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Procedia CIRP 55 (2016) 18 – 22

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5th CIRP Global Web Conference Research and Innovation for Future Production

Service oriented architecture for dynamic scheduling of mobile robots for material supply

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Abstract

This paper presents the design and prototype implementation of a service based control system responsible for the material supply operations in assembly lines. Mobile Assistant Units (MAUs) are responsible for the transportation of the consumables from the warehouses to the production stations. A service oriented, web based software has been developed for the monitoring of the shop floor status and the parts' supply dynamic scheduling, based on time and inventory. The proposed system has been applied to a case from the automotive sector demonstrating the ease of deployment and efficiency in the co-ordination of the mobile units' operation.

Peer-review under responsibility of the scientific committee of the 5th CIRP Global Web Conference Research and Innovation for Future Production

Keywords: Mobile robots; dynamic scheduling; service based control;

1. Introduction

The transition from mass production to mass customization has led to the need for designing flexible manufacturing systems that can handle the increased product variety [1]. Towards this direction, research has been done on algorithms [2] for efficient material flow, allowing effective production volumes [3-8]. However, the proposed approaches focus on scenarios where the material supply operations are performed manually.

The latest trends in European manufacturing deal with the integration of intelligent search algorithms with mobile robotics applications in order to support material supply in production lines [9]. Despite the promising advances in this field [10-14] the proposed solutions are facing poor acceptance in real industrial environments. The majority of the proposed applications discusses the introduction of Autonomous Industrial Mobile Manipulators, but the main focus is given to the individual parts of the robotic application, such as the arm or the platform neglecting real use cases requirements [9]. On the other hand, current industrial practice involves the use of Automated Guided Vehicles (AGVs) but they lack flexibility, since they follow strictly define paths, while the loading/unloading of parts to/from the AGV is performed manually. Also, the need of humans to undertake planning activities and the absence of real time feedback of the shop floor's inventory levels restricts the efficient material flow.

This paper aims to overcome these limitations by implementing a Service oriented Architecture (SoA) that will enable the dynamic scheduling of material supply operations in a shop floor. Mobile Assistant Units are introduced (MAUs) [15] for the autonomous performance of such actions.

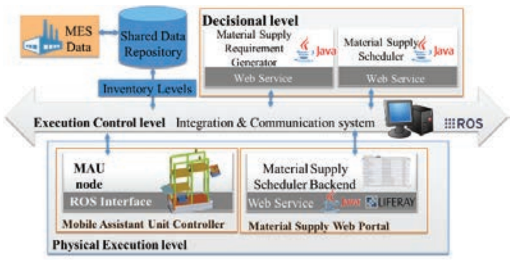

Fig. 1. SoA schema for scheduling material supply operations.

Peer-review under responsibility of the scientific committee of the 5th CIRP Global Web Conference Research and Innovation for Future Production
doi:10.1016/j.procir.2016.09.014

These units can autonomously navigate in the shop floor, while comprise a linear mechanisms with a gripping device for performing the loading/uploaded actions. Through the proposed framework, a material supply scheduler along with the MAUs controllers are integrated into a central integration system that allows their online communication and exchange of data. An online monitoring system of the inventory levels and the shop floor status are also implemented for providing real time feedback. This architecture will enable the online generation of efficient material supply plan based on the shop floor's real time needs in consumables.

2. Approach

The current assembly systems are organized in assembly lines. Such lines involve several assembly stations where the various components of each product are assembled consuming different amount of parts such as rivets, screws, cables etc. [9]. The latter are stored in boxes located in fixed positions, inside each assembly station. Meanwhile, the same type of boxes is stored in warehouses located outside the stations. These boxes are used for replacing the available boxes in the stations when the latter are under depletion.

Given the demand for mass customization, many assembly lines follow the mixed model assembly paradigm where different quantities of parts are consumed by the different models. This results in unbalanced inventory levels within each station. The increase in product variants and the pursuit for random production mix create the need for consumables and parts to be supplied to the stations in a dynamic way [9].

The proposed SoA schema, as shown in Fig. 1 comprises three different levels, namely the 1) Decisional level, 2) Execution Control level and the Physical Execution level. The Decisional and the Physical execution levels are connected through the Execution Control level, which is responsible for the decentralized integration and communication of the system's individual components. In addition, a shared data repository has been integrated into the system.

2.1. Shared Data Repository

The implemented shared data repository that is integrated into the central system stores all the information, provided by the Manufacturing Execution System (MES), while monitoring the shopfloor's status and inventory levels. The latter, provide information on the current activities, dispatched in the shop floor as well as on their status, while monitors the inventory levels in the assembly stations. The modules included in the decisional level have access to this monitoring system so as to retrieve the information concerning the inventory levels. In this way, access to the current quantities of the boxes with consumables is provided at each decision point. Under the material supply scheduler module, specific quantity values have been defined as thresholds for each one of the individual boxes. When the current quantity of one or more boxes is lower than the pre-defined thresholds, the scheduler identifies the need for these boxes to be replaced and the procedure of providing an efficient schedule for their replacement is initialized.

2.2. Decisional level

Since the identification of boxes that have to be replaced has been performed, the material supply requirement generation algorithm is triggered. This algorithm identifies the stations, where the boxes under depletion are located as well as the markets, where such boxes are stored into. Then, it automatically generates a sequence of tasks required for the replacement of each box, defining the precedence relations among these tasks as well. Three type of tasks have been defined: a) Movement tasks, when the MAU needs to travel from one location in the shop floor to another, b) Loading tasks, when the MAU needs to load a box from a market or a station onto its shelves and c) Unload tasks, when the MAU needs to unload a box from one of its shelves to a market or a station. The specific sequence of tasks required for the replacement of one box is listed in Table 1.

Table 1. Task Sequence for the replacement of a single box.

No.	Task name	Type of task
1.	Move to Market X	Movement
2.	Load new box	Loading
3.	Move to Station Y	Movement
4.	Load empty box	Loading
5.	Unload new box	Unloading
6	Move to Market X	Movement
7.	Unload empty box	Unloading

2.2.1. Decision making framework

The material supply scheduler is a decision making module responsible for the extraction of an efficient schedule of the required material supply tasks. This module has been based on hierarchical modelling (Fig. 2). The workload activities have been modelled at a three level breakdown namely, Orders that include Jobs and such Jobs include Tasks. Respectively, the facilities have being modelled at the two-level breakdown. This breakdown identifies the MAU resources that are able to perform a variety of material supply activities in the entire shop floor. A mapping among these two hierarchies, which indicates that the assignment of activities to the MAUs is performed has been defined with respect to the Task level.

Under this study, the material supply problem has been formulated into a search problem using Artificial Intelligent techniques (AI), based on the described modelling. In Fig. 3, there is a presentation of a search tree formulation. In the latter, each level of the tree represents a group of tasks that have to be performed by the respective MAUs (MAU 1, MAU2, etc.).

Each node of the tree represents the tasks that should be performed for the replacement of each individual box (Ti,j,k: index i stands for the destination station id, index j stands for

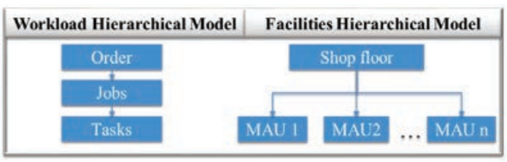

Fig. 2. Workload and facilities Hierarchical Modelling.