BUSINESS INTELLIGENCE IN A GLOBAL AIR TRAFFIC MANAGEMENT VIA INTELLIGENT OPERATIONAL DECISION SUPPORT

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Keywords:
Global Integration, Synchronisation of Operations, Intelligent Systems.

Résumé

Business intelligence in a future global air traffic management can be accomplished via integrated and intelligent operational decision support technology for airports and airline operators, air traffic controllers and pilots. It aims to support decisions regarding the management and the control of the global traffic flows, of the capacity of the airports and of the global air space-time resource allocation to 4D end-to-end trajectories of flights. The business intelligence supported by the computational intelligence embedded in a global infrastructure of integrated operational decision support systems will synchronise operations through global control mechanisms and the integrated and the intelligent operational decision support to all parties involved in the air traffic industry.

1 Business Intelligence Benefits versus Current Practices

Today the air traffic industry is facing daunting problems caused by the increase of traffic and limited capacity of airports. In this paper we introduce business intelligence benefits through the integrated and intelligent operational decision support for the future global system of air traffic control and management. We show the way in which it will benefit airlines, airports, controllers and pilots, and passengers too.

Published statistics show that one in four flights have been delayed 15 minutes or more since 1997. Delays are described as equally caused by the congested airports, the airlines inefficiencies, and the national and local air traffic control centres.

The limitations in the current practices prevent the efficient use of air space-time and airport resources. We will justify the business intelligence benefits versus limitations in the current practices.

The aircraft fly in predefined corridors crossing today smaller air traffic control sectors. The latter is due to the increased traffic and the policies of reduction of workload of controllers via dividing the airspace in smaller control sectors. The throughput of a sequence of sectors along a corridor of flights is limited by the sector with the lowest capacity within each corridor of flights. The current practices do not allow for creating cost efficient mechanisms to avoid sectors with limited capacity. Due to the latter it has been said that spokesmen of the European Airlines Association and the European Union's commissioner for energy and transport agree that the current occurrences of congestions on the ground make it impossible to put more planes in the air at the present time. The cost and the time required is estimated to be too high to render feasible any attempt at reducing the "bottlenecks" caused by the low capacity sectors under the current system. Yet air traffic is growing at a rate of 4 percent a year.

With the ever increasing demand of capacity of airports the global control of traffic flows is becoming of supreme importance to enable the efficient use of the existing capacity of the airports and to avoid congestions on the ground and in the air. The global control of traffic flows can be accomplished via automated monitoring and controlling of four-dimensional trajectories of flights. The latter is possible through an automated allocation and control of air space-time and of airport resources via a global infrastructure of integrated operational decision support systems for airports, airlines and air traffic control.

The automated allocation and control [2,3] of air space-time and of airport resources to four dimensional trajectories of flights is thus also becoming of supreme importance. It will enable airplanes to fly following flexible routes instead of in predefined corridors. The automated monitoring and controlling of four-dimensional flight trajectories by integrated operational decision support systems will obviate the current practices of controlling airspace in sectors. Thus the "bottlenecks" and delays of flights created by the low capacity sectors will also be avoided in a future global system of air traffic management via Integrated Operational Decision Support (IODS) systems.

The computational intelligence embedded in the IODS systems will allocate global resources in response to series of distributed flight requests. It will control the efficient use of the capacity of the global air space-time and of the airports by the end-to-end trajectories of flights. It will monitor four dimensional trajectories of flights and will control global traffic flows too. Thus the computational intelligence embedded in the future global infrastructure of IODS systems will implement global control mechanisms and business intelligence for global air traffic management and control.

The business intelligence benefits are the provision of real-time support for decision making and business processes of stakeholders in the air traffic industry namely airlines, airport operators, air traffic control sectors, aircraft operators.

2 THE BUSINESS INTELLIGENCE AND THE GLOBAL CONTROL MACHANISMS.

A new way of controlling the use of the capacity of the global air space-time and of the airports is through automated monitoring and control of four dimensional end-to-end trajectories of flights via integrated operational decision support systems. The latter systems implement global control mechanisms in allocating air space-time and airport resources to 4D end-to-end trajectories of flights. Thus the systems control the global traffic flows too. The embedded business intelligence improves the management of global resources and the planning of traffic flows according to the resources available. The congestions at airports will no longer occur with the IODS global control mechanisms in place and the embedded business intelligence in the IODS processes. The keeping to the departure and the arrival times of flights will be significantly improved and thus savings and increased profits for airlines too.

The IODS business intelligence objectives are implemented via computational intelligence embedded in IODS processes. The latter automate the global allocation of air space-time and of airport resources [1,3,6] ensure the planning of global traffic flows and four-dimensional end-to-end trajectories of flights according to the resources available and monitor the trajectories and global traffic flows [4,5,7]. Thus it enables better control of the use of global resources of air space-time and of airports and prevents occurrences of congestions on the ground and in the air. It enables the monitoring and the control of four dimensional (4D) end-to-end trajectories of flights. It improves the efficiency of allocation and of control of air space-time and of airport resources. Thus the planning of traffic flows will be significantly improved too.

The computational intelligence imbedded in IODS processes implement global control mechanisms and business intelligence objectives in a global infrastructure of networking architecture of IODS systems.

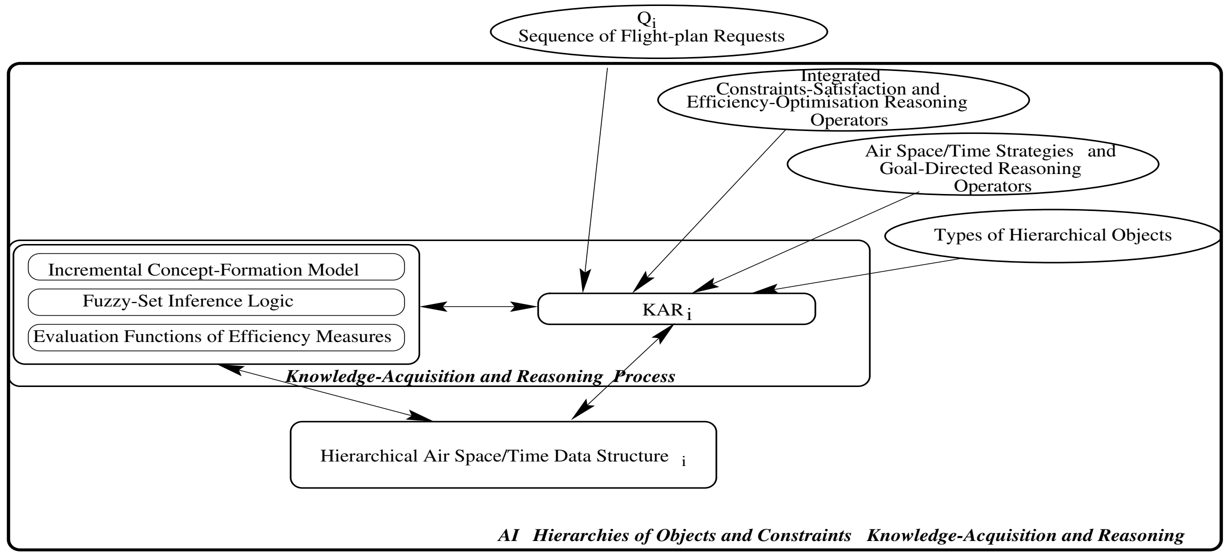
This paper introduces the business intelligence objectives embedded in the computational intelligence of learning air space time (AST) control structures in IODS systems.

The AST control structures are created by knowledge acquisition and reasoning processes. The latter automate the allocation of resources to flights booked by airlines in advance and at the time of their clearances before the take off of the aircraft. The control structures also ensure the conflict-free use of allocated resources as the structures are used by IODS monitoring processes of end-to-end trajectories of aircraft in flight.

2.1 Computational intelligence in learning clearance categories of flights.

Computational intelligence [1,3,6] mechanisms are embedded in a global infrastructure of IODS [2] systems via parallel Knowledge-Acquisition and Reasoning (KAR) and Air Space-Time (AST) monitoring processes.

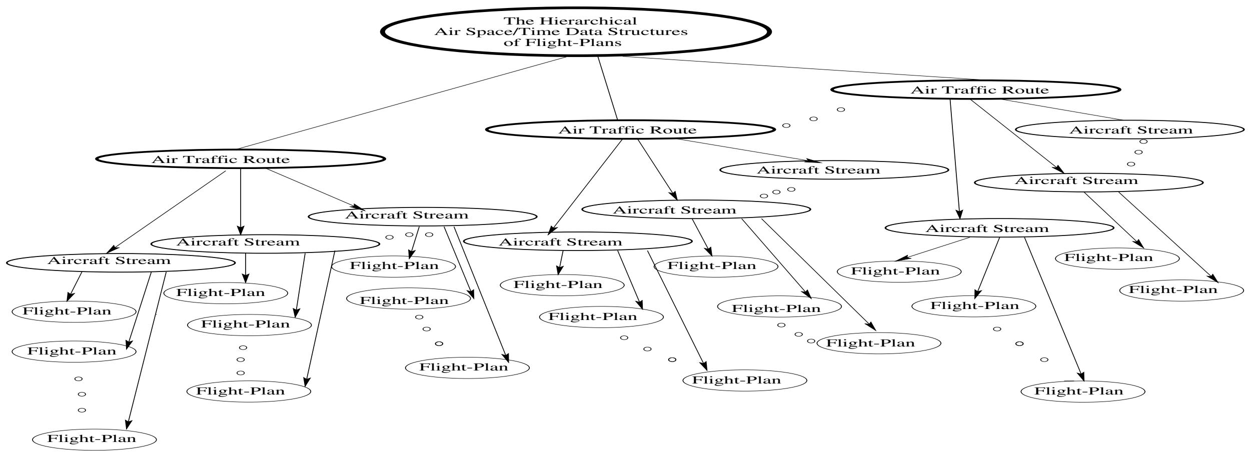
An individual knowledge-acquisition and reasoning KAR_i process (Fig. 1) implements the fuzzy-logic [1] in learning clearance-categories from subset of distributed dynamic series of flight requests. It generates the decision support knowledge about the most efficient clearance-categories of 4D end-to-end trajectories of flights from a departure airport to a destination airport given the global air space-time and airport resources available.



(Fig. 1)

A clearance-category of a flight consists of hierarchical objects organised in an AST knowledge-and-data control structures (Fig 2) such as air traffic routes and streams of aircraft. The categories accommodate most efficiently the 4D end-to-end trajectory of flights in respect of flight efficiency and the efficiency of the use of air space-time and of airport resources. The KAR_i process learns and incrementally updates the hierarchical objects of clearance-categories of flights. It organises the most efficient ones in a hierarchical AST knowledge-and-data control structures of conflict-free and most efficiently cleared end-to-end trajectories of flights from a departure airport to a destination airport given the global resources available.

The hierarchical AST strategies and integrated constraints-satisfaction and efficiency-optimisation reasoning operators guide the concept-learning processes at hierarchical levels of the automated acquisition of an AST knowledge-and-data control structures from series of distributed requests of flights.



(Fig. 2)

2.2 Intelligence in learning global control structures.

Knowledge-acquisition and reasoning processes are managed by agents. The agents dynamically start parallel concept-formation processes and thus they create interactive groups of concept-formation agents in managing individual KAR_i processes. The concept-formation agents create possible disjunctive and overlapping concepts of hierarchical categories of clearances of subsets of requested flights, while collaborating in a search for the most efficient clearance-categories of individual flights within the available global resources. They create and update dynamically fuzzy descriptions of concepts. The latter incorporate fuzzy sets of parameter values of flights associated initially with disjunctive concepts. The efficiency of those concepts of categories are measured by the efficiency of individual flights and by the efficiency of their AST use. The concepts which predict the clearances of sets of requested four dimensional end-to-end trajectories of flights with the best measures of efficiency are accepted as clearance-categories of the hierarchical AST knowledge-and-data control structures. The knowledge-acquisition and reasoning processes incrementally update the hierarchical AST knowledge-and-data control structures in response to flight clearance requests.

The aircraft agents requesting a clearance may influence the decision of an agent managing the relevant KAR_i process, by providing efficiency requirements together with their requests. The agent managing a KAR_i process takes into account the efficiency requirements of flights and the measures of efficiency of concepts. It evaluates possible clearance-categories according to the flight efficiency the prospective categories can secure. The agent prioritises the categories by efficiency and communicates the clearance parameters generated by individual categories to the aircraft agent. The aircraft agent makes its final choice and communicates the decision back to the agent managing the KAR_i process.

The final clearance-categories of flights are included in the global AST control structures. The latter are used by the IODS monitoring processes for controlling the end-to-end trajectories of flights and ensuring business intelligence objective are met and benefits of conflict-free and most efficient use of the global resources of air space-time and of the airports accomplished.

3 THE BUSINESS INTELLIGENCE INFRASTRUCTURE

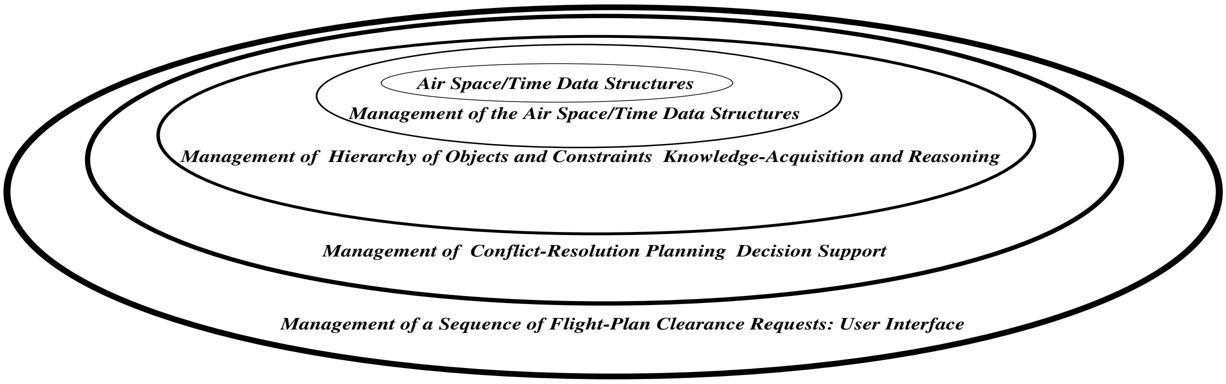
The future global networking infrastructure of dedicated ground IODS systems for airlines and airport operators and air traffic control and management provides business intelligence benefits and a conflict-free planning [3,5,7] for global air traffic.

The intelligent IODS processes automate the Air Space-Time (AST) design, allocation and control [1, 2,3] and the planning of its conflict-free and efficient use. The business intelligence objectives are accomplished via parallel and distributed IODS processes. The latter processes learn clearance-categories from series of distributed flight requests and provide intelligent mechanisms controlling global traffic flows.

The embedded intelligence in IODS technology, processes and control mechanisms provides intelligent, interactive and integrated (I^3) operational decision support (ODS) to pilots via communications though satellites with on-board computer of aircraft and to controllers, airlines and airport operators through synchronized and secure communications between IODS systems and their terminals. The global I^3ODS infrastructure of networking architecture of dedicated ground IODS systems will control four dimensional end-to-end flight trajectories, global traffic flows and the efficient and conflict-free use of the capacity of the global air space-time and of the airports. Thus it will meet the business intelligence objectives in a global air traffic management.

3.1 Layers of components.

Figure 3 shows five management layers of the global infrastructure of IODS systems. Each of these layers forms a concentric circle which associates certain hierarchical components of IODS systems, their protocols, agent-managers and Agents connected with their internal hierarchy and management models. Each of them communicates with the agents managing components in the adjacent management layers.



(Fig. 3)

The outermost layer represents the user-interface components managed by interface agents-managing series of flight clearance requests. The interface agents communicate with the software agents of on-board equipment of aircraft, and the agents managing the decision support components. The latter agents communicate with the agents managing the hierarchies of objects and constraints components of Knowledge-Acquisition and Reasoning (KAR) processes.

The agents managing individual KAR processes are associated with the internal hierarchy of the management of the Hierarchy of Objects and Constraints components of the architecture. The latter agents communicate with the agents managing the Air Space-Time (AST) components and their internal hierarchy of agents managing AST monitoring processes. The latter processes monitor AST knowledge-and-data control structures of clearance-categories of 4D end-to-end trajectories of flights during a certain air space-time period ahead of the current positions of aircraft on their trajectories along the way towards their destinations. The AST structures are associated with the innermost hierarchical layer of the agent-based architecture.

The global networking infrastructure of dedicated ground IODS systems accomplishes the business intelligence objectives by providing agent-based integrated operational decision support to all parties concerned simultaneously.

3.2 Business intelligence communications

Within the global I^3ODS infrastructure the networking IODS systems communicate to each other global AST knowledge-and-data control structures through satellites. Through those global control structures they control end-to-end trajectories and traffic flows and their conflict-free use of global resources. Thus they implement global control mechanisms and secure conflict-free planning for air traffic. They accomplish the latter by integrated management and control of allocation of global air space-time and of airport resources and the planning of conflict-free end-to-end trajectories via Hierarchies of Objects and Constraints [6] `-components and their parallel KAR processes. Via collaboration and communications between agents managing parallel AST monitoring processes and agents managing parallel KAR processes the business intelligence objective of planning and of controlling the conflict-free and efficient use of air space-time and of airport resources are accomplished. The most efficient four-dimensional end-to-end trajectories of flights, their clearances and traffic flows too. These agents keep the 4D end-to-end trajectories conflict-free in the long term through automated monitoring of trajectories and planning of conflict-free trajectory alterations off-line during a certain AST period in advance before signs of AST conflicts can develop in real-time.

The global I^3ODS infrastructure of dedicated ground IODS systems communicate through satellites [3,7] with the on-board computers of aircraft and deliver the synchronised simultaneous updates of conflict-free 4D end-to-end trajectories of flights to the pilots, to the airport operators and to air traffic controllers concerned with the flight trajectories and their conflict-free use of allocated resources.

4 CONCLUSIONS.

The global operations will be synchronized via intelligent control mechanisms embedded in the global infrastructure of IODS systems for air traffic and airspace management. The automation of the allocation and the control of the global air space-time and of the airport resources supported by communications of the control structures and the current positions of aircraft via satellites will enable the automated monitoring and conflict-free alterations of four dimensional end-to-end trajectories of flights. Thus the current practices of control of traffic flows and of airspace in control sectors will be obviated. Furthermore business intelligence benefits of global traffic flow management according to the global resources available will be secured through intelligent, interactive and integrated operational decision support (I^3ODS). Thus the safest management of global traffic, airspace and airport resources will be secured too. The intelligent control mechanisms embedded in the global I^3ODS infrastructure will monitor and protect against hazardous and unexpected events.

The IODS automation of allocation and of control of air space-time and of airport resources secures also the flexibility in planning traffic routes according to the current weather and the availability of air space-time and of airport resources. The IODS monitoring processes secure the control and the conflict-free use of global resources by 4D end-to-and trajectories of fights. Thus the I^3ODS infrastructure secures global control mechanisms and business intelligence benefits not available under the current practices. It prevents the occurrences of congestions in the air and on the ground too.

The IODS embedded business intelligence and control mechanisms will fundamentally change the global system. All parties airport operators and airlines and air traffic controllers and pilots will benefit from business intelligence objectives embedded in a future global I^3ODS infrastructure via the communications of intelligent, interactive and integrated operational decision support via satellites

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5 BIBLIOGRAPHY.

[1] Iordanova, B.,"Fuzzy-Logic in Learning Clearance-Categories of Flights", published in the proceedings of the IEEE International Conference on Computational Intelligence for Measurement Systems and Applications, Giardini Naxos - Taormina, Sicily, July 2005.

[2] Iordanova, B., "Intelligent Decision Support via Global Automation of Air Space-Time Allocation and Control ", published in the proceedings of the VSST'2004, Tooulouse, France, October 2004

[3] B. Iordanova, "Global Neural Network for Automated Air Space-Time Allocation and Control", published in the proceedings of the IEEE International Conference on Computational Intelligence for Homeland Security and Personal Safety, July 2004.

[4] B. Iordanova, "Air Traffic Knowledge Management Policy", The European Journal OF Operational Research, ISSN 0377-2217, vol. 146, no. 1, pp. 83-100, Apr. 2003, [Online] Available: http://www.sciencedirect.com.

[5] B. Iordanova, "Conflict-Free Planning for Air Traffic Supported by an Agent-Based Integrated Operational Decision Support for Pilots and Controllers", International Journal of Knowledge Based Intelligent Engineering Systems, ISSN 1327-2314, vol. 7, no. 1, pp. 46-53, Jan. 2003.

[6] B. Iordanova, "How Hierarchies of Objects and Constraints Reduce Complexity", Iordanova, B, in Proc. IEEE International Joint Conference on Neural Networks (IJCCNN), pp. 535-540, Jul. 2003

[7] B. Iordanova, "An Agent-Based Architecture of Future Integrated Operational Decision Support Systems for Conflict-Free Planning for Air Traffic Management" (via satellites), in Proc. International Conference on Enterprise Information Systems (ICEIS), Setubal, Portugal, pp 508-513, Jul. 2001.

[8] B. Iordanova, Conflict Resolution Planning relevant to Decision Support Systems for Future Air Traffic Management}, Collaborative Establishments: The R&D Directorate of UK National Air Traffic Services, CAA and The R&D Centre of Expertise of European Organisation for the Safety of Air Navigation, EUROCONTROL, Doctoral Dissertation, Available: British Library, March 2000.