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MULTIAGENT APPROACH FOR COLLISION AVOIDANCE SYSTEMS IN AVIATION

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Abstract. The problem of aircraft midair collisions exists since aviation appeared. One of the instruments used for increasing flight safeness is Traffic Alert and Collision Avoidance System (or TCAS). TCAS is an airborne system that monitors the airspace around flying aircraft and detects nearby aircrafts. In critical situations (when distance between aircrafts becomes less then critical miss distance) it sends to the pilot a maneuver advisory (often called resolution advisory). But there are some imperfections in TCAS algorithms, especially in coordination and interaction between systems. These imperfections can be eliminated by applying multiagent approach. According this technology each aircraft can be presented as an intelligent agent. Agents can communicate and generate common decisions that consider interests, technical characteristics and limitations of all aircrafts. Proposed approach can reduce possibility of midair collisions because in this case TCAS does not only make, accept or reject decisions, but also analyses them and so chooses optimal scenario of solving conflict situation.

Keywords: aviation; conflict situation; collision avoidance; multiagent system.

1. INTRODUCTION

The problem of aircraft midair collisions of aircraft exists since aviation appeared. Although airspace seems like it is infinite aircrafts feel lack of space. Nowadays areas near airports are in a turmoil. Large quantity of members of air traffic increases probability of flight accident.

On Fig. 1 it is shown the fragment of interactive map of midair situation in Central Europe. Data were obtained using public flight tracking service Flightradar24.com that provides with real-time info about thousands of aircraft around the world [1].

The primary technology is used to receive flight information is called automatic dependent surveillance-broadcast (ADS-B). It can be explained by these steps:

1. Aircraft gets its location from a GPS navigation source (satellite);
2. The ADS-B transponder on aircraft transmits signal containing the location (and much more);
3. ADS-B signal is picked up by a receiver connected to Flightradar24;
4. Receiver feeds data to Flightradar24;
5. Data is shown on www.flightradar24.com and in Flightradar24 apps.

Today, roughly 60 % of all passenger aircraft (70 % in Europe, 30 % in the US) are equipped with an ADS-B transponder. This percentage is steadily increasing as ADS-B is set to replace radar as the primary surveillance method for controlling aircraft.

Statistically amount of flight accidents increases annually (according to Russian Federation Federal State Statistics Service [2] and Aviation Safety Network [3]). Although most of aircrafts are equipped with TCAS annually about 30-40 flight mortal accidents occur, and about 1000 people die. Herewith about 10–12 % of all accidents are midair aircraft collisions.

When mortal accidents began to occur, International Civil Aviation Organization (ICAO) developed conception and later the international standards of Airborne Collision Avoidance System (ACAS). From all of developments in accordance with ACAS conception Traffic Alert and Collision Avoidance System (TCAS) is widely practiced. TCAS is an airborne system used for reducing possibility of midair aircraft collision [4].

2. STATE OF THE ART

This system (its latest versions and modifications) monitors the airspace around aircraft, detects nearby aircrafts, analyses information about situation (distance between aircrafts), and if nearby aircrafts are considered as a possible midair collision threat, TCAS sends to the pilot a traffic advisory

Fig. 1. Fragment of Interactive Map of Midair Situation in Central Europe (according to Flightradar24.com, February 25, 2014, 9:50 p. m. (UTC +6)

(or TA). If the distance between aircrafts becomes less than critical miss distance, it sends to the pilot a maneuver advisory (often called a resolution advisory, or RA).

Airspace monitoring is accomplished by means of special equipment known as transponder (from transmitter-responder). A transponder is a device that emits an identifying signal in response to an interrogating received signal; it is an active, independent of aircraft navigation equipment and the ground systems used to provide Air Traffic Control services.

Depending on transponder's mode TCAS can get different information, but in most cases it includes information about range, altitude and bearing of another aircraft.

Received data are sent to the TCAS computer unit, and by extrapolating current range and altitude difference to anticipated future values it determines if a potential collision threat exists. TCAS calculates a time to reach the Closest Point of Approach (CPA) with intruder, by dividing the range by closure rate. TCAS primarily uses time-to-go to CPA rather than distance to determine when a TA or RA should be issued. The time to CPA is called the range tau and the time to co-altitude is called the vertical tau. Tau is an approximation of the time, in seconds, to CPA or to the aircraft being at the same altitude [4].

TCAS operations is based on the tau concept for alerting functions. A TA or an RA is displayed only when both the range tau and vertical tau are less than certain threshold values that depend on sensitivity level. Table 1 provides the TA and RA tau thresholds used in each sensitivity level.

Table 1

Sensitivity level definition and alarm thresholds

Ownship Altitude (feet)	SL	Tau (seconds)	
		TA	RA
<1000	2	20	-
1000–2350	3	25	15
2350–5000	4	30	20
5000–10000	5	40	25
10000–20000	6	45	30
>20000	7	48	35

Effective CAS logic requires a trade-off between necessary protection and unnecessary advisories. This trade-off is accomplished by controlling the sensitivity level (SL), which controls the time or tau threshold for TA and RA issuance, and therefore the dimensions of the protected airspace around each TCAS-equipped aircraft. The higher the SL, the larger the amount of protected airspace and the longer the alerting thresholds. However, as the amount of protected airspace increases, the incidence of unnecessary alerts has the potential to increase.

As it has been noticed TCAS can issue two types of alerts – TAs and RAs:

- TAs to assist the pilot in the visual search for the intruder aircraft and to prepare the pilot for a potential RA, and;
- RAs to recommend maneuvers that will either increase or maintain the existing vertical separation from an intruder aircraft.

TA is preventive information. It means that observed aircraft intrudes in protectable area. Pilots must not to do any maneuvers, they just ought to concentrate attention and have to be ready for issuing RA. When RA is issued pilot ought to follow all instructions.

The latest version of TCAS (TCAS II. Version 7.1) was designed to operate in traffic densities up to 0.3 aircraft per square nautical mile (nmi) [4].

3. PROBLEM DEFIITION

TCAS logic functions are shown in Fig. 2. It demonstrates sequence of actions TCAS executes to obtain any recommendation, either TA or RA.

Computation and initial selection of RAs are based mainly on information of geometrical configuration of conflict situation. TCAS runs range and altitude test, but information about different limitations like an engine failure or presence of dangerous cargo is not considered. Also TCAS does not consider such technical parameters like maneuverability or climbing rate. The development of recommendations may depend on operation of such systems as dumping warning, earth collision warning, wind shift detection and etc. These systems have higher priority to TCAS [5].

But these imperfections are not the only, TCAS algorithms and logic have also shortcomings in coordinating and intercooperating between own system and system of target aircraft.

Because at least two systems take part in process of conflict situation solving, two scenarios (solutions) are generated. Of course generally these scenarios will not be identical, thus selection problem comes up. This problem causes another problem of coordination.

At the present time TCAS/TCAS coordination is based on the following principle. In general case first by time conflict solving scenario is selected. If the second system initially generated same type scenario as first system, it has to change its decision to the opposite.

Behavior of aircrafts is described with “do it myself” principle when each aircraft proposes scenario of conflict solving where maneuver will be executed by this aircraft (by itself). This approach does not guarantee that accepted decisions will be optimal (in formal this decision will be optimal by criterion of binding time).

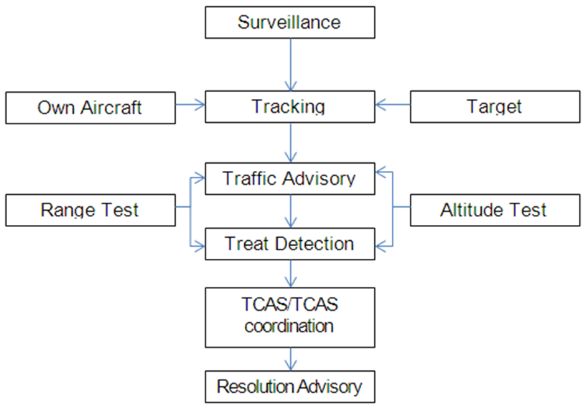

Fig. 2. TCAS Logic Functions

In this case the term optimal decision could be understood as scenario whereby proposed resolution advisory provides required miss distance between aircrafts with minimum deviation from the given trajectory and does not cause additional conflict situations with another aircrafts (so-called “domino effect”). Non-optimal decision is also a decision that proposes maneuver for aircraft with worse technical status or worse maneuvering potential.

Furthermore, in development of collision avoidance systems it is necessary to make a compromise between protection provided by this system and excess alarms as a result of predictive nature of the logic.

Because of collision avoidance systems are a human-machine systems then the development of TCAS is associated with a certain model of pilot’s reaction model. In the existing systems standard pilot’s behavior model is used. This model considers that pilot's reaction time delay after RA is issued and pilot starts to act is not more than 5 seconds.

Any attempts to develop or to improve collision avoidance system needs to satisfy different requirements, standards and specification documents.

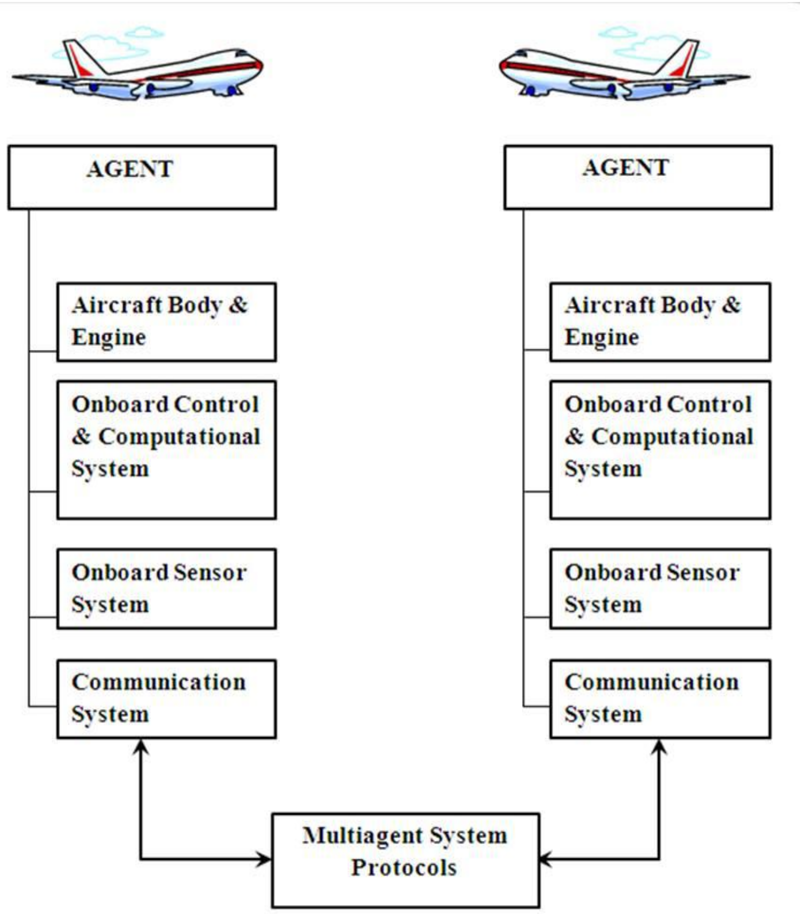

Fig. 3. Structure of TCAS Multiagent System

4. MULTIAGENT APPROACH FOR COLLISION AVOIDANCE SYSTEMS

Nowadays artificial intelligence technologies usually are widely applied for complex technical tasks solving [6-8]. Problem of detection and preventing possible midair collisions can be solved with applying multiagent approach [9,10]. Thus actions of each member of conflict situation are coordinated on base of cooperating of intelligent agents. In the problem of collision avoidance the term agent could be understood as system that solves its local problems and that includes special communication equipment and intelligent instruments. TCAS agents have to consist of following components (Fig. 3):

1. Aircraft body and engine (fuselage that includes power devices);
2. Onboard sensor system (airborne sensors and devices);
3. Onboard control and computational system (information, decision making and executed systems);
4. Communication system (tools, channels, communication languages and protocols).

Agent is characterized with set of properties encapsulated in agent model, with set of events agent can response to, with set of actions it can do. During conflict solving agent considers the following tasks:

1. Adoptive planning of aircraft flight in the midair on the base of internal and external information;
2. Simulation of midair environment and behaviour of other agents;
3. Situations recognition and optimal decision making.

Communication is one of the main properties of agents. From the one side communication can be considered as procedure that updates information about state of the multiagent system. From the other side communicational process is used for reporting the agent’s intentions. In order the transmitted information will not be interpreted in different ways it is necessary to apply special communication languages and protocols that eliminate ambiguous interpretation.

Proposed multiagent system has to be selforganizing. For this aim selforganizing multiagent system has to be built on the base of ascending design principle. It means that at first agent components are developed and then – agents interaction procedures. Thus the level of agents is basically because it describes entire agent behaviour. The level of interactions is secondary because it realizes communications between autonomous agents.

5. CONCLUSION

Thus proposed multiagent approach can improve TCAS coordination algorithms. This could be achieved by the means that TCAS does not only make, accept or reject decision, but it also analyses them; it does not choose first issued conflict solution scenario, but chooses optimal decision that consider additional essential limitations, parameters, etc.

To develop the multiagent system it is proposed aviation specific agent composition that make possible interactions between multiple agents. Development of selforganizing multiagent system has to be based on ascending principle.

The main aim of such improvements of TCAS algorithms is reducing possibility of midair collisions.

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МЕТАДАННЫЕ

Название: Многоагентный подход для систем предупреждения столкновений в авиации.

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Аннотация: Проблема столкновений самолётов в воздухе появилась с возникновением авиации. Одним из средств для обеспечения безопасности полётов является Бортовая система предупреждения столкновений (БСПС) TCAS. БСПС представляет собой бортовую систему, которая сканирует воздушное пространство вблизи собственного воздушного судна. При возникновении конфликтной ситуации (уменьшении дистанции между воздушными судами ниже значения критической дистанции пролёта) БСПС выдаёт пилоту рекомендации по маневрированию. Однако алгоритмы БСПС имеют некоторые несовершенства, особенно в части координации и взаимодействия систем. Эти несовершенства могут быть исключены при применении многоагентного подхода. Согласно данной технологии воздушные суда представляются в виде интеллектуальных агентов, которые могут взаимодействовать и вырабатывать совместные решения, учитывающие интересы, технические характеристики и ограничения каждого из воздушных судов. Предложенный подход может позволить уменьшить вероятность столкновения самолётов вследствие того, что некоторое решение будет не просто выработано, но проанализировано, то есть сценарий разрешения конфликтной ситуации будет оптимальным.

Кючевые слова: авиация; конфликтная ситуация; предупреждение столкновений самолетов; многоагентная система.

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