A CO-OPERATIVE CONTROLING ENVIRONMENT IN MAN-MACHINE SYSTEM

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Abstract: In the disassembling process context, the supervision and control system assumes very large dimensions, represented by the need to automatically plan the disassembly process of the end-of-life product, including generation of product model, identification of the best sequence of operations, planning the actors (persons and machines) and programming the machines used to perform this task. This paper describes supervision architecture by analysing the supervision and control system of a disassembling process, and proposes two types of supervision architecture. It also describes a structure of decision-making system within global supervisory level.

Keywords: supervision, control, planning, man-machine system, decision making, agent

1. INTRODUCTION

Today, supervisory control of industrial processes is a main research area. Supervisory control consists of several tasks: monitoring system behaviour via sensory feedback, control evaluation in accordance with a supervisory control law, and control implementation via appropriate device programs on local control level (Forgel, 1997).

Generally, an industrial process represents a production system, which may be continuous, semi-continuous or a manufacturing system according to the production type (Lambert M., 1999). The manufacturing production system is extremely complex, especially in its assembly process; only recently, flexible automation techniques have been extended to this area (Sanatochi and al. 1992).

A few years ago an idea for a new manufacturing production system emerged, namely: the materials and components present in discarded goods (end-of-life product) should be re-used to manufacture new goods. The simplest way to obtain raw materials is by shredding. However this method is not the best (we have to take ecological conditions and material purity into account). One solution is to re-use what can be re-used before recycling end-of-life products; this requires separation of various kinds of materials using a specific disassembling process (Chevron D., 1999) and (Skaf and al., 1999)

The re-using and disassembling ideology reveals a new process in manufacturing production systems, called the disassembly process, which is not the reverse of the assembly process and which is often more complex then the assembly process. The disassembly process reveals the need for a high level of flexibility in supervisory control and in execution processes.

In the disassembling process context, the supervision and control system assumes very large dimensions, represented by the need to automatically plan the disassembly process of the end-of-life product, including generation of product model, identification of the best sequence of operations, planning the actors (persons and machines) and programming the machines used to perform this task. In this paper, a supervision and control system for disassembling processes is analysed and a supervision structure is proposed. Finally a brief conclusion is given and further work is pointed out.

2. SUPERVISION ACTIVITIES

Supervision can be defined as a set of tools and methods allowing control of an industrial process both in normal operating conditions and in the presence of failures or disturbances (quoted in Lambert M., 1999. pp25).

Generally, supervision activities can be represented by the control, monitoring and detection activities of failures of the industrial process, the diagnosis and decision-making activities for accommodation or reconfiguration of processes (on-line control of industrial processes). These activities can be performed either by algorithms, in the case of completely automated systems, or by one or more human supervisors with computer tools. The latter represents the majority of production systems. Humans, in supervisory control room, assume responsibility on a very extensive technical system with many implications: safety of people on site, production, risks for environment and security of production equipment, etc. For this reason, supervisory activities must be based on sophisticated computer tools aiming at helping the supervisor in his control task, either by assistance or by the assumption of responsibility of part of this task (proposed by Millot quoted in Lambert M., 1999).

3. SUPERVISION ARCHITECTURE FOR DISASSEMBLING SYSTEM

The supervision level in disassembling system incorporates two supervision aspects: global and local supervision (Skaf and al., 2000). These two aspects and their relationship with the system are shown in figure 1, which represents architecture for the supervision level. Global supervision consists of four sub-systems:

1- Sub-system for sequence generation.

2- Sub-system for selecting the best sequence.

3- Sub-system for disassembling operation planning.

4- Sub-system for generating the disassembling plan.

The local supervision itself represents a sub-system designed to cope with perturbations during execution of a disassembling plan generated by global supervision.

The aims of global supervision sub-systems are given below.

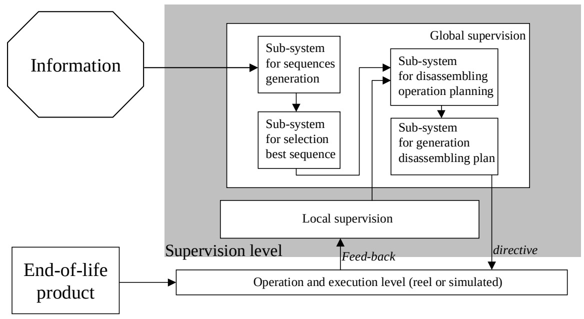


Fig.1. Supervision level architecture

3.1 Sub-system for sequence generation

The aims to be achieved in this sub-system are:

1. Organisation of geometrical and technical information about the product to be disassembled, in a product model. This information is taken from the CAD model and database.

2. Organisation of information about costs related to the disassembly process. This information is taken from the database including technical, ecological and economical conditions that define the relevant cost.

3. Generation of all sequences for disassembling either the whole product or only a component, in one case considering only feasibility, and in another considering cost.

3.2 Sub-system for selecting the best sequence

The aim of this sub-system is to generate an optimal disassembling sequence described by a numbered list of components to be disassembled.

3.3 Sub-system for disassembling operation planning

The aims of this sub-system are organisation of technical information (availability, capability of actors and generation of robot and human tasks) basing on the list of components to be disassembled and on the analysis of each component for selection of tools and gripping method (for generation of a list of manual and robotised operations) (Sanatochi and al. 1992). The robotised operations are used for trajectory planning, which are refined in the simulation environment (see figure 2).

The output of this sub-system is the operations and trajectories planned that the robot and operator must perform in order to handle and disassemble the selected component or all the components.

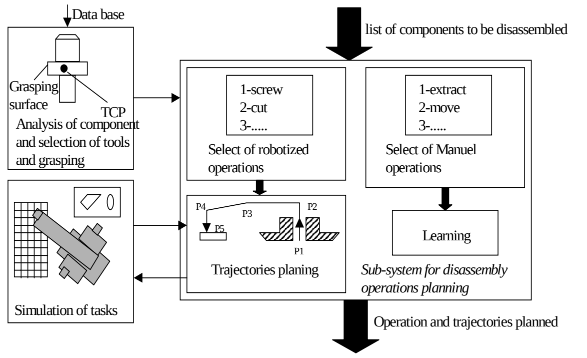


Fig.2. Sub-system for disassembling operation planning

3.4 Sub-system for generating a disassembling plan

In this stage, the operations and trajectories planned are processed to generate a final human and robot task.

Those four sub-systems can be created off-line and on-line. The off-line method is generally not a reliable way for a disassembling system of end-of-life product (many hazards). The on-line method is thus the alternative.

4. PROPOSED DESIGN FOR SUPERVISION LEVEL IN DISASSEMBLING SYSTEM

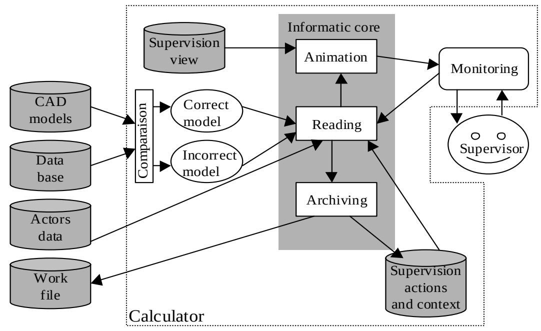
Two structures for the supervision level are proposed; one corresponds to four sub-systems (or global supervision). Another one is for local supervision. In the following sections a description of these structures is proposed.

4.1 Structure for global supervision

The structure, which will be installed for each global supervision sub-system is shown in figure 3. This structure is made up of 3 main parts: supervisor, calculator and external data resources.

Concerning the supervisor, we assume that he performs the following activities (skaf and al.,1999):

- Initialising the disassembly process;
- Participation in direct control or problem solving. His knowledge in the field will enable him to evaluate the solutions proposed by the calculator;
- In case of disagreement, it is up to the man to take the last decision, except if the solution proposed by the man does not conform to formalised know-



how and rules.

Fig.3. Global supervision structure

The calculator is represented by the computer core, which consists of three blocks: animation, reading and archiving. The reading block performs the following tasks:

- Reading the correct (or incorrect) model of the end-of-life product. These models are built by comparison of CAD models (for new products) with the data model from the database, which includes the damage and deformation degree for all elements.
- Reading controlling data and capability of technical actors (machines, robots), and the personal file of the human actor.
- Reading supervision actions of the supervisor from the monitoring block.
- Reading the supervision actions and context from the archive, and comparing them with actual actions and context. Processing the result for controlling the monitoring block.
- Controlling the animation and archiving blocks and thus the monitoring and data archiving.
- Processing received data to generate a work file intended for the operation and execution level. This file contains operation and trajectory planning for the machine (robot), and intervention operations for the human operator.

The animation block is controlled by the reading block and eliminated by supervision data views, which contain all views enabling the supervisor to control the process and to make the best decision. Consequently, this block controls the monitoring block, making it possible to interactively work with the supervisor.

The archiving block performs the following tasks: saving the supervisor's actions, working context and sending the work file.

4.2 Local supervision structure

Local supervision represents a sub-system designed to cope with perturbations during the execution of a disassembling plan generated by global supervision (see paragraph 4). Consequently, the structure of this sub-system is different from what was described in the above paragraph. The structure proposed for local supervision is shown in figure 4.

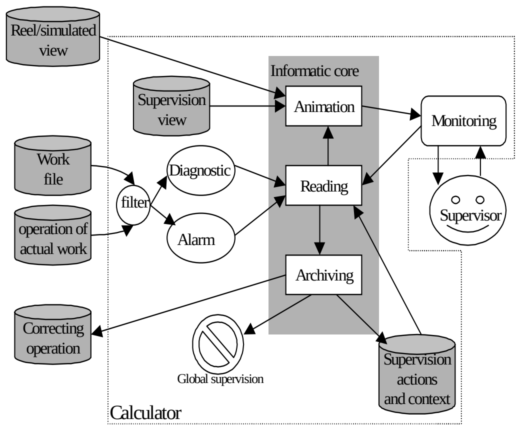


Fig.4. Local supervision structure

The function of this structure is similar to the function of the previous structure with some highlighted points (in order to increase system reactivity):

- The information from the work file and operation of actual work are filtered to generate a diagnosis context for the following operations. This is the case of normal functioning or normal functioning with a little perturbation. Otherwise, an alarm will be activated. Both cases are read by the reading block and processed with participation of the supervisor. If a solution is found, the corrective operation will be generated; otherwise a call for global supervision will be made.

- The animation block completes the supervision views by connecting to a real (or simulated) view. This actually helps the supervisor considerably during decision making.

5. DECISION-MAKING SYSTEM FOR DISASSEMBLING SYSTEM

In this section, implementation of decision aspects of global and local supervision is treated. These aspects are represented by the decision-making system within the reading model of the computer core (see fig. 4 and 5).

The decision-making system is designed to choose and create the best dismantling sequences in real time. The decisions will depend not only on environment context, but also on the current state of the product and current situation. The input of this system is a set of all possible sequences to perform and all information about relationships between the parts of the end-of-life product.

The proposed decision-making system is based on multi-agents system architecture. The advantages of this architecture are easy implementation of system and easy migration to a real system.

5.1 System structure

As shown in figure 5, the system is made up of four units:

1) Database unit: represents a set of inputs, pre-processed and output data. This database especially contains all possible sequences and product models (geometrical, mathematical and other models).

2) Decision-making unit: represents a set of agents with references to database and which dynamically choose the best step to perform from the proposed set of sequences.

3) Controller unit: represents a set of agents that can interact with the actor unit (robots or operators). The controller agents carry out the operations which were chosen by a decision-making unit. To carry out an action, robot and operator objects are used

4) Actor unit: represents a set of actors that interact with the system to attain the objective designated by the decision made. In figure 6, this unit is shown as a supervisor, operator and robot.

5.1.1. Decision-making (dynamic model)

In this paragraph, the decision-making approach will be described by application examples and class and sequence diagrams (using UML language). Concerning the sequence diagrams, three of them will show how the process starts, how to perform a new step and how to modify an action.

a) Application example for decision-making:

As shown in figure 6, there are two actors for the decision-making system. One is the supervisor, who can start or stop the disassembly process, change the decision and perform a manual action. Another is the

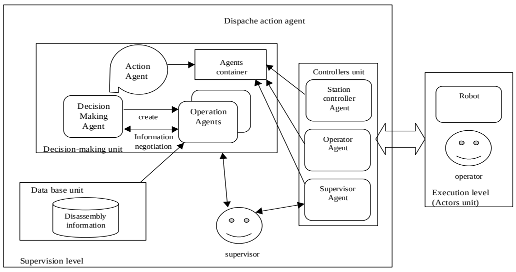


Fig. 5: System structure.

stimulator (a fictitious actor) who can start the decision-making process. The aim of decision-making is to create new actions and/ or to modify old actions.

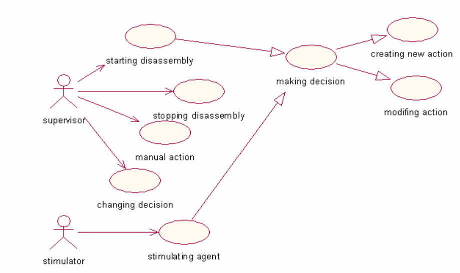


Fig. 6: Use cases diagram

b) Class diagram of decision-making agent

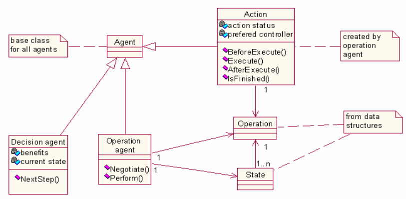


Fig. 7: Class diagram

There are three types of agents in the decision-making unit: Operation, Decision and Action agents (see figure 5 and 7):

The decision agent is an agent that makes a decision based on information from operation agents. This agent has its current state (a node in the state tree: the state tree is the hierarchical representation of all possible sequences).

Initially the state of the decision agent is the tree root. At every step this agent updates its current state. At the beginning of the dismantling process, this agent creates the operation agents for all operations in the state tree. To decide which operation should be performed on the current state, the decision agent asks the operation agents (using the Negotiate method). The decision agent chooses the operation agent which returns the highest value (economic index).

The operation agent is an agent that is created for each possible operation in the state tree. This agent has a Negotiate method which returns a numerical value (economic index).

The action agent is an agent that is created after making a decision. It is created to perform a chosen operation. It is a mobile agent and can be dispatched between two units: decision-making and controllers (figure 5). If the controller unit has problems with performing the action, the action agent is dispatched back to the decision unit. In this case another decision has to be made or the action agent has to be cancelled.

In the next three figures we show the decision-making procedure: first how to start the process, then how to perform a new step by creating an action and how to modify an action should a problem arise.

1) Sequence diagram for starting dismantling

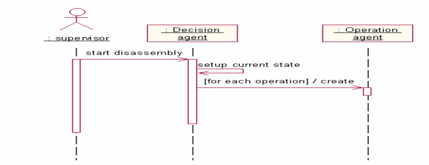


Fig. 8: Starting disassembling

2) Sequence diagram for new step by creating an action

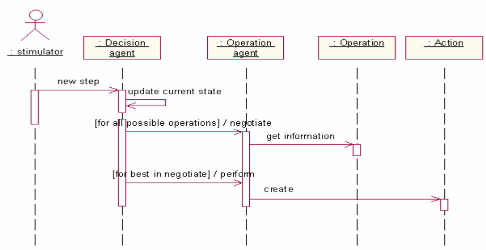


Fig. 9: Creating an action

3) Sequence diagram for action modification

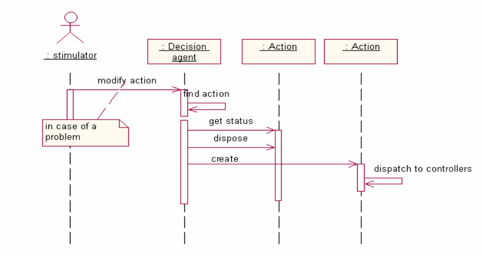


Fig. 10: Action modification

c) Controller unit (dynamic model)

In this unit also, three agents are considered: station controller agent, supervisor agent and operator agent. These agents intersect (and control) with two objects, the robot and the operator (which represent an execution level). Figure 12 shows the class diagram of the controller unit.

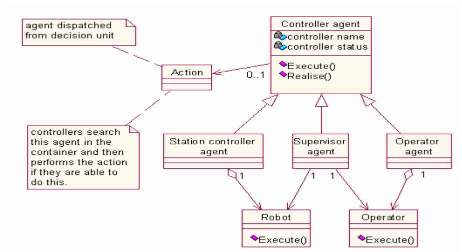


Fig. 11: Class diagram of controllers

Each controller agent is stimulated by the system. Then the free (not occupied) controller agent (in accordance with its specialisation) looks for an action agent in the agent's container (figures 5 and 13), if this agent exists, then the controller agent tries to create it.

If the action was successful, the action agent is disposed of. Then the decision unit will create the next action agent that will represent another operation). If execution failed, the action agent is not disposed of. It is dispatched back to the decision unit for reprocessing (it is analysed, disposed of and a new action agent is created if necessary).

A full functional scenario of the controller unit is shown in sequence diagram figure 13.

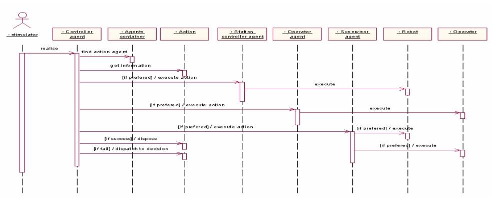


Fig. 12: Sequence diagram of action execution

5.2 Implementation

The two supervision levels and the developed decision-making system are implemented in Microsoft Visual C++ environment. The Application consists of four main windows. The key feature of this application is its flexibility and portability. All four windows were designed for user convenience, incorporating the ergonomic aspects for each interface. This ensures easy interaction and participation in the decision-making process.

6. CONCLUSION

In this paper the supervision architecture for production system (disassembling system) was presented. Two types of supervision were described: global supervision and local supervision. The decision-making aspects were emphasised by proposing a structure of decision-making system based on multi-agent theory.

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