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2 Fundamental Basics and Concepts of Autonomous Control and Cooperation

2.1 Perspectives on Initial Ideas and Conceptual Components of Autonomous Cooperation and Control

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In order to enable the implementation of self-organisation ideas for logistics – concretised as control and organisation principles –, one has to understand the fundamental basics and characteristics of autonomous cooperation and control as well as its foundations. In this respect, the basic underlying idea is the concept of self-organisation like shown above. It is an interdisciplinary concept that has been developing for more than 35 years under labels such as self-organisation, autopoiesis, dissipative structures as well as emergency and complexity theory. The core of the self-organisation concept is the formation and development of order in complex dynamic systems (Paslack 1991). In natural sciences, important exponents are Prigogine (Glansdorff and Prigogine 1971) in chemistry (theory of dissipative structures), Peitgen and Richter (Peitgen and Richter 1986) in mathematics (chaos theory), Haken (Haken and Graham 1971,Haken 1973) and Foerster (Foerster 1960) in physics (synergetics and cybernetics), and Maturana and Varela(Maturana 1973) in biology (autopoiesis).

Those ideas still exert a great influence on other disciplines working on questions of self-order creation. The last concept “autopoiesis” is for example applied to other fields such as sociology Luhmann’s system theory (Luhmann 1973).

Consequently, the idea of implementing the concept of autonomous cooperation and control into the organisation of supply chains and supply networks sees double interdisciplinarity: On the one hand, the fundamental ideas of self-organisation – which is the principle lying behind autonomous cooperation and control – come from sources of various disciplines which could be intertwined; on the other hand, these different interdisciplinary perspectives on its application could lead to different or even diverged interpretations. Therefore the first general task of a scientific process, namely the terminological task (Hill et al.1994), is more important for the research on autonomous cooperation than for other research fields where the objects and approaches are mono-disciplinary. That is why representatives from production engineering, communication technology, electrical engineering, computer science and mathematics, as well as from business studies and management science were invited to contribute to this chapter “Fundamental Basics and Concepts of Autonomous Cooperation and Control” and to explain their individual perspectives on initial ideas and conceptual components of this specific organisational principle for logistics. All the articles in this chapter are intended to contribute towards an overarching conception of the application of autonomous cooperation from an interdisciplinary perspective and to identifying the basics for managing, measuring, and modelling autonomous cooperating logistic processes. This chapter would like to establish a differentiated and multi-usable overview to enable an interdisciplinary understanding of what autonomous cooperation and control is all about. This furnishes the terminological basis for all further research on models, methods, and applications.

The first article **“Prologue to Autonomous Cooperation — the Idea of Self-Organisation as its Basic Concepts”** – written by Michael Hülsmann, Christine Wycisk, Robin Agarwal, and Jörn Grapp – deals with self-organisation, the origin of autonomous cooperation, by exploring different understandings of self-organisation and common characteristics underlying these concepts. Autonomous cooperation describes processes of decentralized decision-making in heterarchical structures. The implementation of autonomous cooperation aims at a flexible self-organizing system structure that is able to cope with dynamics and complexity while maintaining a stable status. The basic idea of the concept of autonomous cooperation derives from concepts of self-organisation, which analyze the emergence of ordered and robust structures in complex systems in general. For transferring the idea of self-organizing systems into the concept of autonomous cooperation, a first step would be to understand the roots and principles of self-organisation. In this chapter, the core aspects of selected concepts of self-organisation are presented with a brief description of each. Next, to give a clear picture of the idea of self-organisation, the characteristics which form the basis of self-organizing systems contained in the selected concepts are extracted and juxtaposed by means of the general criteria of system structure, system behaviour and system abilities.

In the second contribution **"Historical Development of the Idea of Self-Organisation in Information and Communication Technology"**, Markus Becker, Koojana Kuladinithi, Andreas Timm-Giel, and Carmelita Görg summarize how the idea of self-organisation has been applied in ad hoc networks (including mesh and sensor networks), peer-to-peer networks, autonomic computing and autonomic communication. The constituting features of autonomous control (non-centralized design and operation, heterarchy, interaction, autonomy, decision process) have been used and enhanced since the beginnings of Information and Communication Technology. In this chapter, proactive and reactive routings, autonomic address assignment and mobile agents in ad hoc networks are described. Then specific applications of peer-to-peer networks are introduced. Next, examples of autonomic computing with its "self-" principles and examples of autonomic communication as well as related issues concerning self-organisation (i.e. controllability, reliability and security) are presented.

In the article **"Business Process Modelling of Autonomously Controlled Production Systems"** written by Felix Böse and Katja Windt, a specification of the main criteria of autonomous cooperation and control is introduced. Based on this, the ARIS concept (Architecture of Integrated Information Systems) as an integrated method for the modelling of processes and information systems is analysed regarding its suitability for describing autonomous control in production systems. Furthermore, changes in order processing are exemplarily illustrated in several views of a business process model using the ARIS concept.

The next chapter **"Catalogue of Criteria for Autonomous Control in Logistics"**, contributed by Felix Böse and Katja Windt, tries to explain the concept of autonomous control and describes its main criteria in contrast to conventional controlling methods in logistics systems. Over the years there has been an increase in the complexity of production and logistics systems regarding organisational, time-related and systemic aspects. As a result, it is often impossible to make all necessary information available to a central entity in real time and to perform appropriate measures of control in terms of a defined target system. Therefore, demands were placed on new control methods. Autonomous control seems to be an appropriate alternative, whose idea is to develop decentralised and heterarchical planning and controlling methods. In this chapter, a definition of autonomous control is introduced. The constituent characteristics of this definition are considered in a developed catalogue of criteria in the form of an operationalized morphological characteristic schema in order to describe autonomous logistic processes and emphasize how conventionally managed and autonomous logistic processes differ. The criteria and their properties are explained in a concrete way by investigating a production logistics scenario of a job shop manufacturing system.

Lars Arndt and Georg Müller-Christ deal with **"Strategic Decisions for Autonomous Logistics Systems"** and intend to explain decision issues involved in the application of autonomous cooperation. Autonomous cooperation in logistics is based on the capability of logistics objects to decide and coordinate among themselves. Though the role of new technologies, especially multi-agent technology in enabling local self-coordination has been addressed by several authors, the underlying decision problem remains unclear. Therefore, this chapter elaborates the strategic nature of decision in autonomous cooperating logistics processes. More specifically, it describes autonomous cooperation in logistics as a particular form of delegation of decision making, attributes the strategic character of this delegation process to the necessity for organisations to open their boundaries, and outlines a concept of boundary management in order to foster and regulate the boundary opening and thus to provide the appropriate organisational context for the decision to implement autonomous cooperation.

The following article, which describes **"Autonomous Units: Basic Concepts and Semantic Foundation"** – written by Karsten Hölscher, Renate Klempien-Hinrichs, Peter Knirsch, Hans-Jörg Kreowski, and Sabine Kuske – proposes the concept of autonomous units for modelling logistics objects acting autonomously, while interacting with each other for the purpose of accomplishing certain tasks. The guiding principle of autonomous units is the possibility to integrate autonomous control into the model of processes. This provides a framework for a semantically sound investigation and comparison of different mechanisms of autonomous control. Concretely speaking, this chapter describes algorithmic and particularly logistic processes in a general and uniform way, portrays the range of applications and their according methods, introduce the rule-based approach and elaborate autonomous units on different levels.

Bernd Scholz-Reiter, Fabian Wirth, Michael Freitag, Sergey Dashkovskiy, Thomas Jagalski, Christoph de Beer, and Björn Rüffer discuss in their contribution **"Mathematical Models of Autonomous Logistics Processes"** fundamental concepts of autonomy within a logistic network and mathematical tools which can be used to model this property. Autonomous control in a logistic network describes a decentralised coordination of intelligent logistic objects (parts, machines etc.) and allocation of jobs to machines by intelligent parts themselves. To develop and analyze such autonomous control strategies, dynamic models are required. This chapter describes and compares several possible models for autonomous logistic processes (discrete models and fluid approximations, partial differential equations and ordinary differential equations) and discusses how autonomous control enters these models and what its effects on the dynamics and stability of the processes are. By means of an example, this chapter further presents the advantages of autonomous control and points out the related stability problem.

In the chapter **"Autonomous Decision Model Adaptation and the Vehicle Routing Problem with Time Windows and Uncertain Demand"** Jörn Schönberger and Herbert Kopfer investigate generic procedures and rules for an automatic feedback controlled adaptation of decision models for a variant of the well-known Vehicle Routing Problem with Time Windows. This task is driven by the realization that static decision models fail to work at times of changes in the real world. This chapter presents the considered decision problem in more detail, introduces the algorithmic framework for autonomous adaptation of the decision model, and proves the framework's general applicability within numerical simulation experiments.

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