Conceptual and Computational Modelling of Coordination Mechanisms in Air Traffic Management

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The commercial air transportation system comprises many different interacting with each other human actors, such as pilots, actors in Air Traffic Control (ATC) centers, at airlines and at airports. The effectiveness and efficiency of coordination and communication between these actors is essential for achievement of the very high safety records of modern commercial air transportation.

Commercial air transportation is a highly regulated system where the coordination procedures for human actors are well defined up to a certain procedural level. However, in practice non-nominal situations occur for which the set of existing procedures fall short, as a result of which human actors coordinate informally in a partially improvised way. Evidences exist that such an improvised coordination is often successful in practice.

Understanding of generic coordination mechanisms and their breakdowns in sociotechnical teams has been a long-standing challenge, in particular in the areas of human factors and social sciences. A few theories and conceptual frameworks were proposed to describe and explain coordination in teams. However, formal, systematic modelling of coordination in sociotechnical teams is still very limited; strengths and weaknesses of such approaches are not well explored.

In this paper we elaborate coordination processes in ATM using three existing modelling tools: a conceptual model of joint activity (Klein et al., 2004)\(^1\), a conceptual co-ladder model of coordination (Chou et al., 2000)\(^2\), and a formal framework for multiagent situation awareness relations (Blom and Sharpanskykh, 2015)\(^3\). These modelling tools address coordination at different levels of abstraction ranging from abstract conceptual to detailed formal. In the paper we demonstrate how these modelling tools can complement each other, and how by integrating them in a unifying framework a more profound understanding of coordination mechanisms can be achieved. We illustrate this framework by elaborating an ATM scenario, in which multiple non-nominal hazardous situations occurred, and the actors needed to coordinate with each other to handle these situations. A special focus of this study has been on coordination mechanisms related to maintaining common ground, identification of loss of common ground and its repair. Common ground refers to pertinent knowledge, beliefs and assumptions that are shared among the ATM actors.

Based on the elaborated coordination model we developed an agent-based simulation model, which was used to study the dynamics of coordination mechanisms in different variants of the ATM scenario using ‘what if’ simulation.

Among the identified mechanisms that help maintaining common ground among actors in ATM are: acknowledgement/readback of a plan or activity, comparison of expected states attributed to other agents with the observed behaviour of these agents, requesting/providing information when state certainty is low or outdated, reasoning based on communication among other agents involved in the joint activity, group discussion and exchange of stances of agents about disputable issues.

The proposed approach and the identified coordination mechanisms related to common ground could be used to improve training of actors in ATM. Another possible application is in automated support facilitating coordination in ATM. Such automated systems could alert actors when a possible loss of common ground is detected.

