MODELING TRADE-OFFS CONSEQUENCES PROPAGATION AND THEIR IMPACTS

E. RIGAUD[3], E. HOLLNAGEL[3], C. MARTINIE[1], P. PASQUINI[2], M. RAGOSTA[1-2], S. SILVAGNI[2], M. SUJAN[4]

[1]University Paul Sabatier

ICS-IRIT

118, route de Narbonne

31062 Toulouse Cedex 9

{martinie, palanque, ragosta}@irit.fr

[2] DeeBlue Srl

Piazza Buenos Aires 20,

00198 Roma – Italy

{alberto.pasquini, martina.ragosta, sara.silvagni}@dblue.it

[3] Mines-ParisTech – CRC

1 rue Claude Daunesse, BP107

06904 Sophia-Antipolis

{eric.rigaud,erik.hollnagel}@mines-paristech.fr

[4] Warwick Medical School

University of Warwick

Coventry CV4 7AL UK

m-a.sujan@warwick.ac.uk

Abstract. This article describes a model of automation variability propagation in a complex networks. A modelling context constituted of network-based model and socio – technical system fundamental trade-offs is used to structured a four level propagation model.

1 INTRODUCTION

Complex systems such as Transportation Traffic Management Systems can be described with a network based approach (Mitchell 2009). Network in this context, is constituted with container nodes which contain entities that constitute the flow of the network (airplanes, trains, etc.) and supervisory nodes that control flow and are supposed to react to unwanted situations before they affect the performance of the system.

Managing network resilience required among other preoccupation to anticipate potential consequences of a change in the system or its environment and specifically on the capacity to respond to unwanted situations (Hollnagel & al. 2011). Before changing the system with a new technology, a new rule or a new organisation, studies has to be conduct in order to anticipate consequences of the change. Realisation of such studies

can be achieved with different methods and tools such as Focus Group, Delphi or traditional risk assessment methods. Nevertheless those approaches may not capture the complexity of human and organisational behaviours interacting within a complex network and then failed identifying situations where an event such as automation degradation somewhere in a node of the network may impact the functioning of one or several nodes of the network.

In the perspective of allowing the identification of impacts of the propagation of a change in a socio-technical network in considering several dimensions related to human and organisational behaviour complexity, a framework is currently developed. Its purpose is to represent the consequences of the variability of a new system, how they propagate in the network, and the different types of consequences on the nodes and the flows in the wider system.

Finality of this article is to discuss the propagation model in the perspectives of fundamental trade-offs (Hoffman and Woods, 2011, Hollnagel 2010) as both source and target of a propagation model. Paper is structured in two parts. The first part discusses modelling context. The second part presents a first version of model of automation variability propagation in complex network.

2. MODELING CONTEXT

Model of automation variability propagation in complex network is based on a network perspective (Mitchell 2009) and on five levels (cf. Figure 1.).

Network is defined as a set of nodes interconnected by flows. Different types of flows are considered. Flow can be physical, informational, logical, etc. Two types of nodes are considered. First type is a container node that contains the entities that constitute the flows of the network. Second type of nodes is defined as supervision nodes. They are associated to one or several container nodes, and control flows and reacts to unwanted situations before they affect the performance of the system. Container nodes are characterized by a capacity of flow entities they can contain and some actions that can be performed: entering, exiting, moving, etc. Supervision nodes are characterized by a set of responsibilities and a set of resources to perform them. Responsibilities are related to a set of obligations to respond to a set of situations arising with different frequency and to potential sources of perturbations.

First modelling level is related to automation variability impacts on operator's performances. Second level is related to operator's capacity of respond to unwanted situations under their responsibilities. Third level is related to node resilience capacity, that is to say the capacity of respond to regular, irregular and without precedent unwanted situations under their responsibilities. Fourth level is related to the resilience capacity of nodes that constitute network.

Figure 1. Event propagation model.
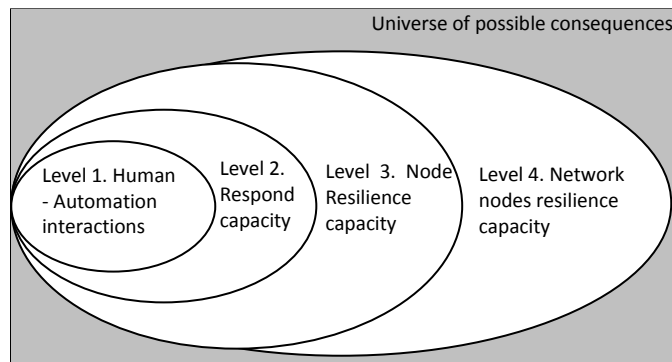
Propagation model is based on a generic propagation pattern:

- Initial event is the initiator of the propagation model. It can be automation variability, human factors variability, clearance reception, etc.
- Targets are elements that are affected by the variability of initial event. It can be human performance, unit performance, flight performance, etc.
- Consequences are impacts of initial event on targets. It's generally related to the increase or decrease of target properties (stress, fatigue, precision, delay etc.).
- Environment is related to a set of dimensions others than initial event and targets that can affect the nature and the intensity of consequences.

2.1. Considering trade-offs

Hoffman, Woods and Hollnagel have described how trade-offs are fundamental to human adaptive systems (Hoffman and Woods, 2011; Hollnagel, 2009). Their work aims to provide new concepts for modelling individual, collective and organisational behaviours and their impacts on system resilience. They identify five trade-offs: 1) optimality–fragility, 2) efficiency–thoroughness, 3) acute–chronic, 4) specialist–generalist, and 5) distributed–concentrated. These relate to different dimensions of a socio-technical system and can affect different aspects of resilience performance.

Taking trade-offs into account implies that:

- Agents perceive their environment relative to their own experience. An agent's perspective depends on factors such as culture, experience, aims or their unit's perspective.
- Strategy and plans designed to support an agent's performance may fail because of resource limitations (time, knowledge, information, human, technological, etc.).
- The system is divided into units. Each unit has its own goals, performance indicators and risks and responsibilities, which constitute the unit's perspective.
- Activities can depend on the joint performance of several units that can belong to independent systems.
- All the events that can occur in the system environment cannot be identified. Therefore resilience implies the implementation of relevant strategies for responding to known events and sufficient capacity and margin to respond to unanticipated events.

The following table describes the potential impact of trade-off variability on each of the four modelling level (human-machine interaction, agent respond capacity, node resilience capacity, network resilience capacity).

Table 1. Influence of trade-offs on the automation variability propagation model

Trade-off	Impacts on propagation model
Acute–chronic	Agent's perceptions of: - Normal and abnormal functioning of the system; - Criticality of situations; - Response plan; - Adaptation to unanticipated situations. - Interactions with automations - Interactions with other nodes
Efficiency–thoroughness	Availability of time, knowledge, information and resources to: - Detect changes on automation interface - Detect an abnormal situation; - Recognise the situation; - Consider the criticality of the situation and decide to respond; - Respond.
Specialist–generalist	Communication capacity between units. Variability in unit's perspective of the criticality of situations.
Distributed–concentrated	Communication capacity between units. Availability of time, knowledge, information and resources of units of the network Transfer of responsibility
Optimality–fragility	Agent's perceptions of normal and abnormal functioning of the system; Agents ability to recognize situations

This modelling context is used to propose a first a model of automation variability propagation in complex network.

3. MODEL OF AUTOMATION VARIABILITY PROPAGATION IN COMPLEX NETWORK

Five levels that constitute the propagation model are presented in the following sections.

3.1 Automation variability impact on individual performance

First modelling level is related to automation performance modes and their consequences on operator's behaviour.

Initial events are automation performance modes. It can be partial or total realisation of function usually performed by automation (Parasuraman et all. 2000) (information acquisition, information analysis, decision and action selection, action implementation, etc.). Targets are operator's behaviours, which directly interact with automation in order achieving tasks. Behaviours can be defines with a set of adaptive modes related to operator's reaction to the variability of his context of action. Environment dimensions are factors that can affect operator's performances. It can be human related factors (stress, focus of attention, umber of task to be performed, etc.) or be related to context of action (work conditions, presence of available time, crew collaboration quality, etc.). Consequences are variability of the performance of the functions to be realised by operators with the support of automation such as precision of the results, delay to obtain the results and to operator's human factors (stress, workload, etc.).

3.2 Level 1 model variability impact on node capacity to respond

Second level aims modelling automation degradation level 1 consequences impact on node respond capacity performance concerned.

Node capacity to respond is decomposed into five processes (Hollnagel E. et all 2011)

- Detect that something has happened,
- Identify the event,
- Recognize that the situation requires a response,
- Define the response,
- Mobilize resources in order to respond.

Ability to respond can be influenced by several factors. Four factors are considered related to the balance between elements required by event to be controlled and elements available:

- Time available versus time required.
- Resources available versus resources required.
- Competences available versus competences required.
- Information available versus information required.

Balance between elements required and elements available has an influence on different dimensions such as duration or precision of the response or the operator's capacities. Consequences of variability of those dimensions influence the life cycle of events to be controlled and associated consequences. If the correct response is not performed events may trigger unwanted consequences, and require other elements to be controlled. Based on this context, initial events are related to Level 1 consequences. Targets are responding capacity performance variability factors. It can be time, resources, competences or information. Environment dimensions factors that can affect operator's performances and situations to be responded consequences. Consequences are variability of the performance of respond functions, to the variability of consequences of the situation to be controlled and the variability of operator's human factors.

3.3 Level 2 model variability impact on node resilience capacity

Third level aims modelling automation degradation level 2 consequences impact on node resilience ability.

Node resilience performance is defines as the intrinsic ability "to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions" (Hollnagel et all 2011).

Four major capabilities determine node resilience performance: ability to respond to both expected and unexpected events; ability to learn for unexpected situations to understand what can go wrong and for expected situation to understand what makes the system go right; ability to monitor the performance of the system in considering both lagging and leading indicators; ability to anticipate threats and opportunities that can be consequence of changes occurring in the system and it's environment (Hollnagel et all 2011).

In order to characterize node resilience, the focus is on the capacity to respond. Node resilience model is structured of three complementary respond capacities related to the different types of situation that can occur (Westrum 2006):

- Capacity to respond to normal events. Normal events are situations related to normal functioning of the system. Respond functions are the application of procedures, behaviours learned during training sessions and use resources regularly checked.
- Capacity to respond to regular unexpected events. Regular unexpected events are unwanted situations that have been anticipated by risk management systems, and for which prevention and protection barriers have been deployed. Respond functions are based on the application of procedures, on behaviours learned during training sessions and on resources that are regularly checked.

- Capacity to respond to irregular unexpected events. Irregular unexpected events are unwanted situations that are known by the system, but where no adequate barriers exist to prevent and protect the system against them. Respond functions are based on the ability of operators to adjust their behaviour according to the requirements of the situation, their knowledge and available resources.

Initial events are Level 2 consequences. Targets are other nodes respond capacities performance variability factors. Environment dimensions are factors that can affect operator's performances and situations to be responded consequences. Consequences are the variability of the performance of all the respond functions, the variability of consequences of all situations to be controlled and the variability of operator's human factors.

3.4 Level 3 model variability impact on network resilience capacity

Fourth level aims modelling automation degradation level 3 consequences impact on network resilience capacity.

Propagation of consequences depends on the nature of the interactions between the different nodes. Related to the modelling context, three types of relations are considered:

- Supervision node – Container node interdependencies. This relation is impacts of supervision node variability on the associated container node.
- Supervision node – Supervision node interdependencies. This relation is impacts of supervision node variability on the supervision node directly or indirectly connected to it.
- Container node – Container node interdependencies. This relation is impacts of container node variability on the container nodes directly or indirectly connected to it.

Node interdependencies can be defined, among others, along several dimensions (Rinaldi et all 2001):

- Infrastructure characteristics: spatial, temporal, operational and/or organizational.
- Type of interdependencies: physical, cyber, logical, geographic.
- Coupling and response behaviour: loose/tight, linear/complex, adaptive, and inflexible.

Initial events are Level 3 consequences. Targets are resilience performance of all the nodes interconnected with the studied node. Environment dimensions are factors that can affect nodes resilience performance. Consequences are the variability of the resilience performance of concerned node, to the variability of consequences of all situations to be controlled and the variability of container nodes

4 CONCLUSION

The overall objective of the ongoing work presented in this paper is to define an overall design framework of automation variability propagation in complex networks, integrating socio – technical system Fundamentals trade-offs. A four level model has been presented in the current paper focusing on the modelling of consequences flowing from automation variability.

Acknowledgment

References

Mitchell M., Complexity a guided tour, Oxforf university press, 2009.

Hollnagel E., Pariès J., Woods D. D., Wreathall J., Resilience Engineering in Practice; Ashgate Studies in Resilience Engineering, 2011

Hoffman, R. R. and Woods, D. D. (2011). Simon's Slice: Five Fundamental Tradeoffs that Bound the Performance of Human Work Systems. 10th International Conference on Naturalistic Decision Making, Orlando FL, 5-31 to 6-3-2011.

Hollnagel, E. (2009). The ETTO Principle: Efficiency-Thoroughness Trade-Off: Why Things That Go Right Sometimes Go Wrong. Ashgate

Parasuraman R., Sheridan T. B., Wickens C.D., A model for Types and Levels of Human Interaction with Automation, IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans, Vol 30, N03, May 2000

Rinaldi S. M., Peerenboom J. P., Kelly T. K., "Identifying, Understanding and Analyzing Critical Infrastructure Interdepencies", IEEE Control Systems Magazine, 2001

Westrum R., A typology of resilience situations, in Hollnagel E., Woods D.D., Leveson N., Resilience Engineering Concepts and Precepts, Ashgate 2006