Developing a Model of Multi-Agent System of a Process of a Tech Inspection and Equipment Repair

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Abstract. This paper examines the issues of efficiency upgrading of using existing tools and possibilities to maintain and repair equipment, and to reduce the workload of the staff. The MRO process of the facility is analyzed in this report. The basic models and the functions they perform are defined in this report. The agent-based approach is used to model a simulation of MRO process. Conceptual and logical models of MRO process are developed here.

Keywords: equipment, maintenance, repair, maintenance and repair, maintenance and repair organization, methodical and software and information support of maintenance and repair, maintenance and repair methodologies, agent-based modeling, multi-agent systems, intelligent methods, automation.

1 Introduction

The main objective of improving the quality of operation of the equipment is to ensure a long and trouble-free processing of the parts with specified performance, accuracy as well as with minimal time, labor and money on maintenance and repair (MRO), which are necessary to restore the technical qualities of machines which, lost during the process of operation. To solve this problem facility organizes system of maintenance and repair (M&R) process of tech equipment (TO).

M&R Management MOT carried with impact on MRO regime characterized by periodic maintenance and maximum admissible (critical) determines the deviation parameter (criterion of limiting state) equipment from the normative values. Consequence of the effective implementation of this intervention is to improve the content of the existing equipment and a clear realization of all kinds of its systematic maintenance and planned repairs. It increases the adaptability of operating period of the life cycle of machines, in other words maintainability, which should be used as a criterion of effectiveness of MRO process [1].

Choice of the methodology takes a major role in increasing the efficiency of MRO, in this report we will consider the methodology MRO according to actual technical condition.

Methodology MRO based on the actual technical condition is aimed to prevent equipment failures and it involves constant monitoring of its technical condition, identification of existing or developing defects and also to determine the optimal time

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to start the repair process. This methodology is based on the fact that there is a relationship between the possible malfunctions of equipment and structural elements by the respective technical indicators. It means that conducting monitoring of various parameters, which characterize the operation of the equipment, can detect the change of its condition in time and it allows conducting technical service only when there is a real threat, in other words, when the parameters show unacceptable performances[2].

Practical usage of this methodology involves fulfilment of the following conditions:

1. Deep understanding of structure of the equipment: for each piece of equipment the following characteristics must be defined:

   - a set of indicators, each of which defines the technical condition of the component instance equipment, and the entire set of fully reflects the state of the instance. Moreover, for each of Index defined a certain critical level, the achievement of which means high probability of breakage;
   - a list of faults (failures). Fault type is determined by the values of a set of technical indicators for this instance of equipment. The necessary work and supplies to eliminate malfunctions are known.

2. Each piece of tech equipment must be monitored in real time to check its technical indicators (usually solved by using PCS).
3. Keep the statistic data of the values of technical indicators, and the history of each instance of MRO equipment. This information serves as a basis for revising critical values of indicators and standards of technical maintenance and repair [3].

In this case, simulation modelling is used, in some sources it called dynamic modelling. Simulation model can be viewed as a set of rules (differential equations, maps of states, machines, networks, etc.), which define the transformation of the current state to the other state. In this case imitation is the process of "making" model, the conducting it through the (discrete or continuous) state changes in time. Generally for complex problems, which involve time and dynamic issues this simulation, is a more powerful tool for analysis.

Advances in the development of approaches and media development of simulation models make them virtually uncontested by support decision-making for complex systems. Recent advances in the field of computer simulation is an agent-based modelling. There exists many definitions of agent and agent-based approach to simulation. Common to all these definitions is that the agent is an entity that has an activity, autonomous behavior, it can make decisions according to a certain set of rules and it can interact with the environment and other agents. Agent-based models are used to study the de-centralized systems, dynamics functioning of which is determined not by the global rules and laws, but on the contrary, these global rules and laws are integral results of individual activity of multiple agents[4,5].

Agent-based approach to simulation modelling has been successfully used in many fields of knowledge - for example, in engineering, sociology, economy and ecology. Reflecting the impact of this approach recently is the selection the independent directions in the various social science disciplines such as “computational economics”, “computational sociology”, etc. [6].

It is obvious that the application of this modelling approach is most convenient when we are interested in the behavioral characteristics of the whole system, which are defined as the integral characteristics by the set of these agents. One and the same system can be built under different paradigms depending on the goal modelling[7].

Thus, now is the actual task of optimizing the system control maintenance and repair of process equipment engineering facilities by maintainability impact on MRO regime based on the implementation of the principles of the process approach[8].

Current scientific developments in this field were reviewed such as the development of a simulation model predicting the dynamic changes of the status of technical systems for effective planning of a cost for maintenance and repair [9]. Creating simulation models based on the MRO intelligent agents [10]. Development of support MRO decision-making process described in [11, 12]. Approach study process of repair and maintenance of the equipment of the facilities integrated in [13]. Modelling of process MRO in aviation and astronautics described in [14, 15].

2 Goals and Objectives

The goal of this work is to improve the efficiency of the use of available funding for the maintenance and repair of equipment, reducing the load on the experts, as well as development of software that would allow simulating the MRO process of a facility.

To achieve this goal we have defined following tasks:

1. Study domain - Maintenance and repair of equipment;
2. Research a MRO facility;
3. Development of conceptual and logical models of MAS of the MRO process.
4. Development of software tools to implement the prototype of MAS, which models the MRO process.

3 Researching of the Subject's Field

The object of the research is the process of inspection and repair. In order to research and to model this process we have selected a repair and service company, which performs maintenance and repair of various equipment for various customers in many geographically dispersed locations.

The subject of our research is the process of repair and maintenance of the repair-service facility, to be more exact it is the way a repair team, which is specialized in one type of the equipment, performs this process. For example, dynamic equipment: pumps. A repair team works by the repair technology according to a factual condition of equipment.

Repair team performs the following tasks:

- periodic inspection of the equipment;
- apply for a parts from store;
- repair of equipment;
- start \ stop equipment;

During MRO, repair team can identify the following periods:

- inspections of equipment;
- deciding if a repair is necessary;
- stop equipment;
- filling and submitting an application for the necessary parts at the store;
- sending a request for missing parts in stock to the supplier;
- obtaining details from the supplier;
- storing parts and giving it to a master;
- obtaining of a set of parts and repairing equipment;
- launch equipment..

The main essence of the MRO process was highlighted:

1. Equipment is technological equipment, which is loaded with materials or blank means, and technological snap to perform a specific part of the process. These include, for example, casting machines, presses, machine tools, test equipment, etc.
2. Master is a skilled worker engaged in inspection, technical maintenance and repair of equipmentt;
3. Warehouse is a space (or a complex of it) for storing the material values and the provision of storage services. In logistics warehouse performs the function of accumulation of reserves of material resources, needed for vibration in the supply and demand, as well as for syncing speed of the flow of goods in the transportation systems from the manufacturers to consumers or material flows in industrial production systems.
4. Supplier is any legal entity (organization, company, institution) or a human who is supplying goods to customers. Supplier carries out business activities in accordance with the terms of a contract, which is a type of a sale contract. In the supply contract, the Contractor shall transmit goods produced or purchased by him to the due date or dates to the buyer for use in entrepreneurial activities or other purposes not related to personal, family, household, or other similar use.

4 Results

The work was investigated and analyzed the process MRO repair - service enterprise, clearly shown in Fig. 1.

During a detailed analysis of the MRO process of the servicing company, the main model objects and sets of functions that they perform were highlighted.

Based on a detailed analysis the model of the multisystem was developed. Another "Mai Engineer" was added who supervises work of all "Engineer" objects. Takes repair requests and distributes their employment depending on the workload remaining.

Agents «Agent» in the model are: the identifier ID (name of agent), O – multitude of agents that are associated with this agent, the action repetition frequency of the owner's agent with other agents Freq, and a plurality of basic organizational structures - ORG^A, relevant to specific functions (roles) agents:

$$\text{Agent} = \{\text{ID, O, Freq, } ORG^A\} \tag{1}$$

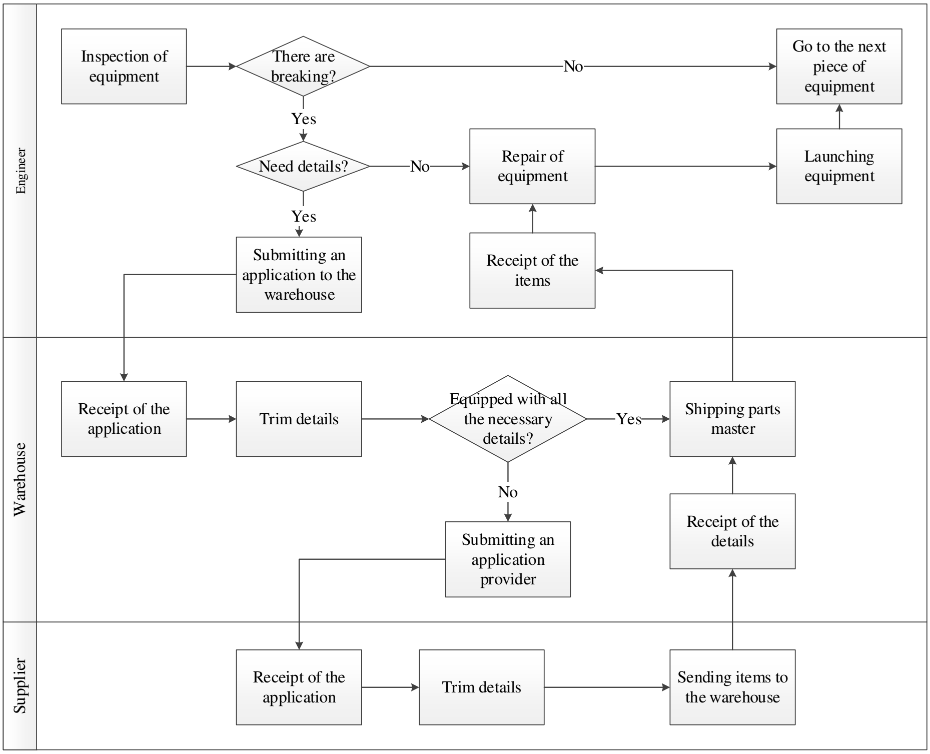

Fig. 1. MRO process of repair and maintenance company

Table 1. Basic model objects and functions

Object	Functions
Equipment	Change in efficiency status.
Engineer	Equipment inspection; Equipment stoppage Parts Ordering; Details acquisition; Equipment launch.
Warehouse	Receiving the order; Order fulfillment; Details acquisition; Parts Ordering; Items reception.
Supplier	Receiving the order; Order fulfillment; Details acquisition;

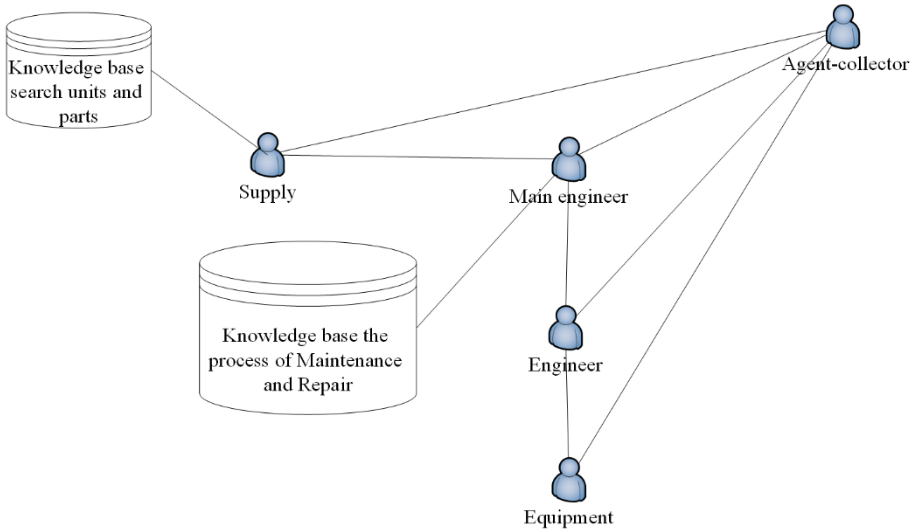

Fig. 2. Model of the MAS

The organizational structure of the agent is formally described as:

$$ORG^A = <S^A, R^A, CP^A, ACT^A, \mathrm{Re}m^A, STR^A, \mathrm{L, ST, SL, T}> \quad (2)$$

where S^A - Agent's goals set that it has to perform to complete for its task ;
R^A- agent roles set which he must act to achieve the relevant objectives;
CP^A - the agent skills and abilities set, which he must possess to give to fulfill the respective roles;
ACT^A- set of the agent's actions;
Rem^A – Agent's memory that stores the actions performed by the agent;
STR^A- agent's behavior strategies set which leads towards achieving the relevant objectives;
ST - set of states of the agent;
SL – agent's operation limitations set.
T - generalized transition function
T: ST×ACT×SL→ 2ST , satisfies the following conditions:
a) for any st, act˛ ACT, sl˛ SL, if the state st satisfies
restriction of φ, st |= φ, and a pair of <act, φ>˛sl, тo T<st, act, sl> -> φ;
b) for any st˛ act˛ACT, sl1, sl2 ˛ SL, if sl1 > sl2 , then T<st, act, sl1>˝ T<st, act, sl2>.
Agent memory - preserving processes executed by the agent is represented as:

$$\mathrm{Re}m^A = Save\ (st_0 - (act^{0/} /sl_0)\text{fi}\ st_1 - (act_1 /sl_1)\ \text{fi}\ ...st_n - (act_n /sl_n /)\text{fi}\ ...) \quad (3)$$

The repetition rate of the owner's agent actions with other agents is presented as a function depending on the interacting Ce, certificate, the relationship between them and the history of the agent $\mathrm{Re}m^A$:

$$\text{Freq}=f(\text{Agent}, O, \text{Re}m^{A}) \qquad (4)$$

Where the function f – the processing of interacting actions frequency repetition and a descending sorting of agents' familiar O-sets.

Agent "Equipment" has the following states:

- work;
- idle;
- breakdown.

He also includes a list of parts and relationships that make up the equipment. Several key parameters for each element by which the values of the state of the equipment are determined.

Agent "Engineer" has the following states:

- diagnostic an equipment;
- launching an equipment;
- repair of an equipment;
- stoppage of an equipment;
- sending an equipment state data to " Chief Engineer " agent;
- receiving instructions from agent "Chief Engineer";
- obtaining materials for the repair of the agent " Chief Engineer".

Agent " Main Engineer " has the following states:

- receiving a report on the state of the equipment from the agent "Engineer";
- analysis of the resulting report;
- deciding on a repair necessity;
- ordering the necessary parts for repair;
- obtaining the necessary parts for repair;
- transfer advice and parts needed for repair to agent "Engineer";
- load distribution between the agents "Engineer".

For a decision on the need to repair agent «Main engineer " uses the knowledge base. Now there is still no generally accepted methodology and universal MRO. Therefore, different methodologies for modeling process MRO must use the knowledge base, designed specifically for the chosen methodology. What complicates the process a little modeling.

Agent «Supply» has the following states:

- receive a list of items from the agent " Main Engineer ";
- order parts from the supplier;
- receipt of the items from the supplier;
- transmission parts agent " Main Engineer ";
- search and order these parts.

In the absence of the necessary parts, agent "supply" can prolime search similar items with the use of a knowledge base on the coincidence of structural parameters and function.

To search for similar items developed knowledge base based on AND / OR graph. Which consists of the following elements:

- Repair Facility - equipment. Contains functions.
- Functions - actions that can be performed to repair or nodes. Contains links and details.
- Node - elements of equipment that can perform a set of functions separately from the hardware. Contains functions.
- Detail - the item is not carrying in itself or any functional singularities.

The developed model is used to determine the amount of labor management technicians servicing company, by building models MRO process with different variations of congestion specialists. Data modeling of these processes are analyzed and compared with each other to determine the most optimal process MRO with an approximately equal load on specialists. Just the proposed improvements on the supply stage can significantly speed up the search process and get the details now.

5 Conclusion

In this paper, we have reviewed and analyzed the modern scientific developments in the field of modeling the process of maintenance and repair of equipment. Reviewed and analyzed the process of MRO repair - service enterprise. The basic model objects and sets of functions that they perform. Developed conceptual and logical models MAC MRO process.

We are planning to use software tools in order to embody the MAS prototype, which models the MRO process and after we are planning to use the developed model.

In the future we plan to implement the software tool for the implementation of the prototype MAC modeling process MRO and validation of the developed model.

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