MULTIAGENTS IN MANUFACTURING PRODUCTION LINES
Designing Fault Tolerant Adaptive Production Lines

Eugen Volk
High Performance Computing Center Stuttgart (HLRS), Nobelstraße 19
70569 Stuttgart, Germany

Keywords: Multiagents, fault tolerant, agent based manufacturing.

Abstract: The usage of multiagents for autonomous, fault tolerant and flexible adaptation of production lines is not widespread in industrial applications. This paper presents usage of multiagents in industrial applications by showing a realization within a fictive example of a car body manufacturing production line. The mechanism presented here for coordination of agents in multiagent based production line factory is based on contract net protocol and uses ontological matching of individual task ontologies, to find an appropriate contractor.

1 INTRODUCTION

Multiagent systems are mostly used for monitoring or planning purposes in industrial applications whereas the usage of multiagents for autonomous, fault tolerant and flexible adaptation of production lines is not widespread in these environments. This paper aims to introduce the usage of multiagents in industrial applications by showing a realization within a fictive example of a car body manufacturing production line.

2 SCENARIO DESCRIPTION

According to Wikpedia, a production line is defined as a set of sequential operations established in a factory whereby materials are put through a refining process to produce an end-product. A production line for automobile has a car as its end-product. The assembly of a car consists of several steps, including forming, welding, grounding, painting etc.. Each step is done by specialized machines. The transport of semi-manufactured products between different machines is done by transport system. Typically a factory produces several car types, in different production lines. Figure 1 shows such a factory, consisting of three production lines: for car types A, B and C.

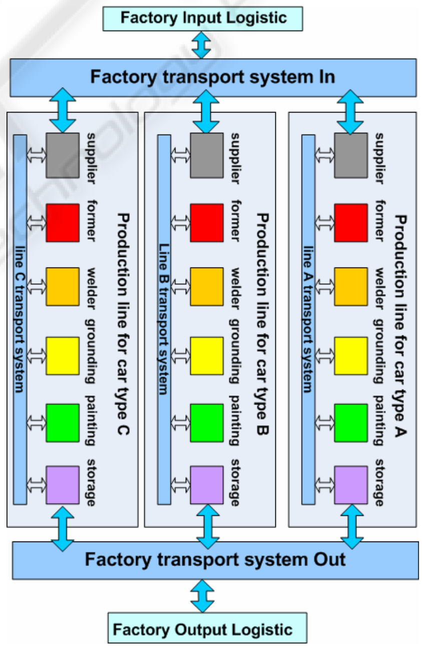

Figure 1: car-body manufacturing with 3 lines.

The process starts with the “Factory Input Logistic”, which supplies the production lines of the factory with material being required for the production of car bodies of different types. The “Factory Input Logistic” uses “Factory transport system In” to transport the right material to supplier of the addressed production line. The supplier of the production line uses “line transport system” to deliver the material to the former. The former processes material to metal pieces/sheets and hands

Volk E. (2008).
MULTIAGENTS IN MANUFACTURING PRODUCTION LINES - Designing Fault Tolerant Adaptive Production Lines.
In *Proceedings of the Tenth International Conference on Enterprise Information Systems - AIDSS*, pages 567-570
DOI: 10.5220/0001712605670570

these over to the welder, via the line transport system. The welder creates a car-body, by welding the metal pieces, which were formed by the former. The welder uses line transport system to transport the car-body to the grounding, whereupon the grounding hands the grounded car body over to the paining. After the car body has been painted, it will be transported via line transport system to line storage and then via “factory transport system out” to “Factory Output Logistic”, where it will be delivered to other manufacturing factories, in order to be finally wired, equipped and assembled to cars.

3 REQUIREMENTS ON PRODUCTION LINE FACTORIES

A production line factory must be fault tolerant. This means it must be able to detect failure, recover from system failure and minimize impact on the whole production.

The classical approach would be to create a centralized system for the whole factory or at least for a single production line. This system is able to monitor the execution of every production step of the involved machines. In case of failure detection, such a centralized system would identify the machine which caused failure and would be able to compensate occurred failure, doing predefined workaround i.e. finding a machine or a resource with the same capabilities as the failed machine and with available capacity, while ensuring transport to and from this founded machine. However, such a central system would require the knowledge about the whole production process, including transportation, and also the information about the status of the machines on every production step. In case of a production line extension, such a centralized system would require updated information about the production process and also the monitoring status of new machines.

In contrast to centralized system, a fully distributed system, realized as Multiagent System, would be able to adopt on occurred failure dynamically in a flexible manner, without the need of keeping ready knowledge on the whole production process. In case of production line extension, the changes would be handled locally, updating only mutual dependency of affected machines being represented by agents.

4 USING MULTIAGENTS

An agent is defined (Wooldridge 1999) as a computer system that is situated in some environment and that is capable of autonomous actions in this environment in order to meet its design objectives. A cooperative Multiagent System consists of several interacting agents, which coordinate their actions in order to achieve a common goal. The design of cooperative Multiagent Systems consists of the design of agents themselves and the coordination mechanisms that enable a group of agents with different capabilities through interactions to combine their capabilities to accomplish as a group in order to reach a common goal, which could not be reached by one of the involved individuals alone. One of the common goals in car-body production line scenario is to keep the production line running, despite the failures or fall out of machines, which are represented in this scenario as autonomous agents with individual capabilities.

4.1 Production Line Agents

The architecture of a single production line of car body manufacturing using multiagents is depicted in Figure 2. A production line consists of several agents with specific capabilities and a Blackboard, which enables agents to interact with each other by writing messages on it, which then can be read by all agents of a production line.

Each production line agent (supplier agent, former agent, welder agent, grounding agent, painting agent) has beside the characteristic capabilities of its machine (transport, welding, grounding etc) also further capabilities:

a. check of performance of its machine
b. check of available free/used production capacity resources
c. fallout detection of its machine
d. access to local production line Blackboard, which is used to exchange information between line agents.

Besides capabilities, each production line agent has following knowledge:

a. task specific knowledge about its capability
b. identification of other agent(s) from which the agent gets its materials.
c. identification of other agent(s) in production line which consumes produced part-products.

Whereas first knowledge must be presented, the last two (identification of other agents) knowledge can be gained by writing announcements on the (production line) Blackboard for agents which deliver material, and announcements for agents who consume produced part-products. In case of a fall-out of a machine, an agent has the responsibility to find another agent who is able to complete its task.

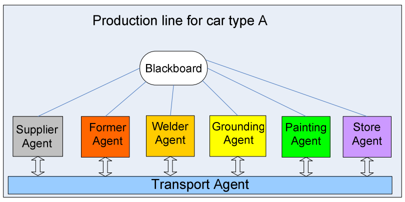

Figure 2: Agents in production line.

4.2 Structure of Factory

As already noted in the scenario description, a factory consists of several production lines. The architecture of a fictive factory, consisting of three production lines (A, B and C) is depicted in Figure 3 It consists of “Factory Transport Agent In”, “Factory Transport Agent Out”, “Factory Input Logistic Agent”, “Factory Output Logistic Agent”, the three production lines (with production line agents) and a factory Blackboard, which enables exchange of information between Blackboards of production lines and factory agents. A factory Blackboard is connected to production lines Blackboards (A, B, C). The announcements on a single production line Blackboard, made by production line agents, will not be published automatically on the factory Blackboard, unless the announcing agent triggers the line Blackboard to submit its announcement on the next higher level Blackboard – the factory Blackboard. The announcements on Factory Blackboards are submitted automatically on all production line blackboards (A, B, C). If an agent replies to an announcement, then its reply will be routed by Blackboards hierarchically to former of the announcement.

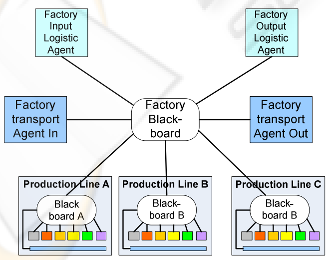

Figure 3: Hierarchy of agents in factory.

4.3 Coordination Protocol

As already mentioned, in the case of a fall-out of a machine an agent has the responsibility to find an agent with similar capabilities, which is able to execute the task of the failed machine. In order to do that it uses a Contract Net Protocol (Huhns & Stephens 1999), a mechanism for negotiation and distribution of tasks. An agent wanting to solve a task is called a manager; agents that might be able to solve the task are called potential contractors.

The adapted contract net protocol consists of the following steps:

From manager perspective:

1. Announce a task that needs to be performed by writing Task (e.g. welding) on local production line Blackboard, with task ontology describing the composition of a car body (e.g. in form of a CAD drawing with size of used materials and area/places where these shall be welded)
2. Receive and evaluate bids from potential contractors:
   - In case of the answer is positive, the manager gets an estimated time for completion of the corresponding task (welding).
   - In case of the answer is negative, go in hierarchy level up and announce task again on Factory Blackboard (Step 1).
3. Check transport possibilities to/from possible contractors by writing transport announcement on local Blackboard.
   - If there are transport possibilities then compare transport and execution time of all bids and award a contract to a suitable contractor.
   - Else go in hierarchy level up and announce on factory board for transport possibility.
4. If appropriate contractor found:
   - Delegate transport of material to contractor.
   - After completion of task delegate the transport from the contractor to the agent which is next in the production chain (consumes part-products).

From a contractor perspective:

1. Receive task announcements by looking periodically on production line Blackboard.
2. Evaluate own capability with the required capabilities of Task.
   - Check available capacity resources.
   - *Compare task ontology of announced task with own task ontology by looking for similarities.*
   - Check received CAD-data for task execution

- Calculate time for task execution

3. Respond (decline, bid)
   - A bid consists of the calculated time for the execution of the task (welding)
   - In case of available capability to execute the task, reserve for the duration of negotiation (defined by time-out of protocol) required available capacity resources.
4. If the bid is accepted, then perform the task (welding)
5. The welded car-body will be transported via from the manager pre-reserved transport agent to the destination agent (painting agent).

The critical step in the proposed protocol is step 2 of contractor perspective: comparison of two ontologies in order to determine whether they are similar and whether the task can be executed from the possible contractor. Several approaches for the automated comparison of ontologies are summarized by Gal, Modica & Jal 2003. One of the approaches that can be used in the selected scenario is the composition matching algorithm, which uses linguistic matching. Another approach could be comparison of schema and data format used in CAD files.

5 PROPERTY OF PROPOSED DESIGN AND CONCLUSIONS

The proposed design of production line factory with multiagents enables treatment of failure by starting on lowest hierarchy level – on production line agent where the failure occurs. The agent, who detects failure on its machine(s), initiates the process of finding appropriate alternative agent with similar capabilities and available resources. The announcements are propagated step by step hierarchically upwards, ensuring the “treat failure local first” strategy, which ensures shortest transport paths. This strategy is also selective and reduces overflow of all Blackboards with announcements. The hierarchy of production line to a factory can be extended to composition of several factories to a concern with different locations or even further to consortium consisting of several concerns. The information spread can be reduced further, if a blackboard system on each level is aware of all agents reading or writing on it. This can be done by announcements made by each blackboard “who is here with which abstract capability”, starting with the lower level and proceeding with higher level and so building routing tables. This enables to distribute announcements more selectively (even to agents), based on abstract capabilities (as topic), but requires routing capability of blackboards. The task ontology based evaluation of agent capabilities presumes no common ontology and so only those agents which are able to understand required task ontology (done by checking similarity between ontologies) and able to execute required task, answer with time calculation for task execution. The calculation of task execution in the bid on task announcement, together with time for transport execution form performance criteria for optimisation of the overall performance and enables so distributed resource scheduling. The usage of multiagent systems in industrial manufacturing enables the factory to adapt autonomous and fast to unknown problem, while keeping production process running.

The proposed approach, based on ontological matching and contract net protocol, could be used in SLA-negotiation of BREIN project, if ontological matching becomes a challenging issue in project. The BREIN project aims at realizing an intelligent, on multiagents, web-semantic and web-services based infrastructure, capable to setup and manage goal-driven dynamic virtual organization of service provider/consumer, while optimizing usage of resources.

ACKNOWLEDGEMENTS

This work has been supported by the BREIN project (http://www.gridsforbusiness.eu) and has been partly funded by the European Commission’s IST activity of the 6th Framework Programme under contract number 034556. This paper expresses the opinions of the author and not necessarily those of the European Commission. The European Commission is not liable for any use that may be made of the information contained in this paper.

REFERENCES

Weiss, G., 1999 *Multiagent Systems, a modern approach to distributed artificial intelligentce.* The MIT press.

Huhns, M., N., Stephens, L., M., 1999. Multiagent Systems and Societies of Agents.

Gal, A., Modica, G., Jamil, H., 2003. Improving Web Search with Automatic Ontology Matching.

Wooldridge, M., 1999. Intelligent Agents, in Multiagent Systems.

The BREIN Project, Website http://www.eu-brein.com/

The Wikipedia Website www.wikipedia.com