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Early Failure Notification and Predicted Logistics Support Personal Assistant

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Key Words: *Personal assistant; predicted maintenance; machine learning; logistics support.*

Abstract. *This paper presents an intelligent modular system for early failure notification and logistics support. This is a multi-agent system with cooperative behavior agents. This work describes the implementation of a personal assistant operating on a mobile devices and delivering user personalized information.*

1. Introduction

The main factor for any organization's high productivity whose activities are related to machinery, installations and devices is the maintenance of this equipment [6]. According to current trends in building networks of smart devices, the equipment maintenance can be automated. A possible option is the integration of sensor elements into the equipment and their connection in a network. The interaction between smart devices depends on the integration of computing, network and physical components, which implements the Cyber-Physical System (CPS) paradigm. It is a key element in the transformation of the Internet into Internet of Things (IoT). The machine interaction model assumes that each device can receive and transmit data about itself or its environment through the available communication infrastructure. Based on this concept, warning signs and equipment problems can be diagnosed in real time and the future performance of the individual units can be predicted. This allows the servicing to be provided only on demand.

The automation and the optimization of work processes have many applications in various fields of industry, agriculture, medicine, etc. Aircraft also does not stay out of this trend. The need to ensure high reliability in the operation of the aircraft equipment creates prerequisites for the implementation of various innovative methods for managing the life of aircrafts and their units.

Modern aircrafts have a wide variety of sensors that generate large volumes of data for different work characteristics. This data belongs to the so called Industrial Big Data (IBD) – big data arrays collected from any industrial equipment. The collection and storage of IBD in aircraft is at a local level. The technology allows online monitoring of the status of the equipment, which is expensive and its implementation is very selective. Current developments for this model include wireless sensors, a web browser that monitors the equipment status and an online alert system that informs the operator or the support team of any deviations. The information is sent by e-mail or text messages.

Implementing the CPS model in the aircraft domain will allow connected aircrafts to automatically update their specific parameters and services based solely on their usage profile. The possibility to connect the onboard platform to the Internet will facilitate the storage and the processing of sensor data using remote servers and cloud platforms. The extraction of knowledge from IBD using machine learning methods in the aircraft operation process is an excellent opportunity to identify potential errors and to prevent potential problems. The application of this model allows the analysis and forecasting of the cost effectiveness of the parts, as well as the identification of components at latent risk and their preventive replacement.

In recent years, there has been a growing interest in artificial intellect and agent systems, which is apparent in theoretical and laboratory studies and the subsequent implementation of the results in various areas of real life. The targeted use of intelligent systems leads to the improved performance of specific tasks and to the reduction of human errors. According to the professor John Oberlander, the entry of the artificial intelligence into mobile communications is a clear example for the potential of smart systems [4].

The implementation of the artificial intelligence in aircraft is necessary in order to solve critical problems in real-time, to optimize workflows, to improve safety, etc. The realization of an intelligent logistics security strategy requires monitoring, analysis, detection and notification of possible details' problems, as well as the optimization of spare parts inventory.

The present article focuses on the creation of a tool aimed at detecting equipment deviations and measuring the rate of change of variations. The aim is to be possible to predict the future state of the equipment and to make informed judgments about what to do next. The recommended action is usually based on the importance of the equipment, on deviations from normal operating restrictions and on a forecast trend analysis. The implementation of an intelligent software system for early personalized failure notification and forecast logistics will improve the security and the servicing of aircraft while minimizing possible costs.

2. Strategies for logistic provision

Traditionally, the strategy for dealing with failures is in fact the provision of different kinds of support. They can be reactive, preventive, proactive and forecast [9].

The reactive maintenance is applied in case of failure. It is in fact the replacement or the repair of the respective damaged element.

The preventive maintenance is performed at regular intervals. It includes various activities for controlling and replacement of certain items. The activities and the periods are predefined by the manufacturer of the facility. The workload and the wear and tear of the elements are assessed by established standards, which must ensure the trouble-free operation of the system. When a problem is identified, a workflow break schedule is created to minimize losses. These schedules tend to be very conservative and are often based on the operator's expertise or experience. The result is a process that actually guarantees higher costs for maintenance than the necessary ones and it can be difficult or impossible to be adapted to an extremely complex or changing industrial scenario.

One of the methods for servicing parts of critical importance is the method of forecast maintenance, also known as condition monitoring. It determines the working life of the parts on the basis of checking their condition. Various indicators are measured, deterioration trends of the characteristics of the parts are analyzed and calculated. For this purpose, an analysis system and an alert system are used. The analysis system is accessible through a browser. It collects data about the parts and analyzes their condition. The alert system informs the operator or the support team of any deviations submitted by the analysis system, using e-mails or text messages.

Proactive support targets both on the warning signs of an impending failure and on the identification of small defects that can lead to major failures after a period of time. In order to identify possible future failures, different scenarios are generated, the results are analyzed and action is taken to prevent them.

Servicing the machinery and the equipment in general is a costly activity. In case of early detection of problems and with the possibility to fix them the maintenance saves money. However, there is no standardized approach for prioritizing spare parts. On the one hand, stockpiling increases costs, on the other hand, parts deficit carries the risk of work stopping and subsequent financial losses.

The forecast maintenance is a very powerful support strategy. It includes monitoring for any unusual operations or equipment mismatches [9]. The degree of variation and the rate of deviation from normal operation are tracked and are used to predict the time of a failure. This type of maintenance is based on the concept that each piece of equipment follows a fault cycle (*figure 1*). It allows the failure to be identified as early as possible during the P-F interval. The sooner a malfunction is detected, there is more time left to decide how to manage the equipment and to balance the requirement for proceeding with the operation.

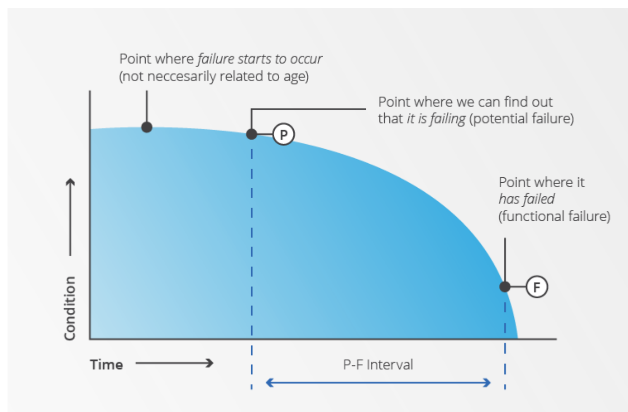


Figure 1. P-F Interval, fiixsoftware.com

3. Equipment control systems

At present time, there are certain implementations that are most often focused on monitoring and controlling operating parameters in order to ensure high performance, shortening downtime and detecting malfunctions.

In [7], a mathematical model for the management of spare parts' stock has been developed, which allows the possibility to determine the moment, the structure and the volume of the required quantity of parts, which minimizes costs by calculating the compromise value between deficit and investment.

[3] presents a structured multi-agent system that takes into account changes in electrical sources and their load in a microenvironment and allows them to be controlled and

replaced. The microenvironment is simulated using Matlab/Simulink. The agent system performs monitoring, control of electrical sources and effective load management in real time.

In [2], is implemented a support of a photovoltaic installation using the Supervisory Control and Data Acquisition (SCADA) system. SCADA exchanges data with controllers, processes information in real time and stores it in a database. It also supports alarms' management and provides communication with external applications. A basic disadvantage of the system is that it is unprotected against cyber attacks.

The presented software for early failure notification and forecast logistics is a modular intelligent system consisting of personal assistants operating on mobile devices, a web application with a H2 database located on a web server and an agent management server. The communication between the different modules of the system and the processing of the information received in the database is accomplished through the exchange of messages about the occurrence of events between different intelligent components.

4. Intelligent agents and personal assistants

Artificial Intelligence Systems are implemented with the help of software units called Intelligent Agents (IAs). An intelligent agent is a computing system that perceives its environment through sensors and influences it with the help of actuators, seeking to achieve its delegated purpose while maximizing its performance assessment [5]. The IA usually lives in a complex environment, observes it and has the opportunity to partially change it. Depending on his internal state and his abilities, it responds to the changes in the environment and tries to accomplish the tasks which he is designed for. The agent's autonomous behavior is based on his choice of one or another action, without the intervention of humans or other external systems. The agent is capable of flexible actions, which effects in reactivity, proactivity and social communication, and can change his goals if he changes his beliefs. The IA architecture is based on the believe-desire-intention (BDI) model and depends on the agent's belief in the current state of the environment, its desires related to possible action scenarios, and its intentions to accomplish the current goal (*figure 2*). The achievement of the objective is related to the decision to implement a certain plan, depending on the observed state of the environment. The intelligent behavior is in the heart of the effective processing of knowledge, even if there is an incomplete information about the subject area.

In order to fulfill a common goal in a multi-agent system, the separate agents show social behavior which effects in cooperation and negotiation. The scalability of the multi-agent system allows the addition or the removal of agents if needed.

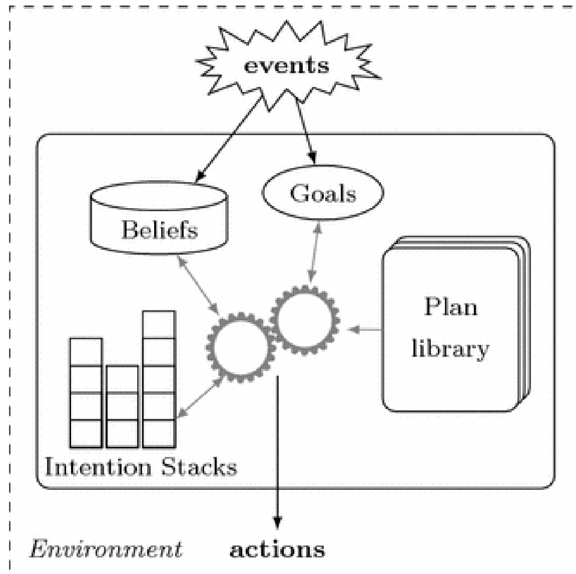


Figure 2. BDI Architecture

Personal assistants are rational smart agents who can use contextual information and make adequate personalized suggestions. They observe and study their user's behavioral model. Intelligent assistants collect, store, and purposefully analyze data, assessing different situations. They commit themselves to solving certain tasks, to choosing the most appropriate plan for that purpose and to acting in order to accomplish it. They operate autonomously and independently, taking into account the contextual characteristics and adapting to them. These essential features make personal assistants suitable for delivering resources of any type. They can be trained, can manage and care for the execution of upcoming commitments and duties.

In recent years, various intelligent personal assistants have been developed that provide a variety of services - information delivery, daily schedule management, organization of telephone calls and contacts, and more. Known worldwide are the personal assistants Google Now, Cortana and Siri.

The early failure notification and forecast logistics security software introduced in this article is a distributed modular system consisting of a web application, a mobile application and an agent management server. Intelligent agents have different functionality – personal user assistant, server agents processing database information, and agents communicating with remote system modules. All agents are accomplished using Java and JADE technologies, which facilitates the communication and the exchange of information in real time.

5. Java Agent Development Framework

Java Agent DEvelopment Framework (JADE) is a software framework for creating agent-oriented distributed applications [8] (*figure 3*). It is based on the Foundation for Intelligent Physical Agents (FIPA) specifications.

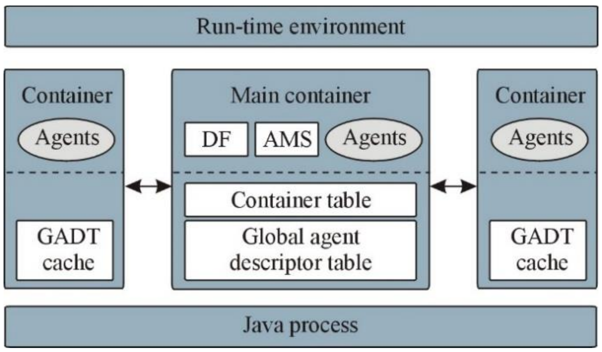


Figure 3. Jade Architecture

JADE consists of two interconnected components - an environment for development of Java agents and a platform for their functioning. The framework provides protocols for working with mobile devices. The agent management is based on built-in services and ontologies. In order to communicate, it is sufficient to extend the interaction protocols with appropriate methods. The work model involves registering the created agents in the platform, where they are given a unique name and an address [1].

The platform maintenance is entrusted to several built-in agents:

- Agent Management System (AMS) – it manages the entire platform, launches and destroys agents.
- Remote Management Agent (RMA) – it provides a graphical administration interface with tools and context-sensitive menus.
- Directory Facilitator (DF) – a service mediator. DF provides "yellow pages' for other agents. They can register their services in the yellow pages or search for services registered by other agents. Each main container must have at least one DF. However, the platform can support any number of DFs.
- DummyAgent – it tests the exchange of messages.
- Sniffer – for debugging.
- SocketProxyAgent – for communication with remote clients via socket.

These agents reside in the main container of the platform. The rest of the agents (user agents) are created in the basic container, and then they can migrate to other containers or platforms that support the FIPA standard. The framework supports asynchronous communication in the form of ACL messages between agents at the same or at different platforms (*figure 4*). The messages are personal for each agent, they queue and when possible – are delivered to the agent.

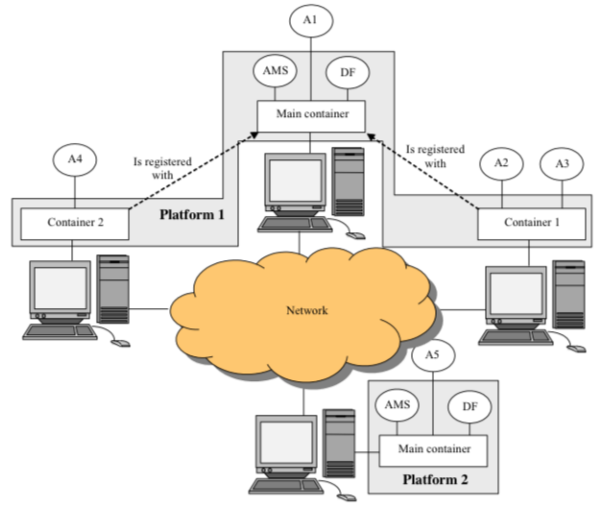


Figure 4. Communication between platforms, jade.tilab.com

6. Mobile application personal assistant

The mobile application enables end-customers to receive real-time information about the status of the various devices and parts they work with. Personalized information is supplied by the personal assistant operating on the mobile device.

The assistant is implemented as a multi-agent system. It consists of a genetic assistant (GA) created on the agent management server and a genetic assistant instance on each mobile device (PA). PA is instantiated and initialized when the mobile application is installed for the client.

PA processes the information about the operation of aircrafts and their units. It is a rational agent and as such is limited in resources. Only locally organized database is accessible for him. It can record, update and retrieve information from it. Important input data for its effective operation are the type and the model of the aircraft, the components and units involved, atmospheric conditions and the geographical location during the flight, fulfilled working hours and possible emergencies. PA does not work in isolation. It exchanges information with several types of specialized server agents.

At the initial launch of the application a GA instance in the mobile environment is created. The application waits for the user to enter his personal data and the information about the aircraft which he works with. The PA initializes and sends the entered information to the server database.

The information is processed by the responsible server agent. It checks for an existing user profile and creates one if such is absent. It retrieves information from the database about the connected aircraft and sends this data to the PA. The PA records them in the local database. For a PA which has a BDI architecture, consumer knowledge and information about the aircraft shape its belief in the environment. This belief is refreshed when connected to the server database and upon entering the flight data. Each time the application is launched, PA executes a plan to update the data in its local database.

The server is running an agent responsible for early warning of a possible premature failure of a unit. This agent analyzes the data for the different units and assigns a resource when there is a possibility of a problem, while at the same time sends a message to the personal assistants at whose database there is a unit at potential risk of failure. As soon as the PA receives a high priority message, its beliefs change and it focuses on executing a user notification plan.

The developed graphical user interface of the mobile application visualizes the possibility of input and output of working information, offering an access to the basic functionalities of the software product (*figure 5*).

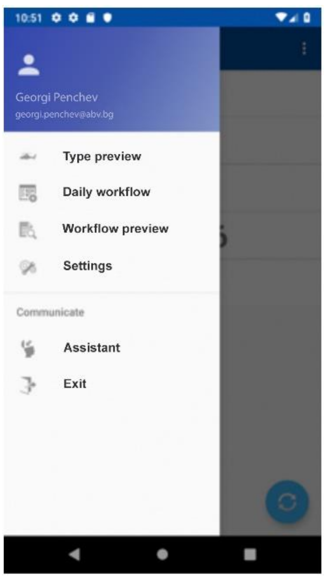
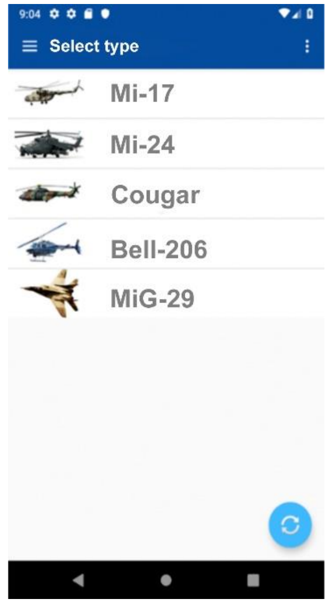


Figure 5. Basic functionalities

Type Preview functionality. The types of aircraft are organized in a tree structure. The user has the opportunity to choose the type of the aircraft for which he wishes to receive information (*figure 6*). The separate models of the selected type, with described main characteristics, are displayed in a new window (*figure 7*). When selecting a particular aircraft, the PA displays a detailed information about its units (*figure 8*).

Daily Working Hours functionality. The form for describing the daily work of the aircraft is an entry point for recording information about all units installed in its systems (*figure 9*). The correctness of the entered information is guaranteed on two levels – with identification and authorization of the user by username and password and with subsequent validation of the entered data.



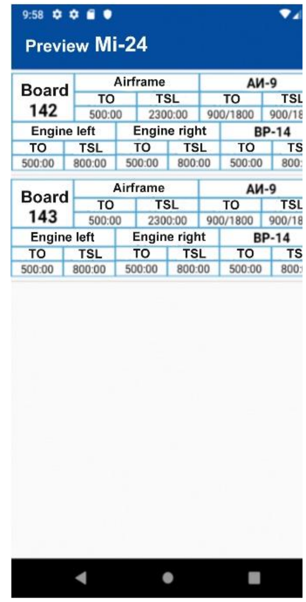


Figure 6. Information about the types of aircraft

Figure 7. Information about aircraft models of one type

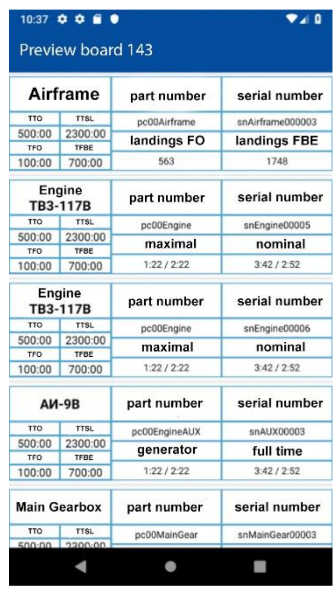


Figure 8. Detailed overview of the units

Upon successful validation, the PA extracts the necessary related data from the sensors of the mobile device (atmospheric pressure, temperature, humidity, geolocation, etc.) and together with the information entered by the user, records it in the application database. The mobile database makes the application work offline. Having internet connectivity, the data is synchronized with the web application database automatically.

Work overview functionality. From the main menu, the user has access to the information about the daily operation of the aircraft, filtered by type and board number (*figure 10*).

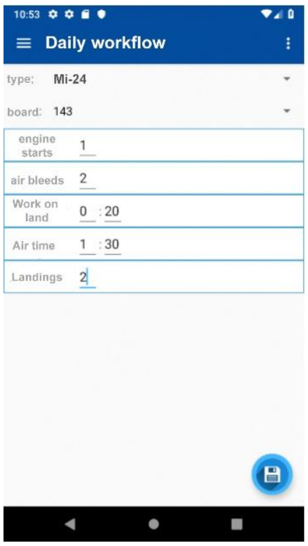


Figure 9. Record of daily working hours

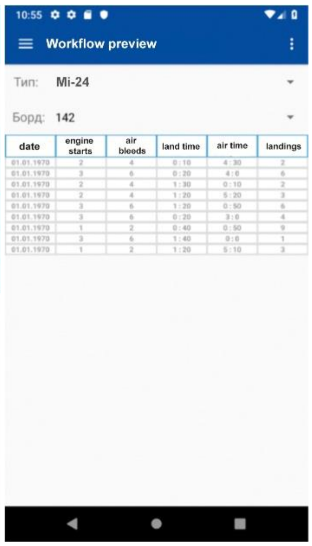


Figure 10. Review of daily working hours

7. Conclusion

In order to optimize the servicing, to reduce the costs and to increase the security when operating aircrafts in aviation, an intelligent multi-agent system for early failure notification and forecast logistics is offered. The system is organized modularly. The implementation of the module for mobile devices is discussed more detailed, which includes an application with an operating personal assistant. The assistant delivers to the user adaptively personalized information about the life and the work of the used aircrafts and their units.

8. Acknowledgments

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