Innovative approaches to handling uncertainty in air traffic management

The 21st century finds Europe facing a number of remarkable changes, many of which involve safety critical complex operations that have to deal with uncertainty, and air traffic is one of them. The management and control of these operations are undergoing a natural trend of becoming more and more distributed, while at the same time their safety criticality for human society tends to increase. Nonetheless, it is human beings who continue to bear the responsibility for safety, and hence they need ways to manage the uncertainties in a predictably safe way.

Within the European Commission project HYBRIDGE, some 50 system theorists and mathematicians from 6 universities (Cambridge, Twente, L'Aquila, NTUA, Brescia and Patras) and from 3 research institutes (NLR, INRIA and CENA) have studied the development of innovative approaches to handling uncertainty in complex safety critical operations. These theorists have brought together state of the art mathematical and computer science approaches to handling uncertainty in automation, finance, robotics and transport. In collaboration with experts from AEAT, BAES, EEC and NLR these approaches have been elaborated for air traffic. The very reason for selecting air traffic is the interactions between the many main agents (humans and systems) are so highly distributed in comparison with other safety critical operations.
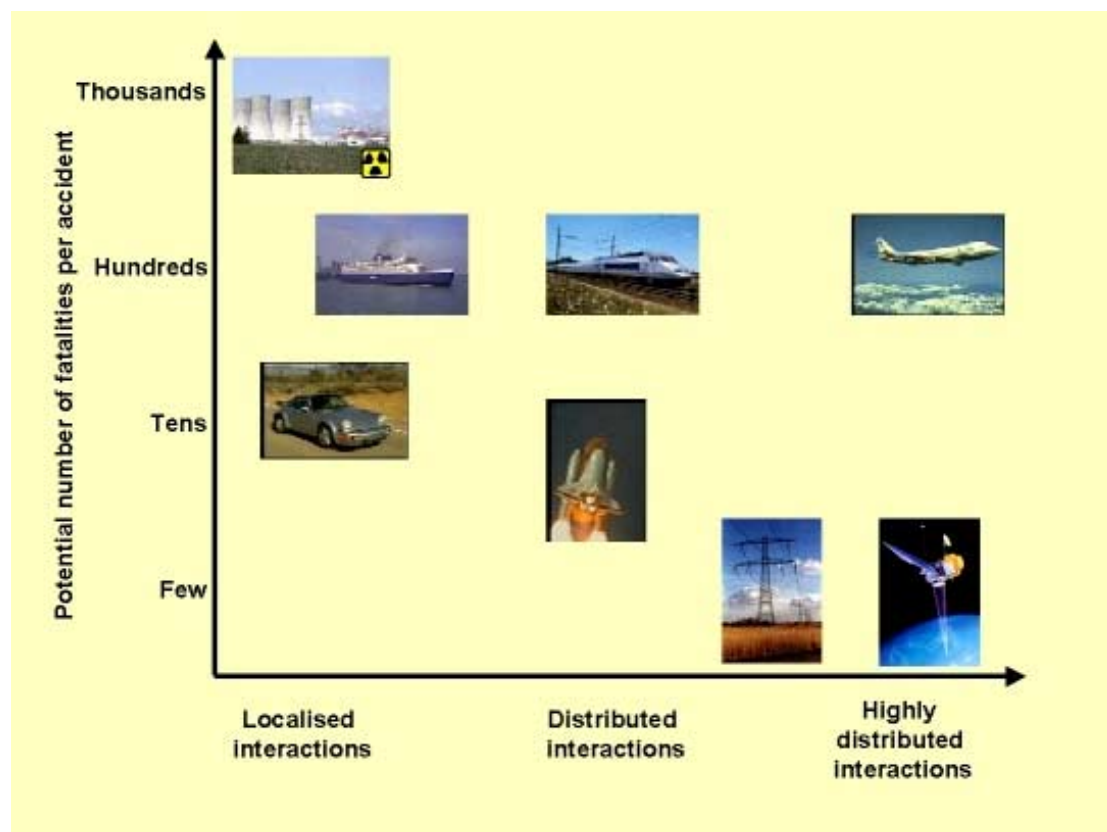

Figure 1. Air traffic management compared with other safety critical operations in terms of potential number of fatalities per accident and the level of safety critical interactions between human and automata agents

In mathematical terms the innovative approaches to handling uncertainty are based on esoteric but powerful studies of stochastic hybrid systems, where 'hybrid' refers to the integration of computer science and control theory. The resulting study reports and papers are available on the HYBRIDGE web site. Because of these powerful underlying concept studies, the basic results obtained add significantly to what is known in safety critical industries. And for air traffic in particular, these results have been elaborated into the following innovative approaches:

- **Managing the combinatorial nature of non-nominal safety critical conditions**. The application of mathematics towards handling combinatorial situations is well known. The key novelty however is the recognition that the larger part of the combinatorial safety critical conditions have to do with Situation Awareness (SA) differences between multiple agents (humans and systems), and the systematic modelling and evaluation of the resulting SA and SA error propagation. This innovative approach is illustrated for two well known safety issues in air traffic: i) Runway incursions, and ii) Level busts.

- **Accident Risk Assessment of air traffic designs by Monte Carlo simulation**. The key behind this development is an innovative way in modelling non-nominal events and responses by pilots, controllers and systems, which connects the resulting simulation code unambiguously to a stochastic and discrete event mathematical model. This connection allows using mathematically powerful tools to speed up Monte Carlo simulations by several orders of magnitude. Such a large speed up factor makes it possible to estimate the probability of a collision between aircraft through Monte Carlo simulations. The effectiveness of this innovative approach is demonstrated for an Airborne Separation Assistance System based en-route operation.

- **Monte Carlo simulation based optimisation of air traffic management**. The optimisation problems that arise in air traffic management are formidable. They involve multiple and complementary objectives in terms of safety, economy and environment, whereas there are major sources of uncertainty such as weather and traffic demand. Recent advances in randomized optimization methods provide an innovative approach in addressing such complex problems. Within the HYBRIDGE project, randomized optimization methods have been further developed and initially applied to collaborative decision support problems that arise in conflict resolution and flight scheduling.

Invitation. On 9th February 2005, the HYBRIDGE consortium will present and demonstrate these innovative approaches to the ATM community. Interested researchers are cordially invited to attend this workshop, which will be held at the Eurocontrol Experimental Centre in Brétigny-sur-Orge, France. If you like to attend or receive further information please send an email to Richard Irvine or to Henk Blom, the HYBRIDGE co-ordinator.

Presentations:
- Introduction to HYBRIDGE, Dr. Henk Blom (NLR, Netherlands)
- Probabilistic conflict prediction, Dr. Maria Prandini (Univ. of Brescia, Italy)
- Extension of robotic conflict resolution theory to air traffic, Prof. Kostas Kyriakopoulos (NTUA, Greece)
- Stochastic optimisation of air traffic management, Dr. Andrea Lecchini Visintini (Univ. of Cambridge, UK)
- Monte Carlo simulation of collision risk in air traffic, Dr. Henk Blom (NLR, Netherlands)
- Managing the combinatorial nature of safety critical conditions, Prof. Maria Di Benedetto (Univ. of l'Aquila, Italy).

When: Morning of February 9th, 2005, from 9:30 till 12:30

Place: Auditorium, EUROCONTROL Experimental Centre, Bretigny-sur-Orge, France
http://www.eurocontrol.int/eec/public/standard_page/visit_us.html