* and its mental image *(signified)* refer to an entity *(object)* (the meaning of a sign is not contained within a symbol, it needs its interpretation).

On the background of semiotics, meaningfull human communication is a sign process. It is a process of exchanging and interpreting symbols referring to objects. The user of an informatics systems sees her interaction with this system on this background. When typing a letter, she does not send mere symbols, but signs to the computer, and the feedback from the machine, the pixels on the screen, are interpreted as signs: to the user, the computer is a 'semiotic machine' (Wolfgang Coy), see figure 3.

In contrast, computer systems are only processing signals, lacking the necessary interpreting capabilities humans have. They only manipulate symbols without *making-sense* out of them. The human sign process and the machine signal process have to be coupled (see figure 4). This holds both for traditional informatics systems and AI systems.

We argue that, in order to make intelligent systems work not merely as a tool or a media, but as actants to whose (de-

[1]As documented in [Alty *et al.*, 1997]

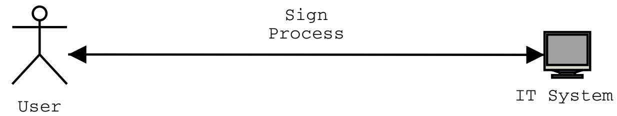

Figure 3: *Semiotics: The human user sees the system as-if it was a partner in communication; the interaction appears to be a sign process.*

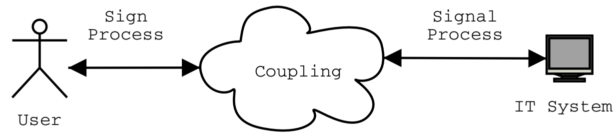

Figure 4: *Semiotics: In human computer interaction, a sign and a signal process have to be coupled. The human sign process is reduced to an algorithmic signal process, which in turn is interpreted by the human user.*

cision) abilities a human user can subscribe, the system must appear *as-if* it was capable of a meaningfull interaction.[2] We use again the *as-if* notion: an intelligent systems behaves in such a way that the user ascribes to the system the ability of participation in a sign process. The upper-level analysis of the work process helps in defining the aspects of user interaction where this ascription has to succeed in order to make the user believe in the system capabilities.

On important challenge here is the ability of the system to show off its abilities. This can be described as a communication problem: the system has to interpret the actions of the user in a meaningfull way and itself present results that make sense for the user. This process of sense-making is highly interactive: an intelligent partner in a communication process asks (meaningfull) questions if an unclear situation occurs and is able to explain its own actions. The semiotic approach is useful to analyse this sense-making process with the help of transferring knowledge about similar processes from other semiotic domains.

3.1 Example

In our drilling problem example, it is due to time constraints important that new knowledge can easily be incorporated both into the system and presented to human users. For a knowledge-intensive CBR system, this can either be done in the form of cases or by enhancing the domain knowledge of the system. Given the latter, the system can monitor its reasoning processes and identify areas where it has insufficient knowledge to find causal relations. By means of plausible inheritance (compare e.g. [Sørmo, 2000]), it can find probable candidates for new causal explanations.

The semiotic approach can be used to model how the system could represent this probably new knowledge to the

[2]Which differs from the interaction with traditional systems in which case the sense-making falls wholly on the side of the human user: You do not expect a text processor to understand your letter, but you expect a decision support system to understand the information you deliver.

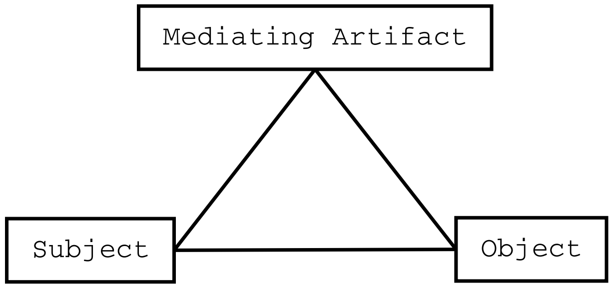

Figure 5: *Activity Theory: The basic triangle of Mediation.*

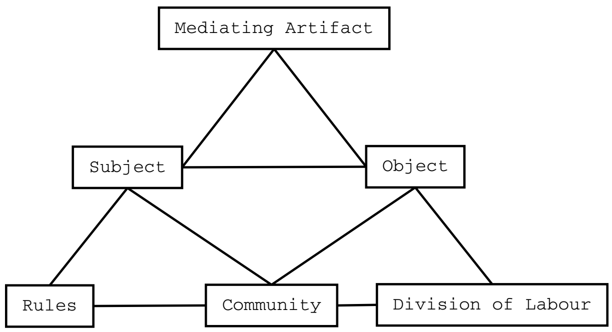

Figure 6: *Activity Theory: Expanded triangle, incorporating the community and other mediators.*

user in a way that strengthens the users believe in the sign-processing capabilities of the system. Therefore, semiotics can be helpfull to find solutions for the *communication issue*.

4 HCI System View: Activity Theory

The semiotics perspective is helpful to understand medial aspects of Human Computer Interaction, e.g. how knowledge is communicated. It is, however, not as helpful to analyze their use as instruments for achieving a predefined (by the human) goal in the work process and especially to understand the transformation of the artifact itself or the the socio-technical system during this process.

In our research, we found the Activity Theory (AT, see e.g. [Bødker, 1991], [Nardi, 2003]) suitable to cover this aspects in our framework. Its focus lies on individual and collective work practice. One of its strength is the ability to identify the role of material artifacts in the work process. An activity (see figure 5) is composed of a subject, an object, and a mediating artifact or tool. A subject is a person or a group engaged in an activity. An object is held by the subject and motivates activity, giving it a specific direction.

Later, the Activity Theory was extended to cover the fact that human work is done in a social and cultural context (compare e.g. [Mwanza, 2000]). The expanded model takes this aspect into account by adding a community component and other mediators, especially rules (an accumulation of knowledge about how to do something) and the division of labour (see figure 6).

Some basic properties of the AT are:

- **Hierarchical structure of activity:** Activities (the topmost category) are composed of goal-directed actions. These actions are performed consciously. Activities, in turn, consist of non-conscious operations.
- **Object-orientedness:** Objective and socially or culturally defined properties. Our way of doing work is grounded in a praxis which is shared by our co-workers and determined by tradition. Praxis forms the look of artifacts, and by these the artifacts are passing on a specific praxis.
- **Mediation:** Human activity is mediated by tools, language, etc. The artifacts as such are not the object of our activities, but appear already as socio-cultural entities.

Taking a closer look on the hierarchical structure of activity, we can find the following levels:

- **Activity:** This is the topmost level. An individual activity is for example to check into a hotel, or to travel to the conference city. Individual activities can be part of collective activities, e.g. when you organize a workshop with some co-workers.
- **Actions:** Activities consists of a collections of actions. An action is performed consciously, the hotel check-in, for example, consists of actions like presenting the reservation, confirmation of roomtypes, and handover of keys.
- **Operations:** Actions consist themselves of collections of non-conscious operations. To stay with our hotel example, writing your name on a sheet of paper or taking the keys are operations. That operations happen non-consciously does not mean that they are not accessable.

It is important to note that this hierarchical composition is not fixed over time. If an action fails, the operations comprising the action can get conceptualized, they become conscious operations and might become actions in the next try to reach the overall goal. This is referred to as a breakdown situation. In the same manner, actions can get automated when done many times and thus become operations. By this, we gain the ability to model a change over time.

Since an AI system is more a partner in a work process than a tool, its role in the user interaction changes. Whereas a classical informatics system is a passive translator and memory of praxis, the intelligent system is constantly re-shaping the praxis through its use. The usage of a tool might change, but the tool itself will not change. If you look at an decision support system, so is the decision making process itself transformed by the ability of the system to react differently, e.g. through accumulated experience and usage context.

But since the AT itself models artifacts as being preformed as socio-cultural entities, we can describe the artifacts in a way which takes this modification into account. Again, our upper-level model helps us to identify the mediation process and the role of both human and non-human actors in the usage process.

As described before is the ability of an intelligent system to adapt to the user very important. In the process of re-shaping the praxis, a user expects from an (*as-if*) intelligent system that it is adopting to the changed praxis.

4.1 Example

Whereas in the beginning of the use of our example Case-Based diagnostic system, it will be important to explain the user in detail why a particular case (former stuck pipe situation) was matched to a new problem, the user expects from an intelligent partner that the same match will be explained in less detail when occurring very frequently (since the artifact should be changed by the changed praxis, that is here the accumulated knowledge on both sides).

This change of interaction over time is related to the *evolvement issue*: the shift between different modi operandi. The AT is suitable for capturing this kind of change over time (transforming of actions into operations and vice versa) and can therefore be helpfull in modeling a change of behavior over time.

5 Related Work

Our group is developing the CREEK[3] framework for knowledge-intensive CBR. CREEK makes extensive use of general domain knowledge and knowledge of the reasoning process itself. This knowledge has to be acquired and engineered at least partly before the system starts learning from cases. In [Tecuci *et al.*, 1999], a mixed-initiative approach for the development of a knowledge base is proposed and evaluated. The type of the acquired knowledge differs from the semantic net structure of CREEK. The concept of having a concept of competence in the building process of a knowledge base and the use of different knowledge acquisition strategies is nevertheless intersting for the CREEK toolchain, but lies for the time being outside of the scope of our tools. This work is located at the Work Process View since it deals with the competence of the newly defined system.

Compared to our own views, a very different approach to design issues on the User Interaction System View is pursued by [Hartrum and DeLoach, 1999]. In their multi-agent approach, they unify the interaction view between different types of actants, being it humans or intelligent agents. They use Z specifications for formally defining the the agents, including structural and behavioral aspects. This approach is complementary to our use of the Activity Theory.

[Langley, 1999] deals with adaptive interfaces. The importance of personalized presentation of information is pointed out. This is not restricted to the form of the presentation, but also the contents. This is a very important point. The challenge of giving a transparent impression of the systems capabilities is directly dependant on the users own knowledge, and on the ability of the system to change its behavior towards a learning user over time. In our framework, this issue is addressed by the ability of the Activity Theory to reflect changes of the involved artifacts over time.

Also looking at personalization issues, [Blanzieri, 2002] proposes a four level analysis of situated intelligent systems. He focuses on the need of a particular user instead of the social stance taking by the Activity Theory. In this sense, his approach is complementary to our framework.

On the User Interaction Interface Level, [Eggleston, 1999] describes a cognitive engineering approach to the modeling of user interface agents. A unified view on human-human and human-agent network communications is taken and design principles from the cognitive engineering stance are stated. Whilst our focus lies on different aspects (the communication aspect of the semiotic theory), his statement on the importance of coupling human thinking and automated reasoning so that joint cognitive work is enhanced can also be found in our notion of a Case-Based Reasoner as enhancing the human capabilities.

In [McSherry, 2002], a taxonomy for mixed initiative dialogue is given. The focus lies on the Interface Level and deals mainly with tool aspects and differs in that sense from our communication oriented approach. Features like the need for the explanation of reasoning and the control issue are nevertheless challenges we have to deal with as well.

An example of a theoretical and empirical validation of the usefullness of an mixed initiative approach to Conversational CBR can be found in [Gupta *et al.*, 2002]. This differs from the CREEK framework we use as we do not focus on text conversation. On the other hand, it might be very interesting to apply the semiotic framework to this approach, since the semitics of written language is a well researched subject.

6 Conclusion

We have proposed a theoretical framework for a consistent model of intelligent systems in work process. Our model includes an upper-level analysis of the work process as a whole as well as means to understand the interaction between user and system.

We have further on outlined that the proposed framework supplies theoretical tools for the analysis of mixed initiative system with different perspectives. We have shown that the different theories in our framework can deal with important issues of mixed initiative intelligent systems.

Equally important, but not topic of this paper, is a translation of this a posteriori analysis into an a priori design methodologies.

[3] Case-Based Reasoning through Extensive Explicit Knowledge.

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