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Role of the Adviser Module in the Hybrid Assembly Subordinating Control Structure

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Abstract

Modern trends in product development are characterized with the rise of product complexity, variety and shorter lifetime. These trends introduce new challenges for assembly systems. Developing line of assembly systems is a part of a general evolution of modern production systems. This evolution is focused on use of computer integration, intelligence and self organization for the improvement of assembly system efficiency. Bionic Assembly System is a very good example of this development. These systems are becoming more and more complex with complex working scenarios and sophisticated control structures. System operator is the main decision maker in modern assembly systems. He has to make real time decisions with good balance between the quality of decisions and the time needed. This directly influences the system efficiency. Intelligent Adviser Module advices the system operator during decision making. Adviser takes into consideration all relevant data and parameters from all parts of the system. Adviser module is a promising tool and a direct realization of artificial intelligence in the modern production systems. This article presents research results on Intelligent Adviser Module structure and its functions.

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Keywords: adviser module; operator; efficiency; hybrid control structure; intelligence; Bionic Assembly System

1. Introduction

Modern product development is characterized with the rise of product complexity, variety and shorter lifetime [1]. This introduces new challenges for assembly systems. In order to adapt to these new challenges, assembly systems need to evolve. Very strong influence on the assembly system efficiency comes from the abilities and

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limitations of the control system, structure, scenarios, algorithms and methods used. Modern assembly systems need to be human centric [2] as shown on Fig. 1 and should be generally characterized adaptability, flexibility, self organization, autonomy and networking. They also need to be adaptable in real time, maintenance friendly, energy saving, life cycle manageable, capacity utilizing and tolerant to faults in processes. The evolution of control structure is focused on the use of computer integration, intelligence and self organization for the improvement of assembly system efficiency [3]. Bionic Assembly System is a very good example of such evolving trends. It is based on a self-organization - phenomena generally known and used in nature [4] as proposed and described by the Intelligent Manufacturing Systems (IMS) group from Vienna University of Technology.

The sophistication of control structures is proportionally increasing with the rise of working scenarios complexity. As a result the complete system is becoming very complex and more difficult to manage and to control. There are more and more subsystems that need to communicate with each other as well as increased number of shop floor elements that need to operate in harmony [5].

Modern assembly systems need to have the following characteristics:

- High efficiency, adaptability and robustness in their realization of working scenarios
- User suitable and friendly for planning, controlling and monitoring
- Able to learn from past working cycles
- Use of Artificial Intelligence tools within the control structure

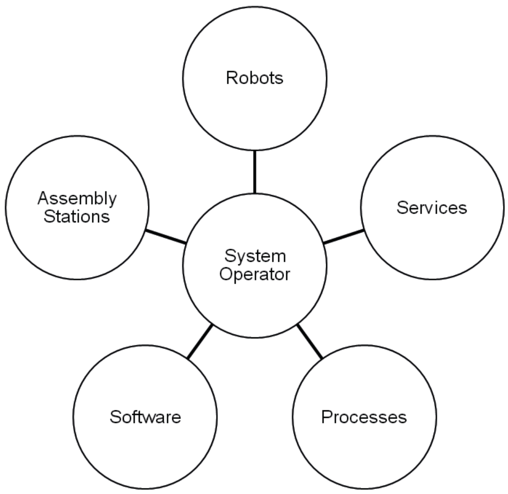

Fig. 1. Human Centric Modern Assembly Systems

IMS group is currently focused on the development and implementation of the Intelligent Adviser Module within the subordinate control structure of hybrid assembly systems. Preliminary results of this research are presented in this paper.

2. Problem Statement

System operator is the main decision maker. He has to make real time decisions with good balance between the quality of decisions and the time needed. This directly influences the system efficiency.

It is difficult for the operator to have an overview of the entire system during long period of time and its states. In addition to that, he works in a place where there are a lot of distractions. They can be in a form of loud noises, less than optimal visual overview of the facility or large amounts of data that he needs to take into consideration [6]. To reach a decision on how to proceed with the assembly, the operator has to know each individual state of different subsystems. These subsystems execute working scenarios which start with orders and finish with assembled products as shown on Fig. 2. During the execution of a working cycle internal and external resources are being used. The same resources are also a potential source of disturbances.

Normal working scenarios are realized automatically according to the planning results. During that time the need for the operator is very low.

There are situations where the need for the operator is very high:

- During the planning of working scenarios
- When the realization of working scenarios is not running according to the planning
- When malfunctions of equipment occur

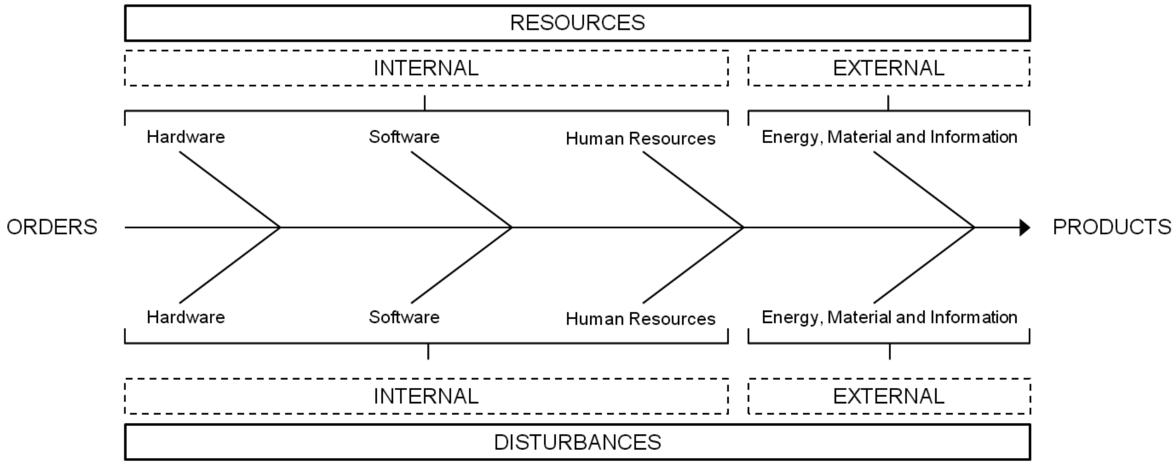

Fig. 2. Resources and Disturbances

3. System Description

Control structure and scheduling in hybrid control structure is described in [7]. Working scenarios in Bionic Assembly system using the cloud as an informational interface are described in [8]. Fig. [3] shows the role of the intelligent adviser module in the subordinating control structure.Adviser Module serves as an informational interface between the system operator and the rest of the assembly system.

It communicates with the following modules within the subordinating control structure:

- System Operator
- Pool of Orders
- Stock of Resources
- Criterion of Planning Module
- Scheduling Module
- Target State Data Module
- Actual State Data Module

It communicates with the following shop floor components within the facility:

- Assembly Stations
- Robots
- Shop Floor Operators

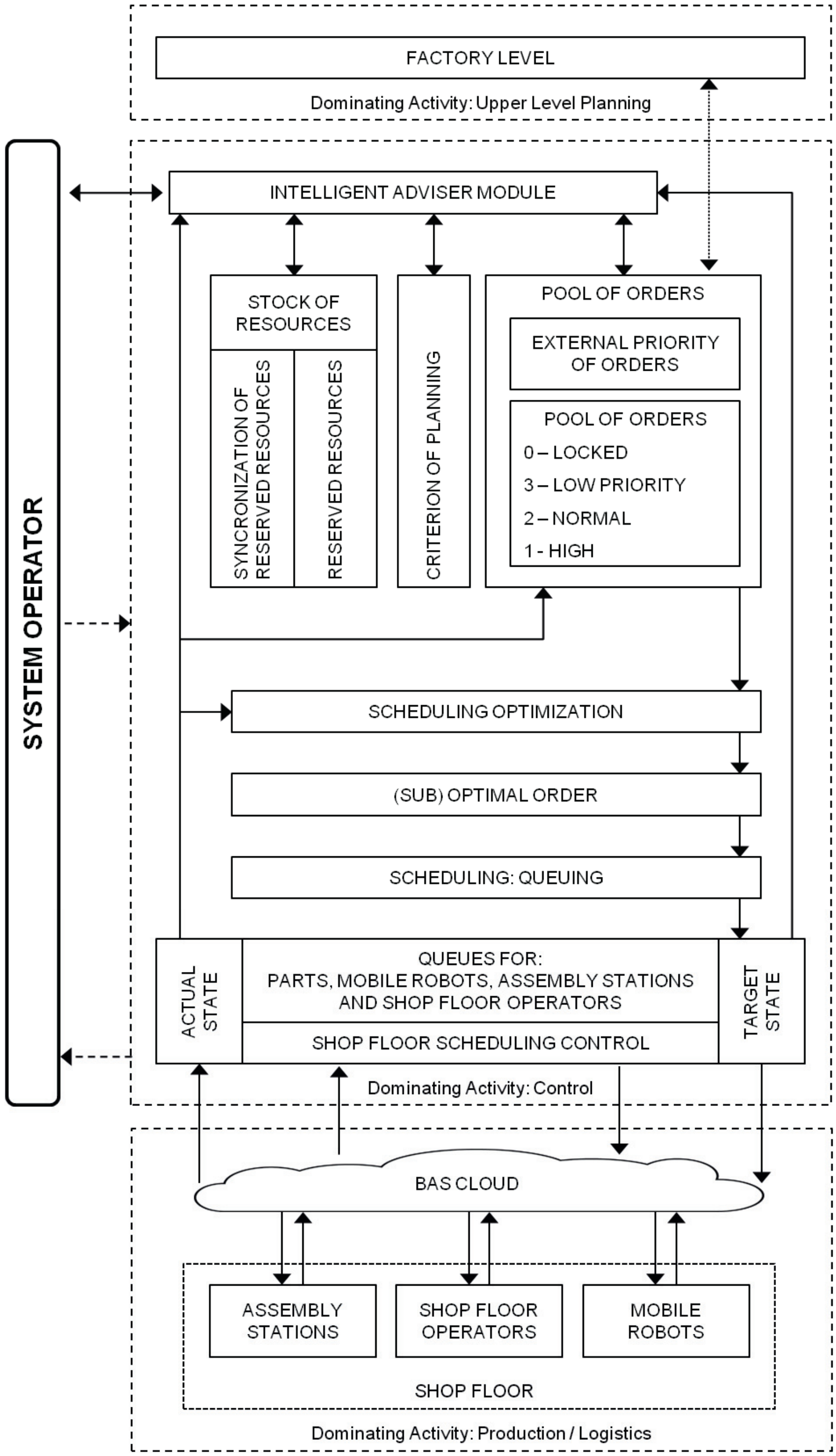

Fig. 3. Role of the Intelligent Adviser Module

A system operator is a human expert whose main task is to overview, control and to make sure that the system completes the orders on time. The operator is the only one who makes decisions and gives orders within the assembly process. Based on his experience, knowledge and intuition he has to be able to recognize signs which indicate that there will be something wrong during the assembly.

System orders are coming from the factory level which represents the upper level of planning. One order contains the customer name, pickup date and type and number of products. The orders are stored in pool of orders. Priorities are assigned to the individual orders. Priorities represent a control mechanism. They ensure that the orders with the highest priority will be finished and removed from the shop floor first. In self organizing assembly this is very important because of the nature of self organization - there is no central command structure. In a context of a factory environment, where everything is being made with a goal, the priorities mechanism main purpose is to direct the collective without specifically issuing an order to each of the individuals.

Stock of Resources tracks the status of all the equipment, additional hardware resources including maintenance and operational materials. It allows making future assembly scenarios and backup plans. This is a very important source of logistical information. The planning phase would be impossible without it.

Criterion of Planning Module sets the desired strategy for completion of the working scenarios [9]. It is used to select the most suitable orders from the pool of orders based on the status of the hardware, software, human resources and the assembly system as shown on Fig. 4.

Scheduling is the next part of the subordinating subsystem. The result is a queue which represents a (sub) optimal order of completion. It is not optimal because the orders, robots, assembly stations and shop floor operators are all variable and thus the system state is dynamic. It is impossible to have a real time optimal calculation due to the infinite number of variables, parameters and results.

The main objective is to achieve harmony between the two levels of organizational structures. The first level is a top - down, subordinating control structure, from which queues and tasks are formed. This is commonly known as hierarchy. In this structure all commands are coming from one source - the system operator. The second level is the execution level.The execution level can represent any kind of shop floor organizational structure. It can be a production or an assembly system. It can be organized as a flexible or self organized system as proposed and described by the Intelligent Manufacturing Systems group from Vienna University of Technology [10]. The goal is always the same: to achieve the balance between the target state and the actual state.

- Target state represents planned activities. It is what should happen.
- The actual state represents the realization of the planned activities. It is what has happened in the real and unpredictable world.

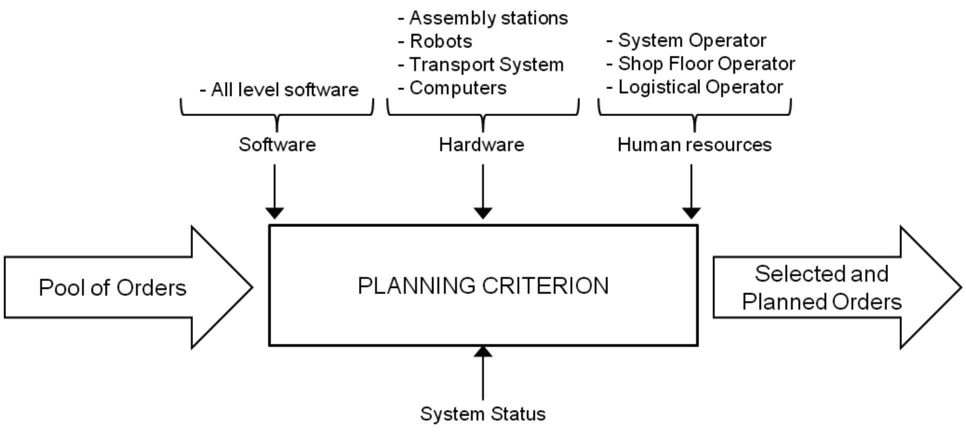

Fig. 4. Criterion of Planning Module

4. Intelligent Adviser Module

The concept of collecting data from all subsystems and their processing in order to achieve better performance is used in Enterprise Resource Planning (ERP) systems. [11] The main principle in Enterprise resource systems is that all data from all parts of the enterprise is available within the central system. This allows making decisions regarding development strategies, human resource demands, storage control, technology utilization etc. [12].

Intelligent adviser module is a local assembly system data gathering and analysis diagnostic software tool. It collects processes and stores relevant information. Intelligent adviser module is not directly involved in control.

Intelligent adviser module has the following functions:

- Track progress of planned scenarios realization
- Data analysis
- Learning

1) Progress of realization of planned scenarios is possible to determine from the analysis of the target and the actual state of the system. If the difference is close to critical the adviser module advices the operator what to do in order to keep the realization of working scenarios. In case that the planned scenario cannot be realized it is necessary to repair the working scenario or to replace it with a new one. Adviser module proposes what to do.

2) Data analysis. Main control information flow is between central control computer and the control system of all the facilities. Through this channel there is a real time exchange of information in both directions. With this channel the control computer gives instructions, commands and data to people, machines and robots. They give feedback information about the realization status and the equipment status. Adviser module continuously analyzes the information from the main control information flow. If he recognizes significant deviations in working conditions (breakdowns, errors, malfunctions) and it proposes solutions to the operator.

3) It has the ability to learn. There is almost always a difference between planned activities and their realization in the real world. System efficiency directly depends on this difference. Smaller difference means higher system efficiency. Adviser module has the ability to precisely predict the duration of future activities based on the experience of planning and execution of equal or similar operations from the past. This ability is described as learning from the past for the efficiency in the future. This is very important for the planning of future activities.

The review of the current development trends of modern assembly systems and its demands on system operators indicates that the proposed Adviser module implementation brings a number of advantages. It is a software solution designed to co -exist with a human operator. The main contribution of such a system is to allow development of human centric assembly systems with increased efficiency in decision making process.

Intelligent adviser module has the following advantages:

- Flexible and universal: this system can be used in any modern production or assembly facility
- detection of early irregularities in the production / assembly
- control experts skill, experience and intuition combined with the data stored in the adviser module help to achieve quick and effective solutions
- reduces stressful decision making environment for the system operator

Intelligent adviser module has the following disadvantages:

- false warnings are possible
- effectiveness improves with higher amounts of stored data. This means that younger systems are less accurate
- rejection of computer suggestions by human operators (“I know better than a machine” principle)

In critical moments, quick and effective operator decisions can have a high impact on the overall performance and efficiency of the system. In such cases, the operator is in a high stress environment. Sometimes this can lead to wrong or less optimal decisions. When irregularities occur, the adviser module notifies the system operator. He has to see what part of the process is not within the specified parameters. He has to decide if it was a false alarm or if there is a need for intervention.

The characteristics comparison between the system operator and the intelligent adviser module are shown in Tab. 1.

Table 1. Characteristics Comparison

Characteristic	System Operator	Intelligent Adviser Module
Intuition	High	Low
Short term memory	High	High
Long term memory	Low	High
Learning	Natural ability to learn	Limited technical ability to learn
Analysis	Medium	High
Robustness	Easily tired	Does not need rest

Human system operator has a high intuition and a natural ability to learn. He has a high capacity for short term memory [13]. There is always a possibility of a human error because he becomes easily tired in comparison with a computer. On the other hand, adviser module has infinite memory capacity with designed ability for quick and precise analysis. The strengths of one side practically eliminate the weaknesses of the other side. This could be viewed as an asymmetric symbiosis between the system operator and the adviser module, where the operator has the master position.

5. Conclusion

Increased product complexity, variety and shortened lifetime have brought new challenges for assembly systems. As a result of that, these systems are becoming very complex. It is very difficult for system operators to efficiently control them. To help them make quality decisions within an acceptable time the adviser module has been introduced. Adviser module is a software tool within the adaptive control structure. It takes into consideration all relevant data and parameters from all parts of the system. Adviser module is a direct realization of artificial intelligence in the modern production systems. These systems are characterized by adaptability, flexibility, self organization, autonomy and networking. They also need to be adaptable in real time, maintenance friendly, energy saving, life cycle manageable, capacity utilizing and tolerant to faults in processes. Utilization of adviser module helps to achieve these goals and characteristic. The main contribution of such a system is to allow development of human centric assembly systems with increased efficiency in decision making process. This research is very relevant in today's context of ever increasing demands on assembly systems.

Future research will be focused on the simulation of adaptive reactions of the control system and the adviser module to the changes during the assembly process. The simulation will be based on a generation of output data from the execution layer. This will allow to observe and to analyze the control and diagnostic algorithms of the upper control structure. The results will be described in the next paper.

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