Michael Hülsmann · Katja Windt (Eds.)

Understanding Autonomous Cooperation and Control in Logistics

The Impact of Autonomy on Management, Information, Communication and Material Flow

With 91 Figures



Contents

1	Changing Paradigms in Logistics – Understanding the Shift from Conventional Control to Autonomous Cooperation and Control1		
		Katja Windt, Michael Hülsmann	
	1.1	Introduction	1
	1.2	Drivers and enablers of autonomous cooperation and control in logistic processes	2
	1.3	Autonomous cooperation and control – a general understanding	2
	1.4	Aims of the edited volume	.11
	1.5	Structure of the edited volume	.12
2	Fu Co	indamental Basics and Concepts of Autonomous Control and poperation	d . 17
	2.1	Perspectives on Initial Ideas and Conceptual Components of Autonomous Cooperation and Control	.17
		Katja Windt, Michael Hülsmann	
	2.2	Prologue to Autonomous Cooperation – the Idea of Self- Organisation as its Basic Concepts	23
		Michael Hülsmann, Christine Wycisk, Robin Agarwal, Jörn Grapp	
	2.2	2.1 Introduction	23
	2.2	2.2 Concepts of self-organisation	24
	2.2	2.3 Characteristics of self-organizing systems	35
	2.2	2.4 Conclusions	38
	2.3	Historical Development of the Idea of Self-Organisation in Information and Communication Technology	45
		Markus Becker, Koojana Kuladinithi, Andreas Timm-Giel, Carmelita Görg	
	2.3	3.1 Ad hoc networks	46
	2.3	3.2 Peer to peer networks	50
	2.3	3.3 Autonomic computing	51

2.3.4 2.3.5	4 Autonomic communication
2.4	Catalogue of Criteria for Autonomous Control in Logistics57
j	Felix Böse, Katja Windt
2.4.1 2.4.2 2.4.2 2.4.2 2.4.4 2.4.4 2.4.4 2.4.1	1Introduction572Definition of autonomous control583System layers of autonomous control614Derivation of a catalogue of criteria625Operationalisation of the catalogue of criteria646Application of the catalogue of criteria667Conclusions and outlook69
2.5	Business Process Modelling of Autonomously Controlled Production Systems
	Felix Böse, Katja Windt
2.5.2 2.5.2 2.5.2 2.5.4 2.5.4	1Introduction732Autonomous control in production systems743Business process modelling of autonomous control754Changes in order processing by autonomous control775Conclusions82
2.6	Strategic Decisions for Autonomous Logistics Systems
L	Lars Arndt, Georg Müller-Christ
2.6. 2.6.2	 Introduction
2.6.4 2.6.4	 Delegation of decision making as a process of boundary opening and its strategic relevance
2.6.:	implementation of autonomous cooperation
2.7	Autonomous Units: Basic Concepts and Semantic Foundation103
	Karsten Hölscher, Renate Klempien-Hinrichs, Peter Knirsch, Hans-Jörg Kreowski, Sabine Kuske
2.7. 2.7. 2.7.	1Introduction

	2.7 2.7 2.7	7.4 7.5 7.6	Parallel semantics
	2.8	Mat	hematical Models of Autonomous Logistic Processes 121
Ber Das		Bern Dasi	nd Scholz-Reiter, Fabian Wirth, Michael Freitag, Sergey hkovskiy, Thomas Jagalski, Christoph de Beer, Björn Rüffer
	2.8 2.8 2.8 2.8 2.8 2.8 2.8 2.8	3.1 3.2 3.3 3.4 3.5 3.6 Auto	Introduction121Logistic processes124Mathematical modelling of logistic processes126Autonomous control and its effects on the dynamics of131Iogistic processes131An illustrative example132Conclusions136pnomous Decision Model Adaptation and the
	2.9	Veh Den	icle Routing Problem with Time Windows and Uncertain nand
	2.9) 1	Introduction 139
	2.9	0.2	The vehicle routing problem with time windows and
	2.9	0.3	Model-based planning in dynamic environments
2.9		9.4	Numerical experiments
	2.9	0.5	Conclusions
3	Au Int	itono forma	mous Control Methods for the Managment, ation and Communication Layer163
	3.1	App Con Con	roaches to Methods of Autonomous Cooperation and trol for the Management-, Information- and nmunication-Layer of Logistics163
		Mici	hael Hülsmann, Katja Windt
	3.2	Self	F-Organization in Management Science169
		Mici	hael Hülsmann, Jörn Grapp, Ying Li, Christine Wycisk
	3.2 3.2	2.1 2.2	Introduction
			-

3.2.	.3	Major characteristics of self-organization in management science
3.3	Auto A Wa	nomous Cooperation – ay to Vitalize Organizations?
	Mich	ael Hülsmann, Christine Wycisk
3.3. 3.3. 3.3. 3.3. 3.3.	.1 .2 .3 .4	Complexity and dynamics of social systems –theproblem of unlocking
3.4	Self- Com	Organization Concepts for the Information- and munication Layer of Autonomous Logistic Processes 207
	Mark	cus Becker, Andreas Timm-Giel, Carmelita Görg
3.4. 3.4. 3.4. 3.4.	.1 .2 .3 .4	Autonomic communication, autonomic computing and self-star207Service discovery and gateway discovery209Ad hoc routing211Conclusions212
3.5	Distr Envi	ibuted Knowledge Management in Dynamic ronments
	Hage	en Langer, Jan D. Gehrke, Otthein Herzog
3.5 3.5 3.5 3.5 3.5	.1 .2 .3 .4 .5	Introduction215Intelligent agents216Agent-based logistics216Knowledge management based on roles and parameters218Conclusions229
3.6	Proa	ctive Knowledge-Based Risk Management233
	Mart Schu	in Lorenz, Boris Bemeleit, Otthein Herzog, and Jens macher
3.6 3.6	.1	Introduction

	3.6	.3	Requirements for risk management for autonomous	242
	3.6	.4	Implementation of proactive risk management for	243
	3.6	.5	Conclusions	247 252
	3.7	Aut	onomy in Software Systems	255
		Ingo Timi	9 J. Timm, Peter Knirsch, Hans-Jörg Kreowski, Andreas m-Giel	
	3.7 3.7 3.7	.1 .2 .3	Introduction Ideas of Agency Ideas of autonomous units	255 256 264
	3.7 3.7 3.7	.4 .5 .6	Advanced concepts of agency	265 267 270
	3.8	Spec Log Cha	cifying Adaptive Business Processes within the Production istics Domain – A new Modelling Concept and its llenges	n 275
		Berr	nd Scholz-Reiter, Jan Kolditz, Torsten Hildebrandt	
	3.8 3.8 3.8 3.8	.1 .2 .3	Introduction Autonomous control of logistic processes Development of a logistics system based on autonomous cooperating processes Modelling autonomous control	275 275 277 277 281
	3.8	5.5 6	Fulfilment of requirements	290 292
4	Au Flo	itono ow La	mous Control Methods and Examples for the Material ayer	292 295
	4.1	App Con	roaches to Methods of Autonomous Cooperation and trol and Examples for the Material Flow Layer	295
		Katj	a Windt, Michael Hülsmann	
	4.2	Eval Ana	luation of Autonomous Logistic Processes – lysis of the Influence of Structural Complexity	303
		Thoi Reit	rsten Philipp, Christoph de Beer, Katja Windt, Bernd Sch er	olz-
	4.2	2.1	Introduction	303

Autonomy in production logistic 305 Complexity of production systems 305 Measurement and evaluation of logistic objectives 309 Shop floor scenario 314 Conclusions and outlook 322
momous Control by Means of Distributed Routing
d-Ludwig Wenning, Henning Rekersbrink, Andreas Timm- Carmelita Görg, Bernd Scholz-Reiter
Introduction325Routing algorithms in communication networks326Comparison of logistic and communication networks328A distributed routing concept330Conclusions and outlook334
amic Transport Reference Scenarios
d-Ludwig Wenning, Henning Rekersbrink, Markus Becker, eas Timm-Giel, Carmelita Görg, Bernd Scholz-Reiter
Introduction
Traditional scenarios337Components of dynamic transport logistic scenarios338Evaluation criteria for transport scenarios341Example scenarios343Conclusions349
Traditional scenarios337Components of dynamic transport logistic scenarios338Evaluation criteria for transport scenarios341Example scenarios343Conclusions349nomously Controlled Storage Allocation on an351
Traditional scenarios337Components of dynamic transport logistic scenarios338Evaluation criteria for transport scenarios341Example scenarios343Conclusions349momously Controlled Storage Allocation on an mobile Terminal351: Böse, Katja Windt

4.6	Intelligent Containers and Sensor Networks Approaches to apply Autonomous Cooperation on Systems with limited
	Resources
	Reiner Jedermann, Christian Behrens, Rainer Laur, Walter Lang
4.6	5.1 Introduction
4.6	5.2 Local data pre-processing
4.6	Relation to the definition of autonomous cooperation373
4.6	Linking quality information and transport planning374
4.6	5.5 Measurement of spatial distributed environmental
	parameters
4.6	6.6 Applying autonomous cooperation in sensor networks 379
4.6	5.7 Conclusions and outlook
4.7	Transport Scenario for the Intelligent Container
	Reiner Jedermann, Jan D. Gehrke, Markus Becker, Christian Behrens, Ernesto Morales-Kluge, Otthein Herzog, Walter Lang
4.7	7.1 Scenario setting
4.7	2.2 Steps of the transport demonstration
4.7	7.3 Institutional cooperation
Index	