



Agent-Based Modelling and Simulation (ABMS) Applied to Air Transportation

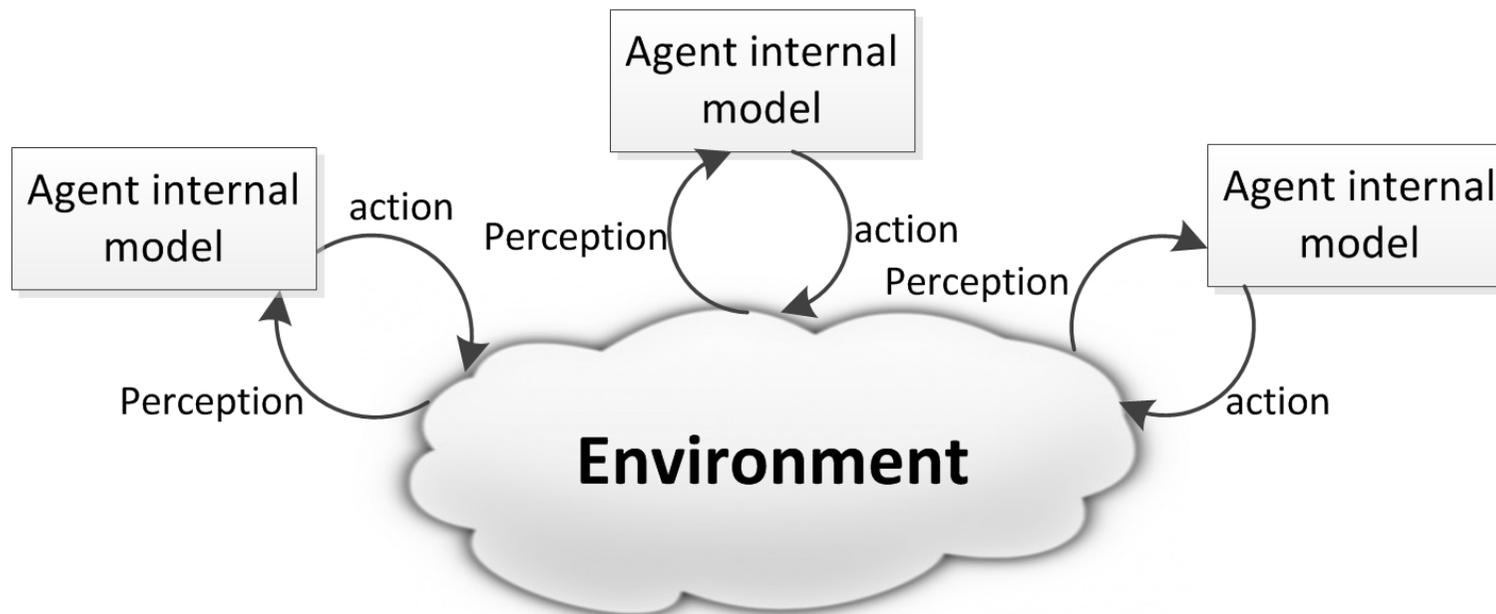
ComplexWorld 2015 Event
7th-8th April 2015, Brussels

Soufiane Bouarfa
Air Transport Operations Section
Faculty of Aerospace Engineering
Delft University of Technology

This work is supported in part by SESAR Long-term and Innovative Research WP-E, through the research network ComplexWorld

What is ABMS?

- Strong roots in the field of Multi-Agent Systems
- Aims at capturing emergent phenomena
- Not only tied to artificial agents, but also modelling human & team agents
- The latter requires knowledge of human & team cognition and performance



- *No common memory*
- *No overall director*

Research Goal & Applications

Research Goal: *To study the complex socio-technical air transportation system through ABMS*

Research Question

Does ABMS allow identifying emergent behaviour in air transportation that was unknown before?

How to investigate the role of coordination in air transportation resilience using ABMS?

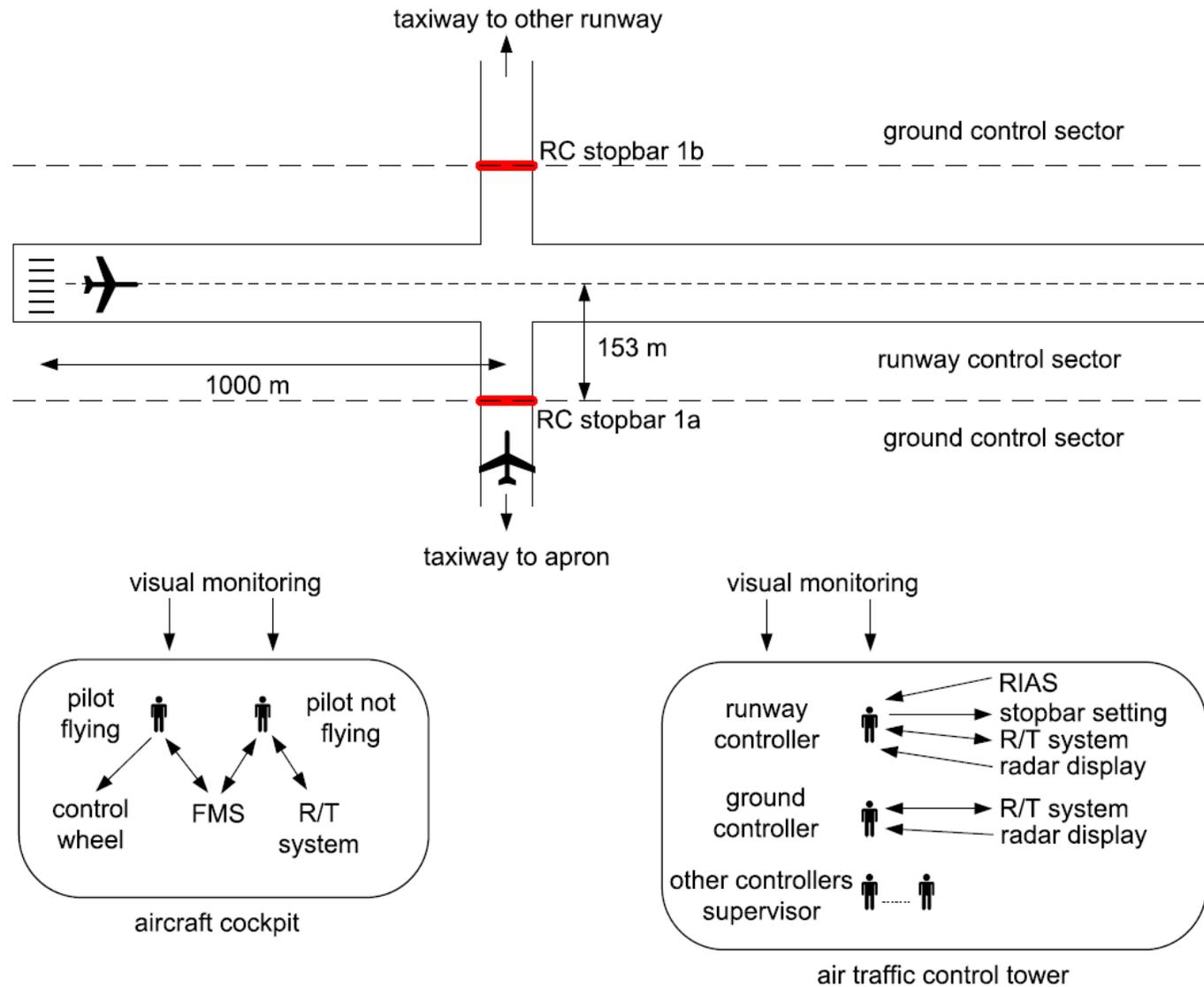
Application

Active Runway Crossing

Airline Disruption Management

Active Runway Crossing

Existing agent-based model (TOPAZ-TAXIR)



ABMS vs. Event Sequence Based

Event-Sequence Based Assessment

ABMS Safety Risk Assessment

Dynamics

Limited number of possible event sequences

Petri-nets dynamics and stochastic differential equations

Varying conditions

Requires the development of a novel event-sequence model

Adapting model parameters and plug & play

Outcome

- Pilots are assumed to brake upon ATCo instruction only.
- Model outcome is what has been modelled.

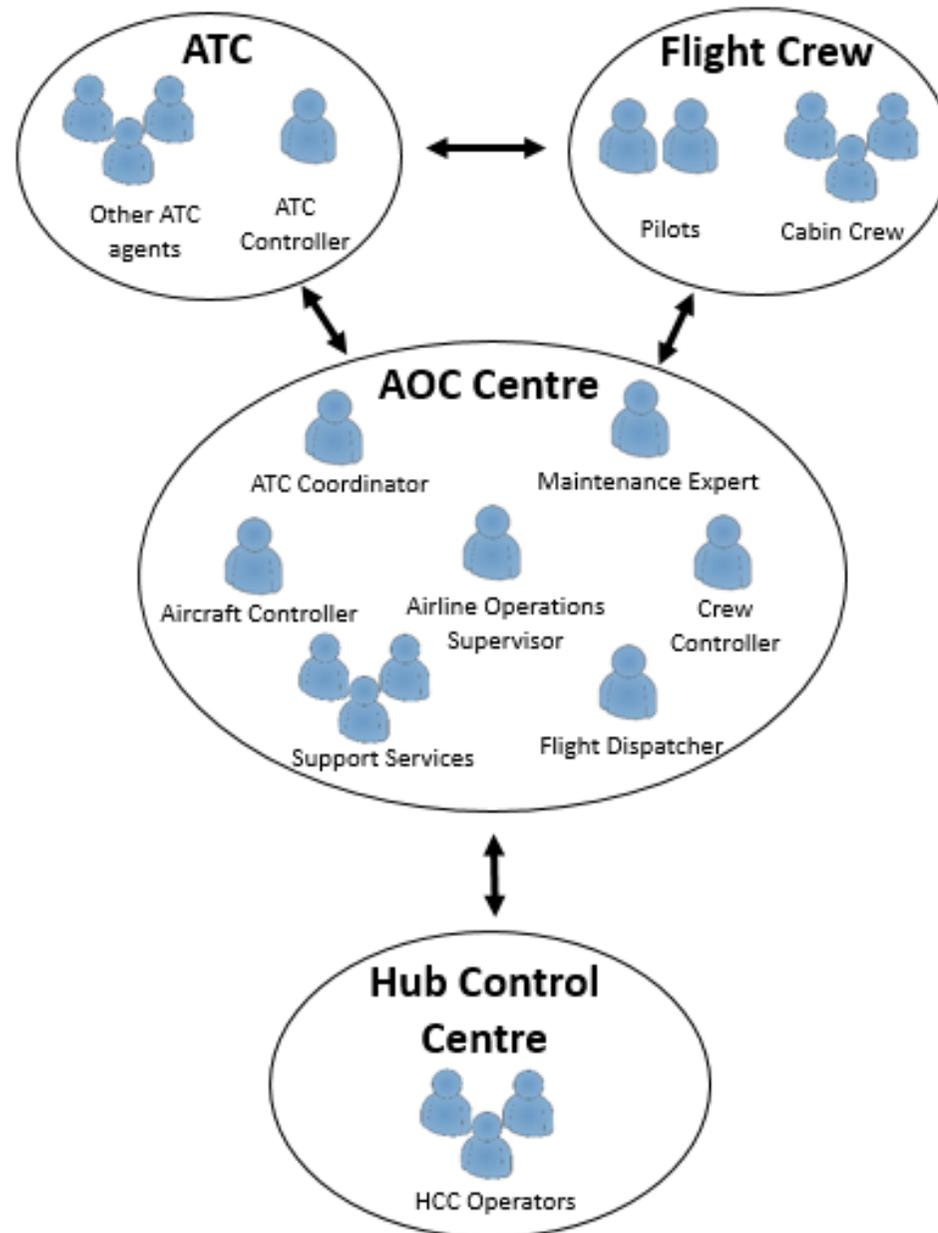
- Pilots also brake upon own observations.
- ATCo's experience this as a rapid response to their call.

Practical meaning

Largely underestimated safety risk (1-2 orders magnitude)

Novel insight in the roles of ATCo's and pilots in runway crossing safety and capacity

Airline Disruption Management Application



ABMS vs. Established approach

Expert Panel Approach

ABMS

Dynamics

Mental simulation of several alternative scenarios

Prolog time-based rules per agent

Varying conditions

Requires re-assessment of the disruption by the expert panel

Adapting model parameters and plug & play

Outcome

Rerouting via BOM is best:

- Replacing crew at BOM
- 8 hrs delay
- 126 kEUR pax. compensation

No need for rerouting:

- Use crew flight 706
- 3 hrs delay
- No pax. Compensation needed

Practical meaning

Airline disruption may be too complex for a panel of experts

ABMS addresses the complexity of airline disruption management

ABMS Platforms

- Numerous ABMS platforms available [1-3]
- Two platforms used from the wide spectrum

Aspects	Active Runway Crossing Application	Airline Disruption Management Application
Modelling Formalism	Stochastically and Dynamically Coloured Petri Nets (SDCPN)	Temporal Trace Language (TTL)
Development Environment	Delphi/ TOPAZ	LEADSTO (Prolog like)
Development Efforts	2 years	2 Months
Ontology	Defined by the places and colours used in the petri nets	Defined using sorts, elements of sorts, and logical predicates
Dynamics representation	Stochastic differential equations and petri nets transitions	Time-based rules (predicates)
Rare event Monte Carlo Simulation	Yes	No
Computational load	Relatively low	Relatively high

1. C Nikolai, G Madey, 2009. **Tool of the trade: A survey of various agent-based modelling platforms**. Journal of artificial societies and social simulation, vol. 12, n 22.
2. Allan, 2010. **Survey of agent-based modelling and simulation tools**. Technical report DL-TR-2010-008. Science and technology facilities council.
3. http://en.wikipedia.org/wiki/Comparison_of_agent-based_modeling_software

Summary of ABMS Results

- Significant novel results from ABMS vs. established approaches.
 - **Active Runway Crossing Application:** Key emergent behaviour revealed through ABMS, which was unknown before
 - **Airline Disruption Management Application:** AOC performance can be improved using ABMS
- Wide spectrum of ABMS platforms available
 - Experience gained from using two entirely different simulation platforms from the spectrum.
- ABMS is very valuable in optimizing the complex socio-technical air transportation system.