Nationaal Lucht- en Ruimtevaartlaboratorium

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Summary

As advanced crew support technologies will more and more be available in future military aircraft, it is necessary to have a good understanding of the possibilities in this area, taking into account operational demands and technical possibilities. A Crew Assistant (CA) is a decision support system for air crew, designed to improve mission effectiveness and redistribute crew workload in such a way that the crew can concentrate on its prime tasks. Designing a complex system with multiple crew assistants can be tackled by using a multi-agent system design. In this paper we propose a multi-agent system architecture for crew assistants.

List of Abbreviations

AWACS	Airborne Warning And Control System
CA	Crew Assistant
DESIRE	Design and Specification of Interaction Reasoning Components
EUCLID	European Co-operation for the Long Term in Defence
HMI	Human Machine Interface
MAW	Missile Approach Warning
MLW	Missile Launch Warning
MSDF	Multi Sensor Data Fusion
NLR	National Aerospace Laboratory
RWR	Radar Warning Receiver
SAM	Surface to Air Missile
SPEW	Self-Protecting Electronic Warfare

Contents

(12 pages in total)

1 Introduction

Software is a major part of current and future on-board avionics. Current developments in software engineering and advanced information processing enable complex crew assistant applications. Support of the aircraft crew in carrying out primary and secondary tasks is more and more provided by electronic systems. Applying crew assistants in fighter aircraft is a challenging task, both with respect to the research and development of the software, and with respect to the human factors aspects concerning its optimal use and trust of the pilot in the system.

We propose a multi-agent system approach to design complex crew assistants. We first give an introduction to crew assistants, followed by a description of multi-agent systems, and then propose a multi-agent architecture for crew assistants.

2 Crew Assistants

Modern military operations take place in a complex operational environment to accomplish a spectrum of missions. The workload of fighter aircraft crews increase rapidly because of:

- the increase of the complexity of the military environment in general (e.g. combined joint task forces, peace keeping/peace enforcement).
- the increase of the complexity of the types of missions to be flown.
- the increase in the number of different (kinds of) threats.

Another factor is the technological development of fighter aircraft. The increase in aircraft speed, aircraft types and on-board systems causes the aircraft itself to become much more difficult to manage, putting more pressure on the crew. During high-stress situations, the crew can get overloaded with information, while it has to perform a multitude of actions.

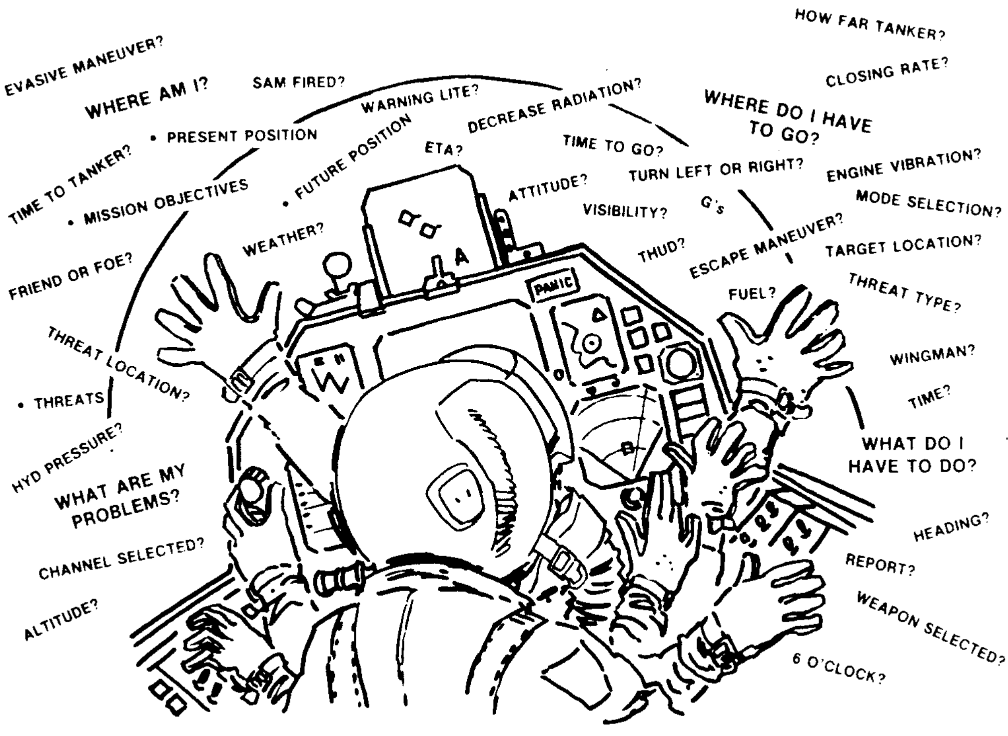

Figure 1: The information requirements on the crew, Yannone [11]

A crew assistant is an on-board decision support system that supports the crew in performing its mission. It aims at improving mission effectiveness, flight safety and/or survivability by providing the crew with concise and relevant information, depending on the mission phase. This enables the crew to concentrate on mission decisions and make more effective decisions [9].

Ideally, a crew assistant assists a pilot, or other crew members, by providing the following kind of functions:

- Acquire the necessary information and merge the input from different sensor and information systems into one timely and consistent view of the current situation (the status of different on-board systems, the situation outside, etc.).
- Process the merged information to give advice (weapon selection, route planning, tactics evaluation, fuel management, etc.).
- Perform tasks autonomously when allowed by the pilot or another crew member (autopilot, target tracking, systems monitoring, etc.).

3 Multi-Agent System overview

In this chapter we will first give a definition of what we mean by an agent and then propose a multi-agent architecture for crew assistants.

3.1 Definition of an agent

The notion agent has become popular in recent years. It is used for several different applications ranging for simple batch jobs to intelligent assistants. It's good to get clear what we mean by agent. The weak notion of an agent as described in [5] (the characteristics to call the system an agent):

Autonomous behaviour: The system should be able to act without the direct intervention of humans (or other agents) and should have control over its own actions and internal state.

Reactive behaviour: Agents should perceive their environment (which may be the physical world, a user, a collection of agents, etc.) and respond in a timely fashion to changes that occur in it.

Pro-active behaviour: Agents should not simply act in response to their environment, they should also be able to exhibit opportunistic, goal-directed behaviour and take the initiative where appropriate.

Social behaviour: Agents should be able to interact, when they deem appropriate, with other artificial agents and humans in order to complete their own problem solving and to help other with their activities.

The weak agent definition describe above can be extended with intentional notions to make it a strong agent definition. These notions are for example beliefs, desires, intentions, commitments, goals, plans, preference, choice and awareness.

3.2 Agent Design

The agents are designed according to the DESIRE method from [1]. We chose the DESIRE method for its well-defined generic agent structure and its compositional architecture, which enables us to design the model on different levels of detail. We present in this paper the top-level design of the architecture.

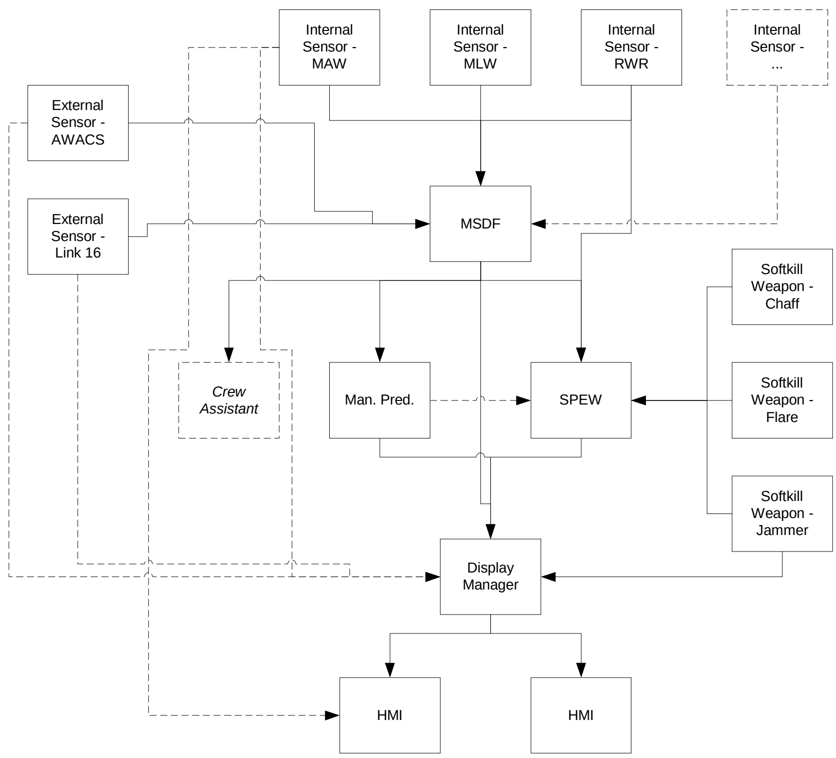

Figure 2: Multi-Agent System overview; dotted lines represent alternative information flow when components fail

3.3 Overview of the architecture

In this section an overview of the multi-agent architecture for the PoWeR II project is presented. The proposed architecture has been based on the results of earlier projects, like the EUCLID (European Co-operation for the Long Term in Defence) Research and Technology project 6.5 [12]. The project on crew assistants for military aircraft started with extensive user interviews to establish an inventory of operational user problems and needs for pilots flying F-16, Tornado and AM-X. The project came up with a generic on-board crew assistant architecture and indicated a challenge in the application of multi-agent systems and knowledge based systems. The architecture that has been set up distinguishes four groups of functional agents. The groups are (1) data and information input agents, like sensors and the multi-sensor data fusion agent, (2) data processing agents which form the actual crew assistant functions, (3) information output agents which communicate mainly with the pilot, and finally, (4) the weapon agents.

Apart from these, other agents perform functions for controlling and monitoring the overall system's status and health. In this paper, we will focus on the functional part of crew assistants (Figure 2).

Internal sensor agents are system components that transform the raw input data from the sensor hardware to an understandable format for the Multi-Sensor Data Fusion (MSDF) component. In our example, we included sensors to detect and distinguish SAMs and to detect incoming missiles. A Radar Warning Receiver (RWR) provides the position of ground threats (SAMs), including an indication whether the SAM is in search, track, or guidance. The Missile Launch Warning (MLW) is a passive infrared plume detector that provides missile information by detecting its engine. The Missile Approach Warning (MAW) is an active short-range radar that detects a missile body, usually in a two to three miles range.

External sensor agents are components that obtain their information from sensors or information systems that are physically located outside the aircraft, for example an AWACS or a Link-16. These sensor agents transform data and information into an understandable format for the MSDF agent or for the CA agents.

The Multi-Sensor Data Fusion agent combines the sensor information from all internal and external sensors into a combined sensor data picture. This agent may perform complex situation assessment tasks. In the current implementation, this is a fusion process that only provides the information to the crew assistants that is really necessary for the assistants to perform their task. Different projects have already shown the complexity of a multi-sensor data fusion process and have proposed architectures. [4] proposes an agent based architecture for multi-sensor data fusion, which shows the flexibility of agent systems, where agents can delegate tasks to (sub-)agents.

Crew Assistant agents are the intelligent pilot support functions. The ones mentioned in figure 1 are developed at the NLR (based on [12]), however, the range of pilot support functions is not limited to these. Crew assistants can be further classified into functions as information finding in the fused sensor picture, pilot advice (like manoeuvre prediction), pilot monitoring, mission monitoring, etc. Other classifications are possible ([2], [6]).

Weapon agents control the weapon delivery. In this example, a number of softkill weapons to countermeasure ground threats are displayed. Their intelligence for example consists of providing the correct jamming against a recognised threat or dispensing a complex pattern of chaff and flare.

The Display agent is responsible for assembling an integrated picture of crew assistant information and for prioritising information provision to the pilot. If necessary, it can hold information that is considered less important at a certain moment or less time critical, if the pilot is assumed to get overloaded with information. Once the situation is more relaxed, it can decide to provide this information. An even more intelligent display agent can decide what information should be provided on which cockpit display, or what information should be provided on which

part of the cockpit display and automatically adapt the contents of the available displays if at (a certain part of) one of the displays an information overload is eminent. This technology, however, should be introduced with care [10].
The Human Machine Interface agent is the actual cockpit display that provides the information on the user interface. It may take input from the user.

3.4 Flow of control

The internal sensor components receive raw sensor information from the sensor hardware. This sensor data is transformed to an understandable format for the Multi-Sensor Data Fusion (MSDF) component. The external sensors receive information from external sources like an AWACS. This data in transformed to an understandable format for the MSDF components. The MSDF component collects all the sensor data and combines this data to derive the kind of threat. For example the MSDF component could derive a SAM-site threat. This data serves as input for the crew assistants, e.g. SPEW (derives counter measures) and Manoeuvre Prediction (predicts manoeuvres to avoid a threat). The crew assistants also get input from the Softkill Weapon components. This is data about the status of the softkill weapon components, e.g. the amount of chaff and flares available.
The output of the crew assistants is passed to the Display Manager, which makes sure that the output data is put on the right HMI.

3.5 Advantages of using agents

We have chosen the multi-agent approach for the crew assistant application specifically because of the following characteristics of agents:

- Autonomity: The different agents in the crew assistant application should be able to operate independently of each other, i.e. if an internal sensor agent fails the MSDF agent still derives useful information, or when the MSDF agent fails the crew assistant agents should still be able to assist the pilot. Of course less data reduces the accuracy of the agents.
- Pro-active/Re-active behaviour: The agents have to operate in a pro- and re-active manner, for example the sensor agents have to independently observe the environment and the crew assistant agent pro-actively warns the pilot of incoming threats. This pro-active behaviour is modelled as a goal for the agent.

These agent characteristics make the design and implementation of the crew assistant application more natural.

4 Conclusions

An architecture, based on multi-agent technology has been set up, where different examples of crew assistants have been integrated. The architecture of the multi-agent system is only at top-level for simplicity, the crew assistant components are composed of other components. The multi-agent technology used to design this system allows for components to fail while the overall system still produces sensible output data. Of course when more components fail the output will be less accurate. The architecture is now partially specified with the DESIRE tools [1]. Future work will be directed to the maintenance of the architecture provided and to the further integration of agents, both functional and for system control and monitoring.

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