Predicting and Managing Multifactor Unknowns in Flight

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Problem

A critical flight situation is typically the result of a spontaneous mixing and unfavorable cross-coupling of several risk factors in the 'pilot/automaton – aircraft – operating environment' system dynamics: adverse weather, pilot errors, automaton's logic flaws and mechanical failures. In spite of a negligible probability of occurrence, multifactor (off-normal) scenarios do happen in operations, often leading aircraft to 'chain reaction' accidents (**Fig. 1**). The majority of multifactor scenarios are not known to pilots and engineers. The difficulty is 'the curse of dimensionality': too many cases are to be learnt in advance. At present, the volume and the quality of knowledge on multifactor scenarios (programmed in control automata and described in pilot manuals) may be insufficient.

Solution approach

In order to be avoided or safely resolved, a broad spectrum of potentially dangerous multifactor situations must be explored in advance and timely recognized onboard. A knowledge-centered solution approach to flight automation has been developed to address the problem of accident prediction and prevention in multifactor/unknown situations. High-fidelity mathematical modeling, fast-time computer simulation, artificial intelligence, knowledge mining and mapping techniques should be harnessed earlier in the lifecycle. The goal is to fill the gaps on the complex system dynamics in a pilot's (automaton's) knowledge base and help de-materialize dangerous multifactor flying experience from the outset (**Fig. 2**).

Technique

Using the system dynamics model as a virtual test and operation article, it is possible to screen potentially unsafe multifactor domains ('alternative futures') in advance. Large sets of realistic off-normal scenarios are automatically explored and analyzed for safety in the form of a situational tree (**Fig. 3**). Situational trees are used to store information on potential anomalies in the system behavior, quantify critical combinations of risk factors, derive recovery options, and depict optimal and prohibited control using 'a bird's eye view' knowledge maps (**Fig. 4**). The objective is to predict flightpaths and implement safety protection tactics under complex/uncertain conditions for 10…30 seconds ahead.

An artificial intelligence system (AI pilot) model has been developed for safety prediction and protection based on a self-preservation imperative. Its key components are: theory of multifactor flight domains, fast-time flight M&S techniques, low-cost large capacity memory, guaranteed quick access methods to knowledge, knowledge mining and mapping techniques.

Major challenges

There are several challenges on the way of bringing safety protection AI onboard. These include: trust in safety AI, knowledge base competence measurement and comparison, control authority transfer rules, knowledge base verification, validation, accreditation and update for a fleet of vehicles.

Conclusion

An affordable memory-based AI safety protection automaton can be developed. It should incorporate a comprehensive knowledge base on the system dynamics in multifactor situations generated in virtual fast-time flight M&S experiments, what-if flightpath prediction and self-preservation techniques. The knowledge base should have a tree-type structure with a guaranteed real-time access capability. Its volume can exceed the volume of multifactor flying practice accumulated by all pilots for all relevant aircraft types operated in the past.

References

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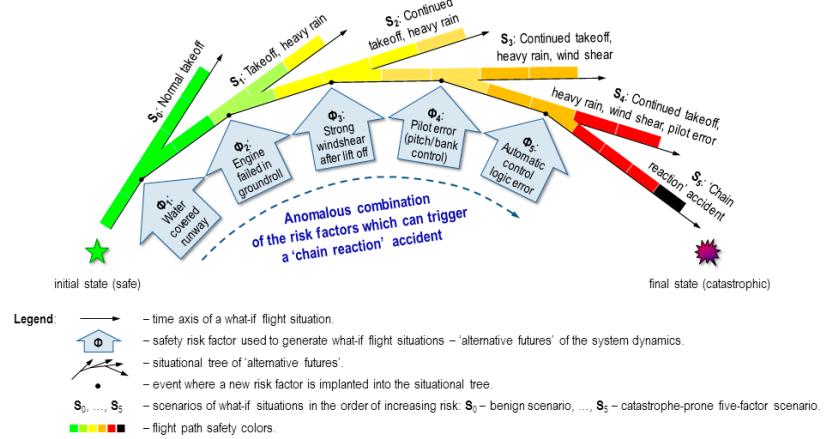
Fig. 1 – Build-up mechanism of multifactor flight situations – takeoff domain example
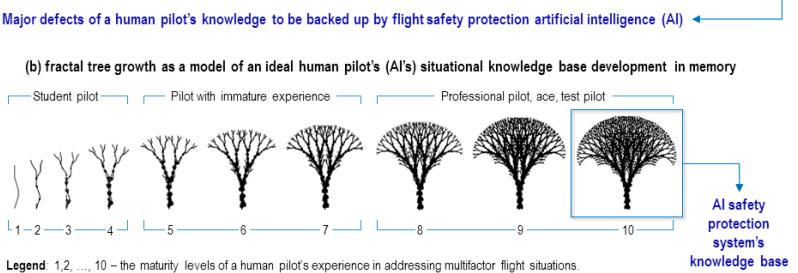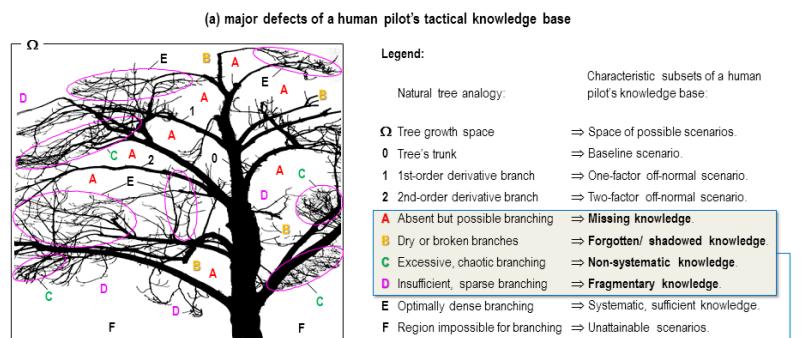
Fig. 2 – Bad and good structures of a knowledge base on multifactor flight situations
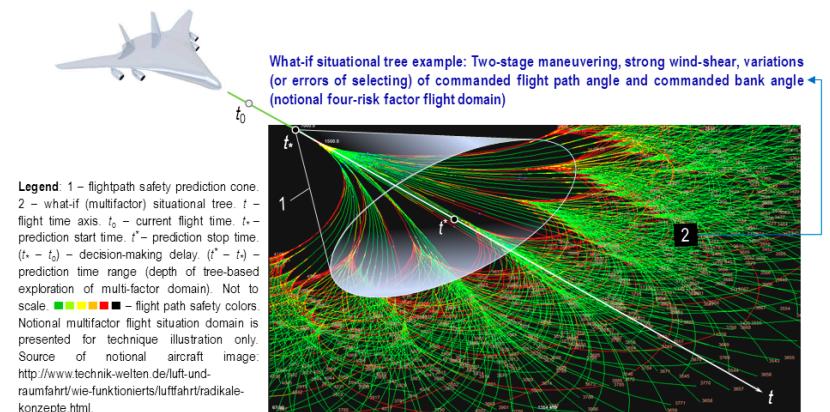

Fig. 3 – Real-time flight path safety prediction in multifactor/ unknown conditions using situational trees
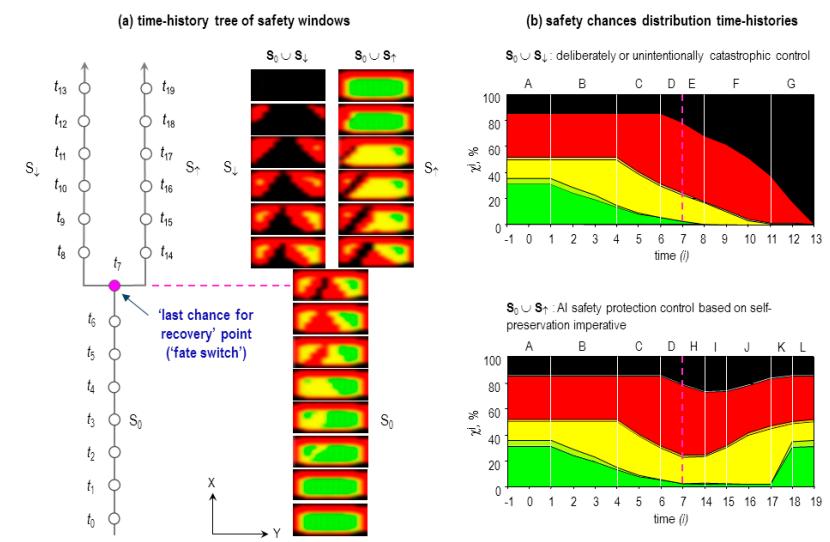
Fig. 4 – Knowledge maps for representing catastrophic and recovery control tactics (flight in the presence of an obstacle: 11.09.2001 and 24.03.2015 accidents model cases)