Latent Organisational Reliability

L. Rognin[a], P. Salembier[b], M. Zouinar[b]

[a]Interaction Design Centre, University of Limerick, Limerick, Ireland
[b]ARAMIIHS - CENA, 1, rue de Champagne, 91 200 Athis-Mons, France

ABSTRACT

During the last decade, the emergence of CSCW domain brought a considerable number of studies focusing on coordination mechanisms, internal to teams and aiming to support cooperation among agents. These studies described mainly how cooperation works, including environmental features as external support used for making human cooperation easier.

The analysis of cooperative working situations highlights the role of cooperative work in global dependability. Our approach aims at understanding how teams use specific mechanisms in order to improve the efficiency of their activities, indirectly ensuring the socio-technical systems reliability. Our study questions the impact of cooperation, trying to understand in which terms cooperation is a support for reliability, why cooperation allows the improvement of the working and the dependability of the human-machine system. We propose a holistic view of the system, considered as a set of mutually dependant human and technical components. Technical entities are then not only considered as influencing human actions, but also as influenced by human contribution; this view leading us to consider equally these components and their role in the global reliability.

1. Introduction

Cooperative activities appear to be nowadays a main feature when considering the design of complex reliable work settings. From a reliability perspective, Human factors approaches evolved from quantitative and technical to qualitative and human perspectives. The new trends rest now on the integration of whole set of interacting agents and environmental resources when designing new work settings.

In the past recent years, in the domain of CSCW-related studies, numerous empirical researches aimed at understanding "how" agents cooperate, focusing mostly on coordination aspects of cooperation. The objectives were to describe types and modes of cooperation. The technical components of the system were considered from the human agent point of view, mainly as a support for human activity.

We do consider cooperation from a different point of view, wondering now "why" agents interact and analysing the role of cooperation in terms of system reliability. The system is viewed as a whole and interrelated network of sub-systems, both human and technical, in which each element mutually interact, not only harming, but also ensuring the global reliability. Indeed each component (human and technical) is seen both potentially as a weak element and as an efficient reliable support for error tolerance.

This paper is composed of four sections. In the first section, we retrace the historical evolution of human reliability assessment, underlining the passage from quantitative to qualitative analysis.

Assuming that regulation loops implemented within teams contribute directly to system reliability (allowing error detection, recovery and prevention), we highlight, in the second section, associated underlying mechanisms. Using examples issued from field studies in various domains (nuclear process control, air traffic control) we illustrate how the existence of shared context ensure and improve human cooperation, allowing cognitive processes such as intention recognition, interpersonal awareness or collective control to be performed.

Analysing cooperative activities allow the authors to propose, in the third section, a model of socio-technical reliability based on the notions of cooperation and regulation loops, supporting not only the description of how agents participate collectively to the reliability of the system, but also the design of new cooperative environments, in accordance with system requirements and reliability. In the last section, we illustrate, as a conclusion, the impact of introducing new artefacts on the reliability of socio-technical systems via the involvement of these artefacts in the construction process of shared context.

2. Human reliability

In complex situations, ensuring reliability often appeared to be one of the major concern. Socio-technical reliability went through various evolutions during the last decades, first focusing on the technical components, then evolving from quantitative to qualitative approaches, ending on considering the human central position. In this section, we propose a historical review of human reliability, of approaches aiming either to quantify human unreliability, or to describe mechanisms leading to error occurrence.

2.1 *From quantitative to qualitative approaches of reliability*

Various models aim at analysing human reliability. Differences are noticed when considering their objectives (identify, quantify or reduce errors), their features and the consequences of their applications (Gerdes, 1993) .

Between 1950 and 1970, human reliability is first approached by analogy with technical reliability. The human agent is then considered as a component, whose probability of failure has to be measured. Human reliability, defined as the probability that an agent accomplish successfully his mission under fixed time and fixed conditions (Rook, 1962) is then assessed using probabilistic and ordinal methods, such as THERP (Swain, 1964).

Since 1980, cognitive ergonomics studies are oriented towards the analysis of problem solving, mental representations and cognitive processes. People no longer consider human error but are rather interested in whole systems composed of technico-organisational components in interaction with human agents (Kasbi, 1995) . Human reliability is now defined as the opportunity for agents to reach explicit and implicit goals within acceptable limits (De Terssac & Chabaud, 1990). The interesting point here is the evolution from the idea of probability of failure to the notion of opportunity to succeed, the environmental conditions being integrated as a major factor of reliability. The analysis focus on understanding the errors, trying to localise them at different levels of cognitive processes.

This second qualitative approach is composed of two currents, one proposing a categorisation of errors, the other a support for their prevention.

The first current does not aim at reducing errors, but at providing tools supporting error collection and analysis. Various models, classifications and methods are proposed (Leplat, 1985; Norman, 1981; Rasmussen, et al., 1987; Reason, 1987; Reason, 1990; Rouse & Rouse, 1983). Methods emerge in order to describe problem solving situations, identify phases in information processing (acquisition, diagnosis, planning, action and validation) and explain mechanisms under the error production (Rasmussen, et al., 1987) .

The second current is based on mental models of agents, used to describe errors, predict their occurrence, but also identify their consequences.

Other researches, oriented towards understanding the emergence of errors and associated underpinning mechanisms (Norman, 1983 ; Rasmussen, 1986) brought static models, not very operational, but essential to understand human information processing.

Most of these approaches are retrospective, analyse a posteriori the course of events, underlining the factors contributing to the emergence of errors. We assume that a generic model focusing on the emergence of accidents is still missing, while we observe a great need for understanding and modelling the processes of degradation.

2.2 *Collective dimension of reliability*

Most of these approaches focused on the reliability of single agents, while it now appears that the collective dimension of work has to be taken into account.

The evolution from technical systems to human components, and from quantitative to qualitative aspects of reliability should now be followed by the integration of the collective and social dimension of work.

In many complex systems (nuclear power plant, control room, ...) the global reliability (Socio-Technical system) strongly depends on the efficiency of collective decision making. Cooperative work, either reduced to punctual interactions supporting problem solving, or extended to long-term projects, is essential for any working organisation. Cooperation among various human agent is necessary in order to solve complex problems, not only when various sources of information have to be confronted, but also when tasks have to be distributed explicitly and formally.

Critical systems require a good understanding of cooperative features in order to identify how teams could contribute to their dependability. Designers are facing a dilemma regarding the human role, and more specifically the collective role in the global reliability. A trade-off has now to be found between efficient human mechanisms and their weakness in specific situations.

The observation of cooperative activities in real work settings allows us to identify various mechanisms, such as information injection, error recovery and workload regulation, which seem to contribute directly to the socio-technical reliability (Rognin, 1996).

3. **Regulation loops in cooperative activities**

3.1 *Cooperative activities*

Ethnographic studies provided rich and useful description of cooperative activities, pointing out the contribution both of human agent and technical environment on the efficiency of cooperation. Yet, this approach is often focusing on exhaustive description, without proposing solutions to design cooperative tools. We assume that complementary concepts are required in order to explicit and understand how cooperative agents take part in the dependability of socio-technical systems.

The examples presented below highlight the contribution of cooperation to reliability, through the implementation of various and numerous cooperative mechanisms (such as information injection, regulation, ...). These mechanisms also contribute to the building and updating of a shared context, itself allowing the appearance of regulative loops.

In order to describe these phenomenon, in the present part, we first introduce the concepts of shared context and regulative loops, then underline the conditions of cooperation inefficiency and last of all propose a model for analysing cooperative situation, useful to point out requirements in terms of designing new cooperative reliable environments, respecting the reality and complexity of human cooperation.

We assume that the main notion explaining the reliability of human activities is the implementation and use of regulative loops, allowing anticipative and corrective actions to be performed within the team. These regulative loops rest on the existence of a context elaborated by and shared among the partners. This shared context is regularly updated by various means such as peripheral awareness, mutual control, as described in the next part. The implementation of these means will differ according to external conditions (type of

copresence, type of communication, ...) or pre-requisite (themselves related to perceptive capabilities). These latter are allowed by the environment and its features.

3.2 *Efficient loops*

3.2.1 *Shared context and Intention recognition*

3.2.2 *Broadcasting information*

In many working situations, agents exchange information in order to co-operatively achieve a common objective. In order to operate efficiently, they need on the one hand, to distribute relevant and understandable data, and on the other hand to acquire appropriate updated information from others.

As described in various studies (Hutchins, 1995; Hughes et al., 1992), when located in the same work space, the agents are able to access "shared information", either embedded in shared resources (control panels, interfaces or blackboard), expressed verbally by agents speaking loudly or supported by people 's behaviour (e.g. meaningful position in the work space). The physical workspace functions as a common information space (Schmidt & Bannon, 1992) in which agents distribute and access information related to the common working situation.

Focusing on verbal communications, various modes are observed, such as address and broadcast messages.

(i) *Mono-addressed* message refers to a communication intentionally and explicitly addressed to an identified listener and coming from an identified speaker. From the speaker point of view, the intention is to have a one-to-one exchange, while the presence of other agents in a shared space turns mono-addressed communication in multi-addressed one.

(ii) One of our studies in a space mission control centre (Pavard et al., 1993) stressed the use and efficiency of *multi-addressed* messages supported by audio communications network. This mode refers to explicit distribution to a set of listeners, previously identified as members of the net. From the listener's point of view, multi-addressing reduces individual workload allowing only relevant messages to be exchanged. Yet, at the same time agents miss peripheral information, considered punctually useless, but eventually related to foreseen activity.

(iii) *Broadcast message* are transmitted by a speaker who does not explicitly identify the addressees; in these situations, it becomes listeners' tasks to identify if the messages are relevant to their own activities. The study of co-operation within a control room emphasises the importance of broadcast information between collocated agents and its contribution to socio-technical reliability (Rognin & Pavard, 1996). The co-presence of agents in the same control room allows *implicit mutual monitoring* to be performed, through peripheral modes of perception (Heath et al., 1995). Yet, broadcast information also introduces a certain amount of uncertainty as it strongly rests on the one hand, on assumptions related to the listeners abilities, or even availability and on the other hand, to close collaboration and mutual understanding among team members .

The public nature of broadcast information allow each member of the team to control the working situation (others' needs), and mutual adjustments to be performed in order to ensure the efficiency and the reliability of the collective activity.

3.3 *Context for Inefficient regulations*

- confidentiality, privacy
- erroneous attribution of competencies (under/over-estimation)
- erroneous attribution of needs or expectations

power related to information

4. Which cooperative settings have to be specified ?

4.1 *Limits of existing settings*

Current work settings generally allow information to be broadcast verbally among members of teams as long as they are co-located in the same environment (even virtually). Yet, in many situations, complementary supports seem necessary, in order to increase the quality of information distribution and acquisition. For example, hearing the communication exchanges is not sufficient to get a global understanding of the situation, and may be improved by being informed about other people's actions and objectives. This is currently enabled, for example, through observing their position in the working environment, or watching the consequences of their actions on a control panel.

Artefacts, as shared resources, contribute to the possibility of mutual monitoring within a team. These peripheral modes of becoming informed reduce the cost in terms of explicit communication. As long as agents are able to provide knowledge about their activities, without interrupting them, their efficiency and reliability should be ensured. Allowing actions to be visible or objectives to be inferred also has consequences in terms of control, in the sense that it enables implicit monitoring to be performed, and in some situations implicit orders to be given.

From what they observe or hear within the shared workspace, agents infer their co-workers' performance; this allows for the emergence of mutual knowledge[1] within the team. Yet, in many current settings, the content as well as the flow of information are difficult to track, as verbal communications are ephemeral and disappear as soon as they have been uttered. Thus, the result is that every agent has an incomplete representation of others' knowledge, based mainly on their assumptions of what the others might have heard.

- contre-courant / conception et design of CSCW : traces dans l'Et (affordances,
- ex approprié à une situation : délégation au pilote, faciliter reconnaissance d'intentions, expliciter certaines stratégies

5. Conclusion

6. References

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[1] Mutual knowledge is a concept referring to the knowledge agent develop about the others' knowledge.

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