Available online at www.sciencedirect.com
ScienceDirect
Robotics and Computer-Integrated Manufacturing 24 (2008) 572–578
Robotics and Computer-Integrated Manufacturing
www.elsevier.com/locate/rcim

Autonomy in production logistics: Identification, characterisation and application

Katja Windt, Felix Böse, Thorsten Philipp*

Bremen Institute of Industrial Technology and Applied Work Science at the University of Bremen, Bremen, Germany

Abstract

Competitive enterprises have to react fast and flexible to an increasing dynamic environment. To achieve the ability to adapt on these new requirements autonomous cooperating logistic processes seem to be an appropriate method. In order to prove in which case autonomously controlled processes are more advantageous than conventionally managed processes, it is essential to specify what is exactly meant with autonomous control, how autonomous control does differ from conventional control and how the achievement of logistic objectives in autonomously controlled systems can be estimated and compared to the achievement of objectives in conventionally controlled systems. This paper introduces a general definition of autonomous control as well as a definition in the context of engineering science and its meaning in a logistics context. Based on this, a catalogue of criteria is developed to ensure the identification of autonomous cooperating processes in logistic systems and its distinction to conventionally controlled processes. To demonstrate this catalogue, its criteria and the concerning properties are explained by means of an exemplary shop-floor scenario.

Keywords: Autonomous control; Logistics; Production systems; Production planning and control

1. Initial situation and call for action

Over the past years, an increase in structural and dynamic complexity of production and logistics systems could be observed. This development is caused by diverse changes, for example, short product life cycles as well as a decreasing number of lots with a simultaneously rising number of product variants and higher product complexity [1]. As a result, new demands were placed on competitive companies, which cannot be fulfilled with conventional controlling methods. Conventional production systems are characterised by central planning and controlling processes, which do not allow fast and flexible adaptation to changing environmental influences. Establishing autonomous cooperating logistics processes seems to be an appropriate method to meet these requirements. The idea of autonomous cooperating logistic processes is to develop decentralised and heterarchical planning and controlling methods in contrast to existing central and hierarchical aligned planning and controlling approaches [2]. Autonomous decision functions are shifted to logistic objects. In the context of autonomous control logistic objects are defined as material items (e.g. part, machine, conveyor) or immaterial items (e.g. production order) of a networked logistic system, which have the ability to interact with other logistic objects of the considered system. Autonomous logistic objects are able to act independently according to their own objectives and to navigate through the production network themselves. The autonomy of logistic objects is possible since recent developments by information and communication technologies (ICT), for example radio frequency identification (RFID) for identifying, global positioning system (GPS) for locating or universal mobile telecommunications system (UMTS) for communicating of logistic objects [3].

These new approaches are currently investigated within the Collaborative Research Center "Autonomous Logistic Processes—A Paradigm Shift and its Limitations" at the University of Bremen, which deals with the implementation of autonomous control as a new paradigm for logistic processes [4]. The intention of this paper is to

*Corresponding author.
E-mail address: tphilipp@uni-bremen.de (T. Philipp).

0736-5845/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rcim.2007.07.008

explain what is meant by autonomous control and to show potentials in logistic systems, particularly in production systems.

Therefore, a definition of the term autonomous control is given. Based on the main statement of this definition, a catalogue of criteria is developed in order to identify autonomous cooperating logistic processes and to emphasise how conventionally managed and autonomous logistics processes differ. The criteria and its individual properties are explained on a concrete object of investigation by a scenario of a manufacturing system. In conclusion further research activities concerning evaluation of autonomous control are presented.

2. Definition of autonomous control

The vision of autonomous cooperating logistics processes emphasizes the transfer of qualified capabilities on logistic objects as explained above. According to the system theory, there is a shift of capabilities from the total system to its system elements [5]. By using new technologies and methods, logistic objects are enabled to render decisions by themselves in a complex and dynamically changing environment. Based on the first results of the work in the context of the Collaborative Research Centre (CRC) 637 "Autonomous Cooperating Logistic Processes—A Paradigm Shift and its Limitations" at the University of Bremen [6], autonomous control can be defined as follows:

> Autonomous Control describes processes of decentralized decision-making in heterarchical structures. It presumes interacting elements in non-deterministic systems, which possess the capability and possibility to render decisions independently.
>
> The objective of Autonomous Control is the achievement of increased robustness and positive emergence of the total system due to distributed and flexible coping with dynamics and complexity. [7]

Based on this global definition of the term autonomous control a definition in the context of engineering science was developed, which is focussed on the main tasks of logistic objects in autonomously controlled logistics systems:

> Autonomous control in logistics systems is characterised by the ability of logistic objects to process information, to render and to execute decisions on their own.

For a better understanding, the main statements of the given definitions of autonomous control such as decentralized decision-making in heterarchical systems, system elements ability of interaction as well as non-deterministic system and positive emergence, are described and discussed below.

2.1. Decentralised decision-making in heterarchical systems

One feature of autonomous control is the capability of system elements to render decisions independently. Autonomy regarding decision-making is enabled by the alignment of the system elements in the form of a heterarchical organisational structure [8]. Therefore, decentralisation of the decision-making process from the total system to the individual system elements is a typical criterion of autonomous control. Each system element represents a decision unit, which is equipped with decision-making competence according to the current task [9]. Due to the fact that decision-making processes are purposeful, according to the decision theory, each system element in an autonomously controlled system is characterised by target-oriented behaviour. Global objectives, for example, provided by the corporate management, can be modified independently by the system elements in compliance with its own prioritisation. For example, the objective of high due-date punctuality can be replaced in favour of high machine utilization by the machine itself. Thus, the objective system of single elements is dynamic because of its ability to modify objects prioritisation over time, i.e. during the production process.

2.2. System element's ability of interaction

Decentralised decision-making processes require the availability of relevant information for the system elements. Consequently, the capability of system elements to interact with others is a mandatory condition and thus one constitutive characteristic of autonomous control. The ability of interaction can accomplish different values depending on the level of autonomous control. The allocation of data, that other autonomous logistic objects can access, represents a low level of autonomous control. Communication, i.e. bi-directional data exchange between autonomous logistic objects, and coordination, that means the ability of autonomous logistic objects to cooperate and coordinate activities of other objects, stands for a higher level of autonomous control.

2.3. Non-deterministic system behaviour and positive emergence

In accordance with the above-mentioned definition, the main objective of autonomous control is the achievement of increased robustness and positive emergence of the total system due to a distributed and flexible coping with dynamics and complexity. Non-determinism means that despite precise measurement of the system status and knowledge about all influencing variables of the system, no forecast of the system status can be made. Knowledge of all single steps between primary status and following status is not adequate enough to describe the transformation completely [10]. Thus, a fundamental criterion of autonomous control is that for same input of initial values, there