What is Enterprise Integration / Interoperability?

And Why is it Important for Automatic Control?

33. Österreichischer Automatisierungstag

Georg Weichhart

PROFACTOR – Head of Flexible Production Systems
IFAC – Chair of TC 5.3 Enterprise Integration and Networking
JKU – Lecturer Business Informatics / Communications Engineering

OCG, ÖGART, IFAC Beirat Ö

FROM RESEARCH TO PRODUCTION

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Agenda

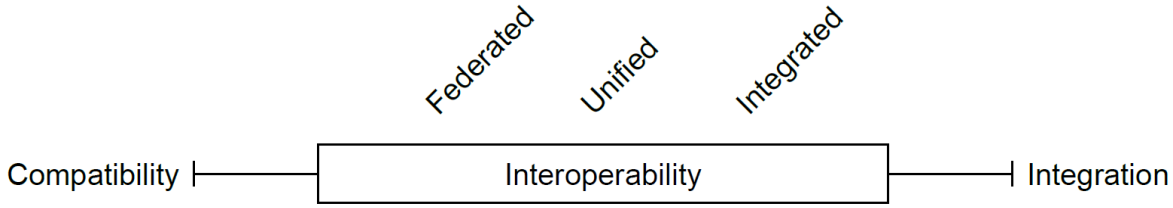
- Intro and Terms
- Motivation: Future Enterprise Systems
- Perspectives on Enterprise Interoperability
- Standards
- Automatic Control
- Work in Progress

Introduction

- Personal Motivation
  - too many Multi Agent Systems built from a single point of view
  - got rigid and complex

  - *Interoperability* stresses heterogeneous world views / world models

- Concepts
  - Compatibility vs. Interoperability vs. Integration



- Focus on *Enterprise Interoperability*

Motivation: Future Enterprise Systems

Table 1. Shifting organisations from information-processing to knowledge-managing entities.

Factors	Organisations processing information	Organisations managing knowledge
Structure	Hierarchy	Network
Dynamics	Processes	Learning
Measures	Towards high efficiency	Towards high effectiveness
Assets	Tangible	Tangible and intangible
Economic environment	Certainty, little change	Uncertainty, high dynamics
Values	Based on 'law of scarcity'	Based on 'law of abundance'
Jobs	Based on traditional skills	Based on intertwined skills and digital media literacy
Production	Oriented to mass	Oriented to mass customisation
Products and Services	Fordian	Value-added products and processes
Overall	Focus on decomposition and stability	Focus on integration and dynamics albeit diversity

Motivation: Future Enterprise Systems

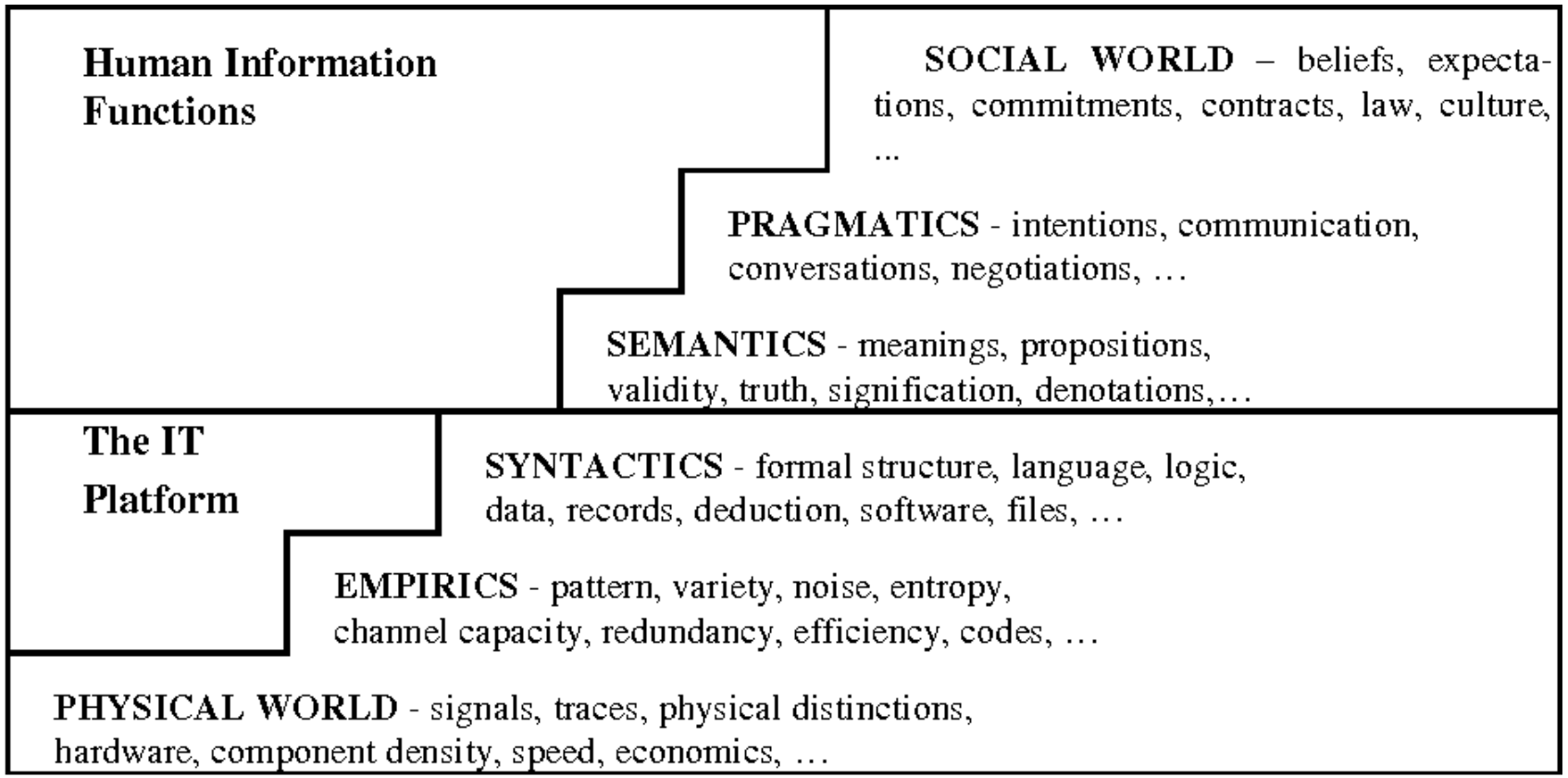
- Enterprise as a Complex Adaptive System
  - Human and Artificial Agents
  - Sensing, interacting
  - Information processing and smart Algorithms

- S^3 Enterprise: Sensing, Smart and Sustainable

  - top-down approach to the design of enterprise systems in a static mode is insufficient

Organisational Semiotics: Ronald Stamper's Semiotic Ladder

- Enterprise as socio-technical information system



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Systems Perspective

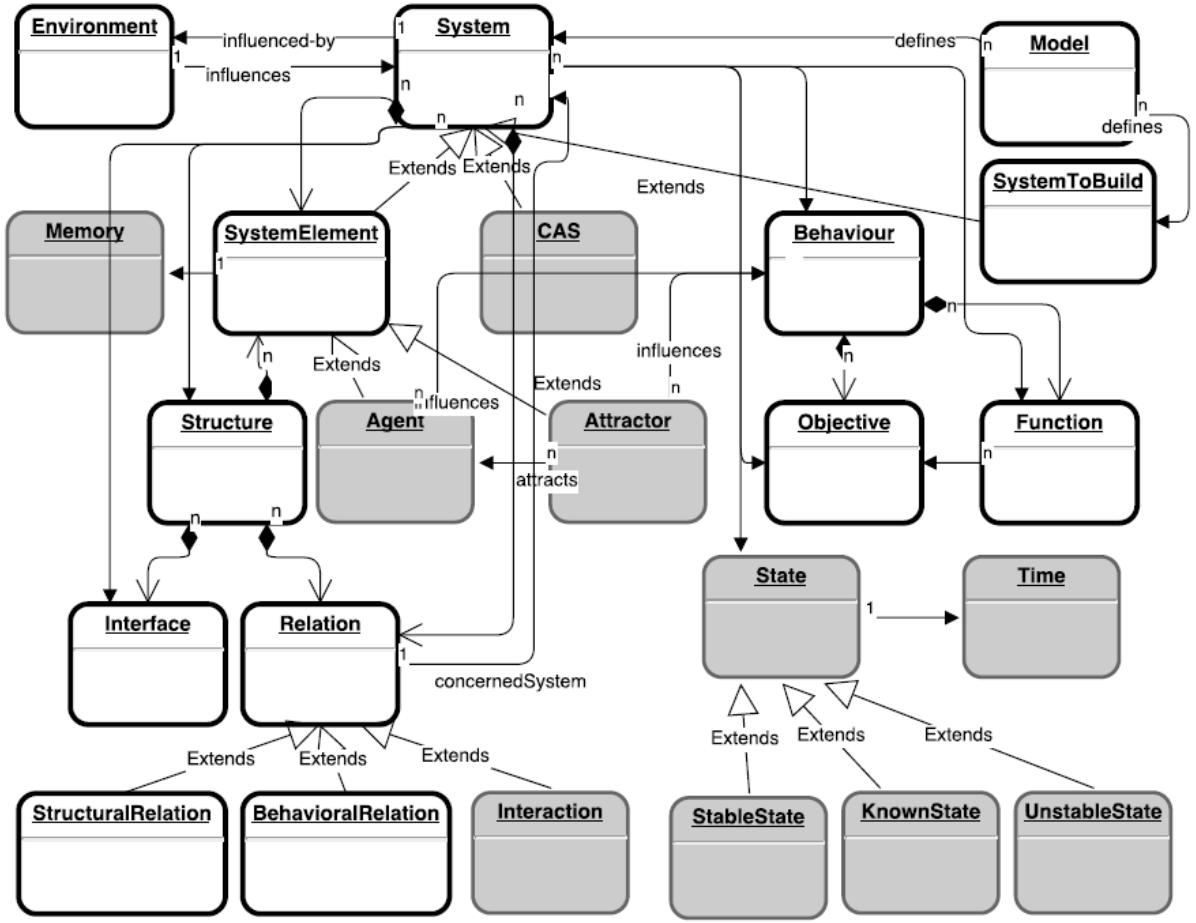
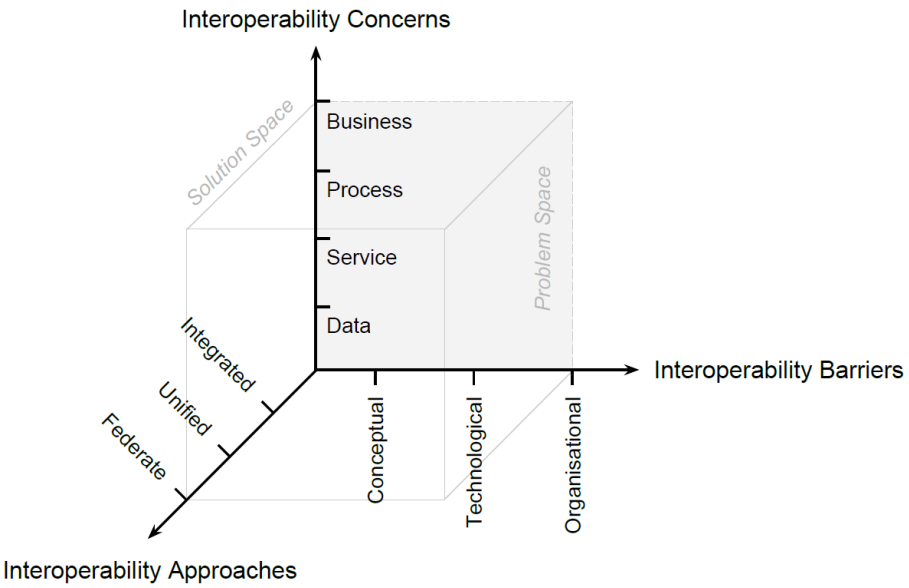


Figure 2: Conceptual diagram of the systemic core of the OoEI [41, 42], extended with CAS related concepts.
(*Legend of Boxes: White . . .* `Concept from OoEI`*; Grey . . .* `CAS extension`*;*
Legend of Arrow-heads: Empty triangle . . . `subclass / subsumption`; Diamond-shaped . . . `partof`; Black triangle & no label . . . `has`;) based on [7]

Systems Perspective: Scala / akka implementation

```
 trait System {
  def systemName: String
  def hasBehaviour: Option[SystemBehaviour] = Some(nilBehaviour)
  def hasState: Option[SystemState] = Some(systemStateExisting)
  def hasInterfaces: List[SystemInterface] = Nil
}
trait SystemElement extends System {
  def providesFunctions: Seq[Option[SystemFunction]]
  def hasObjectives: Seq[Option[SystemObjective]]
  // the system element defaults to an empty internal structure
  override def hasStructure: Option[SystemStructure] = Some(emptyStructure)
  var partOf: Option[System] = None
  var Memory = new scala.collection.mutable.HashMap[String, Option[AnyRef]]()
}
trait SystemAgent extends SystemElement {
  def actorpath: String = implementation.get.path.toString
  val implementation: Option[ActorRef]
}
abstract class SystemActor(val systemAgentModel: SystemAgent) extends Actor {
  override def preStart(): Unit = {
    if (systemAgentModel.implementation != null)
      directoryFacilitator().get.tell(RequestRegister(systemAgentModel.implementation,
          systemAgentModel.providesFunctions), context.parent)
  }
}
```

EI Problem-space



C/D-3	Data semantics	Data meaning disagreements
C/S-1	Service content	Differences in the coverage, i.e. content, of the services offered
C/S-2	Service syntax	Language/formalism syntax used to describe the services
C/S-3	Service semantics	The meaning of services descriptions
C/P-1	Process content	Coverage, i.e. content, of the processes
C/P-2	Process syntax	Process description language grammar and graphical representation
C/P-3	Process semantics	The meaning of the processes description
C/B-1	Visions, strategies and culture	Differences in the respective companies goals, views, etc.
C/B-2	Business syntax	Format, template or model used for describing enterprise business
C/B-3	Business semantics	Meaning of terms used to express business issues
T/D-1	Exchange format	Protocol or format available to exchange information
T/S-1	Service granularity	Definitions of what constitutes the services, i.e. interface problems
T/P-1	Process behaviour	Order of operations in the computerised processes
T/B-1	Degree of computerisation	How much of data, services and processes that are automated in IT
T/B-2	IT requirement fulfilment	The ability of IT to support the requirements of the business
O/D-1	Information ownership	The structures for assigning rights to data (different rights for different partners)
O/D-2	Classified information	Differences in which an information is to be regarded as classified with respect to the collaboration partner
O/S-1	Service management	Incompatible service management rules and practices
O/P-1	Business process behaviour	Order of operations in business processes
O/B-1	Legislation	The legislative requirements that influence different actors
O/B-2	Organisation structure	How enterprises are organised on a high level
O/B-3	Methods of work	High level differences regarding how work is performed in the organisations

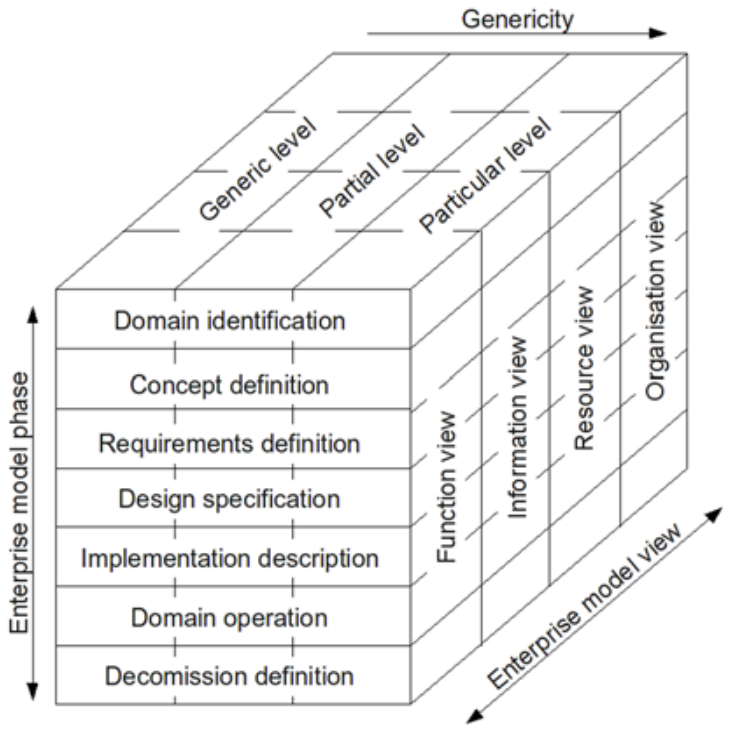
▪ ▪ ▪

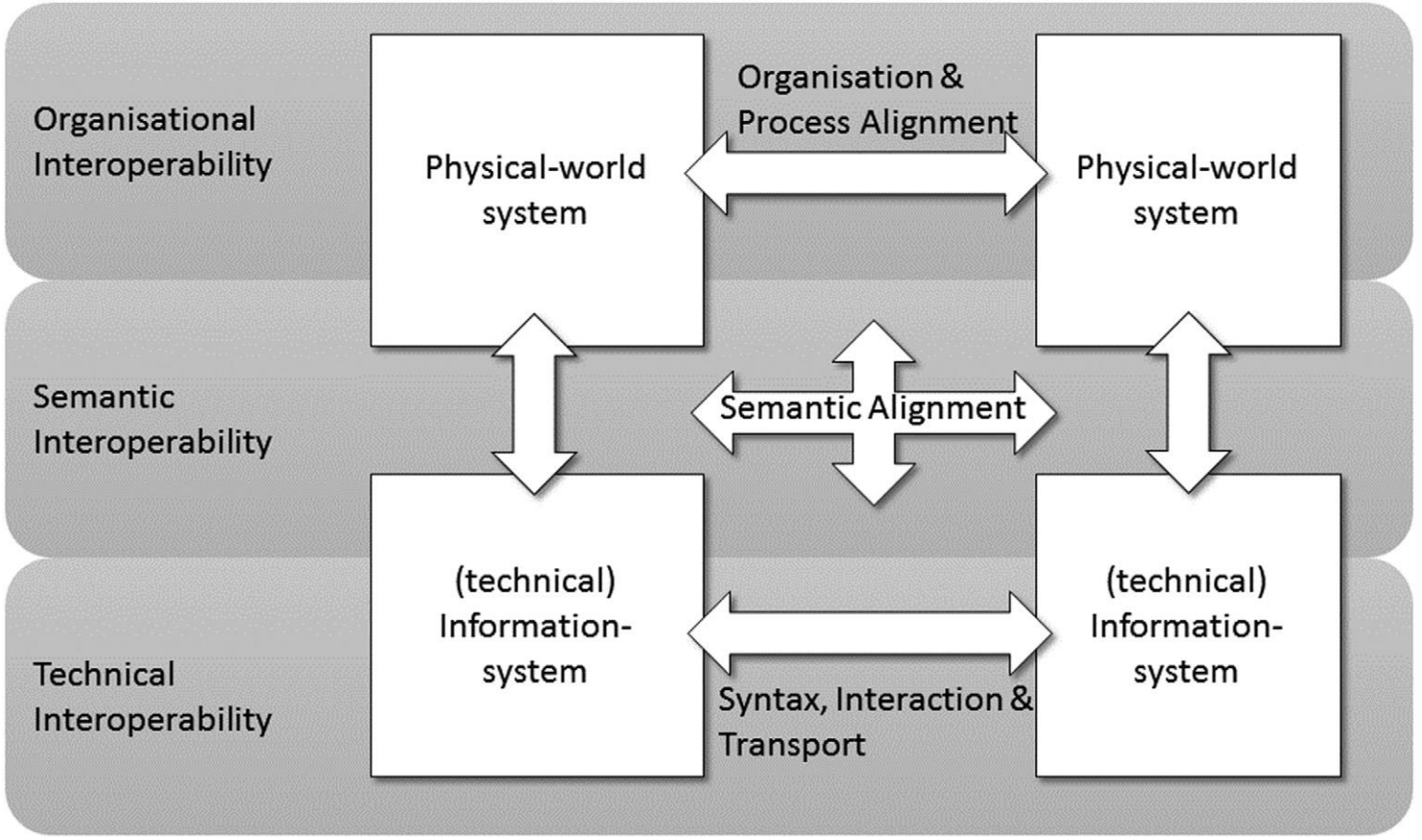
EI Problem-space

Barriers / Concerns	Conceptual	Technological	Organisational
Business	Visions, strategies and culture; Business semantics; Business syntax	IT requirement fulfilment; Degree of computerisation	Methods of work; Organisational structure; Legislation
Process	Process semantics; Process syntax; Process content	Process behaviour	Business process behaviour;
Service	Service semantics; Service syntax; Service content	Service granularity	Service Management
Data	Data semantics; Data syntax; Data content	Exchange format	Classified information; Information ownership.

Enterprise Modelling: CIMOSA, ISO 19439; Enterprise Interoperability

Enterprise Model - Point of View





Interoperability of Models - Point of View

Existing and Ongoing Standardisation Work for Interoperability

- ISO/TC 184/SC 5 - Interoperability, integration, and architectures for enterprise systems and automation applications;
- Joint WG ISO/TC 184/SC 5 - IEC/SC 65E : Enterprise-control system integration
- Data Structures, Protocols & Service Interfaces
  - OPC UA (OLE for Process Control Unified Architecture)
  - MQTT (Message Queuing Telemetry Transport); AMQT (Advanced Message Queuing Protocol)
- Semantic Interoperability Standards
  - Ontologies
  - OPC UA information models: EUROMAP 77
  - ISO/CD 19440: Enterprise modelling and architecture – Constructs for Enterprise Modelling
  - ISO/DIS 15704: Enterprise modelling and architecture -- Requirements for enterprise-reference architectures and methodologies
  - ISO/CD 16300: Automation systems and integration – Interoperability of capability units for manufacturing application solutions
  - ISO/DIS 20140: Automation systems and integration — Evaluating energy efficiency and other factors of manufacturing systems that influence the environment
  - ISO/CD 15746: Automation systems and integration -- Integration of advanced process control and optimization capabilities for manufacturing system

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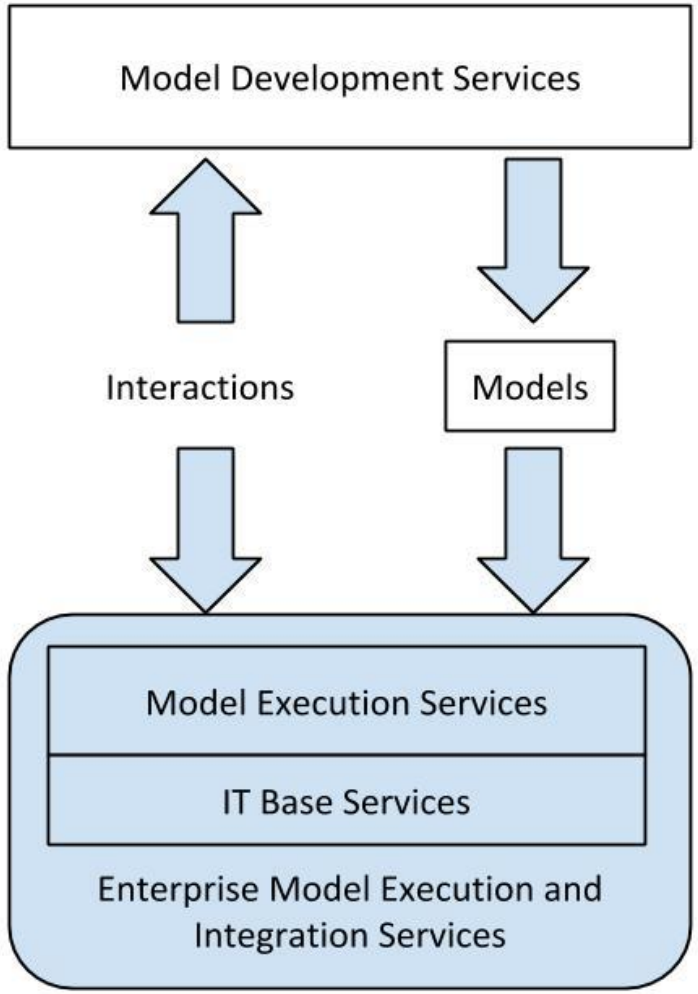
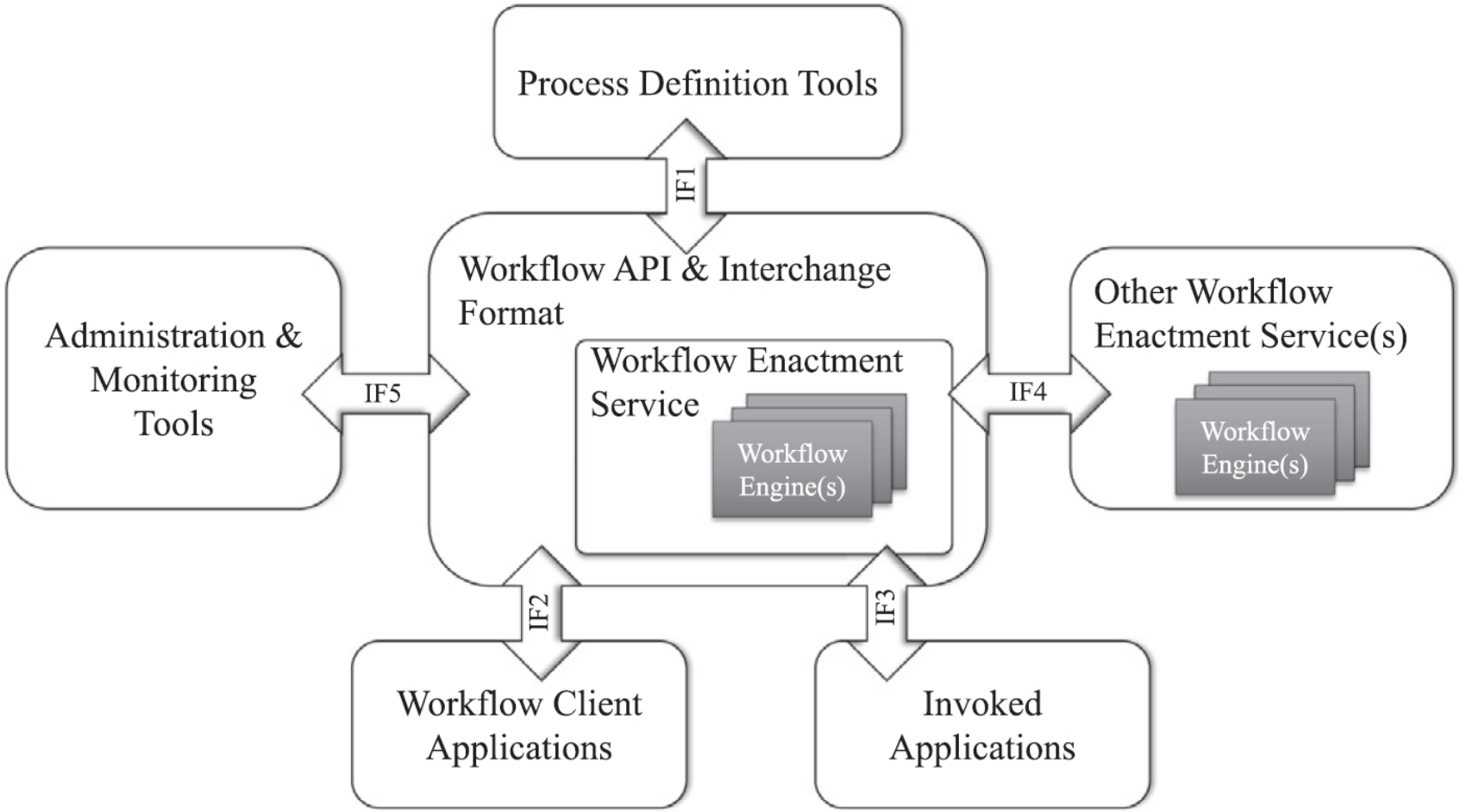
(Enterprise/Process) Interoperability for Automatic Control

- Executable Machine Models
  - EN 61499
- Enterprise Operating System
  - Process-based
  - Production & Business Processes
  - Service Oriented (?) :-(

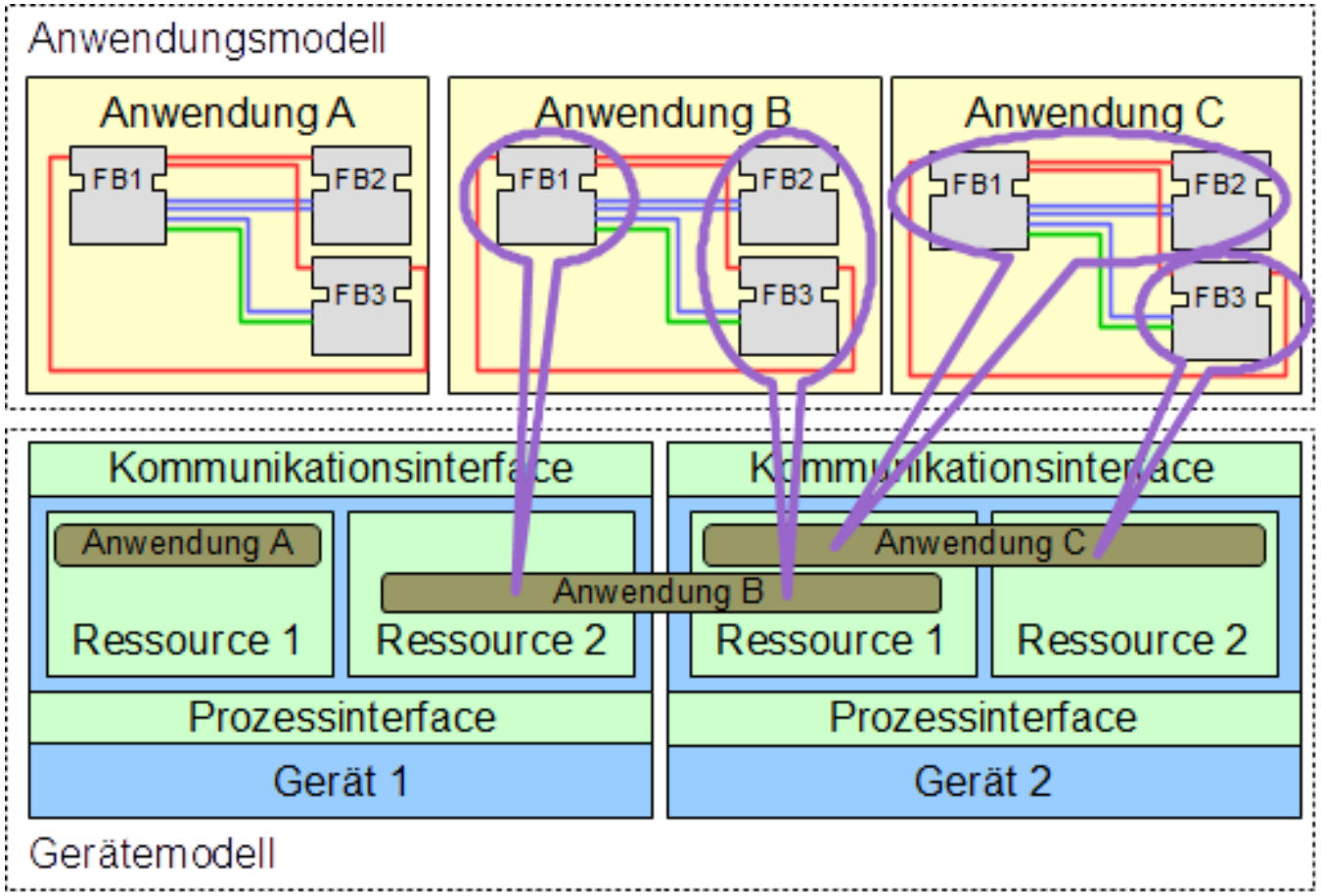


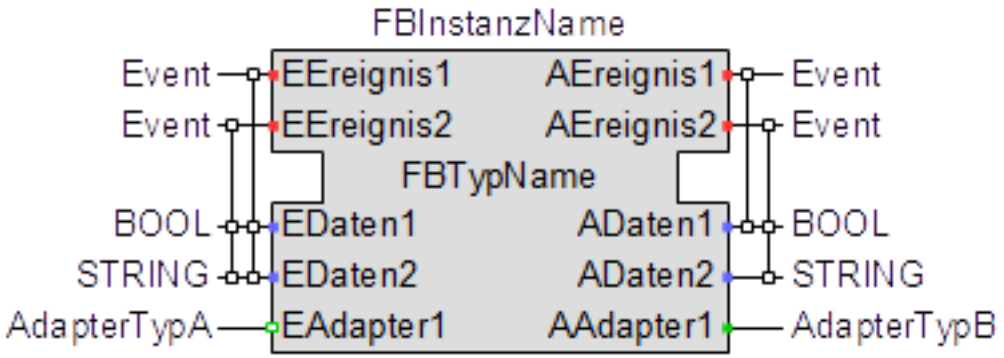
Enterprise Model Execution and Integration Services

Process Interoperability – Manual Workflow Design & Automatic Execution

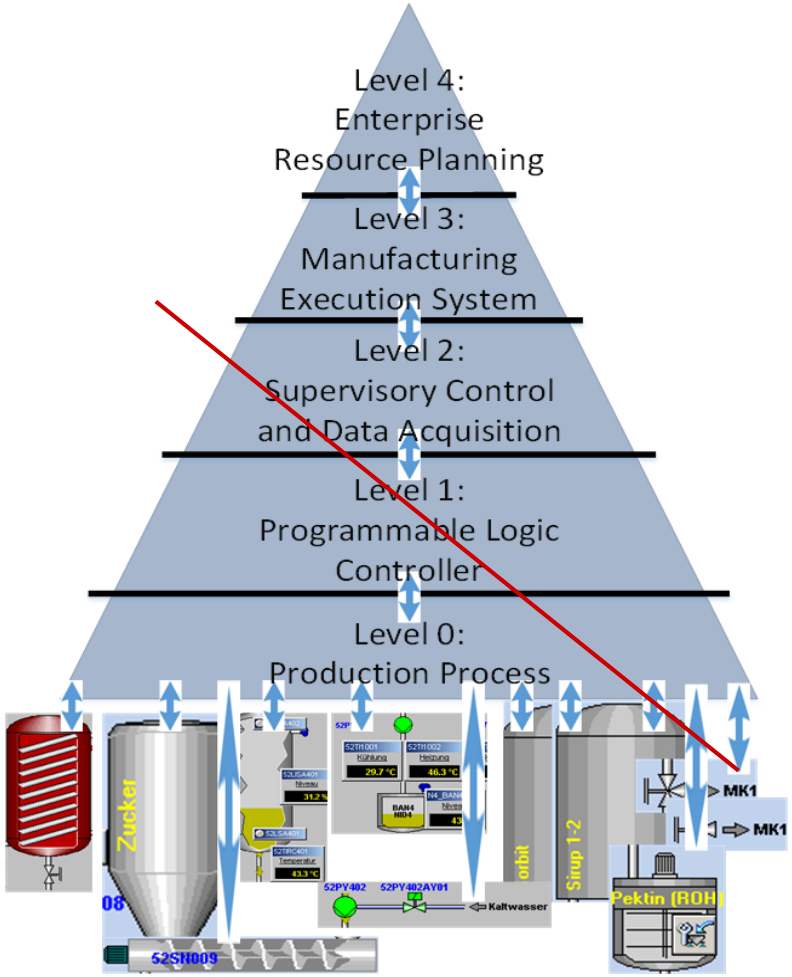


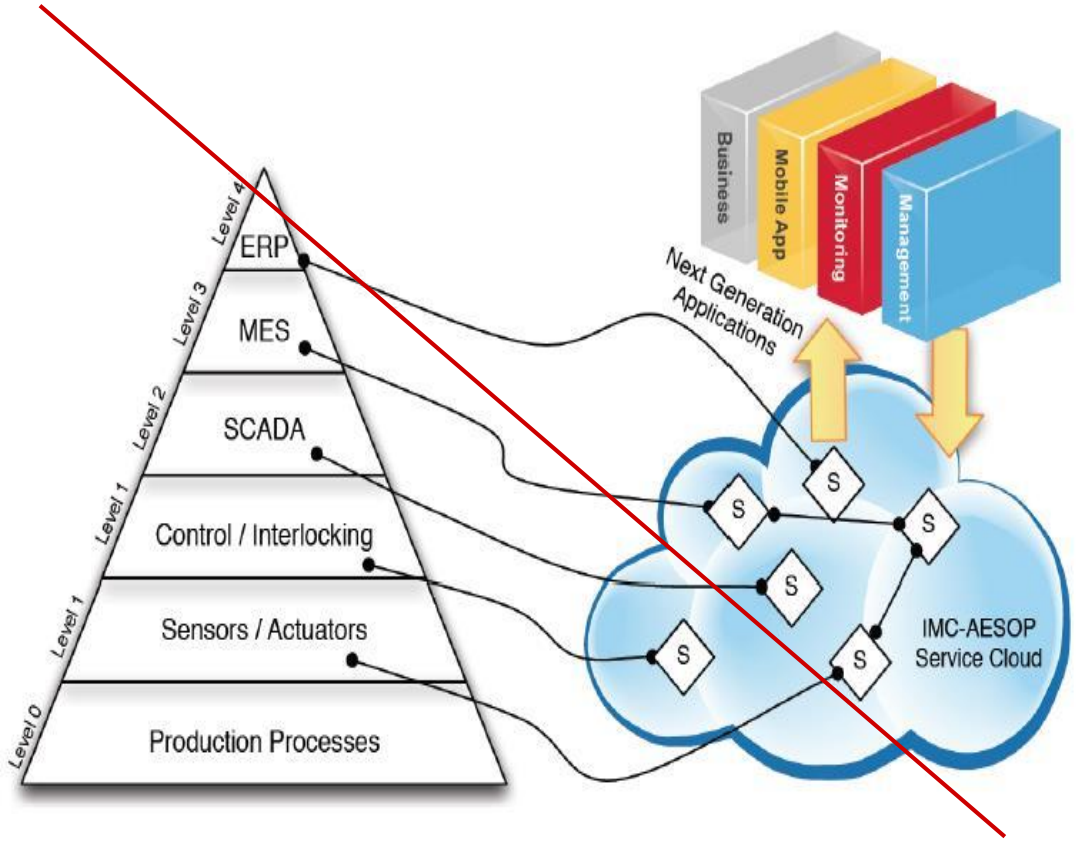
Process Interoperability - Manual Workflow Design & Automatic Execution



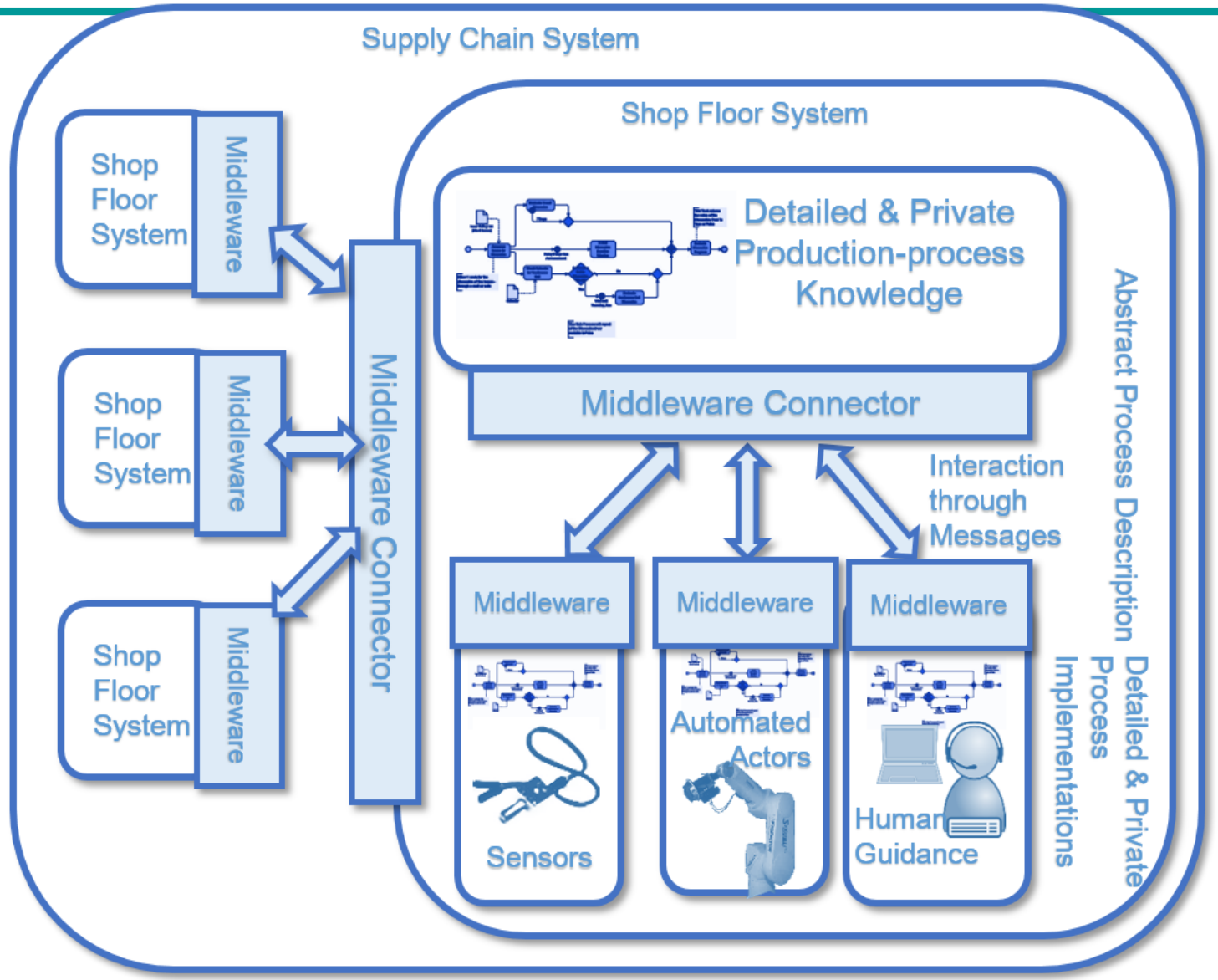


Other approaches tightly integrated or just compatible





Modular Process Oriented Framework for Production Process Interoperability



Pro²Future

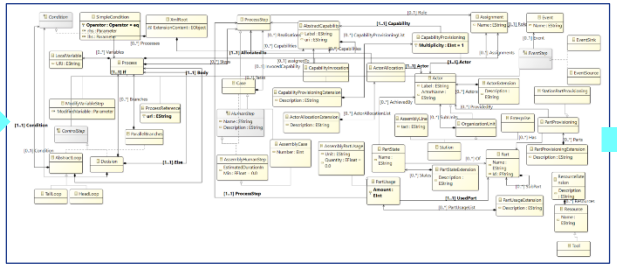
Modular Process Oriented Framework for Production Process Interoperability

Pro²Future

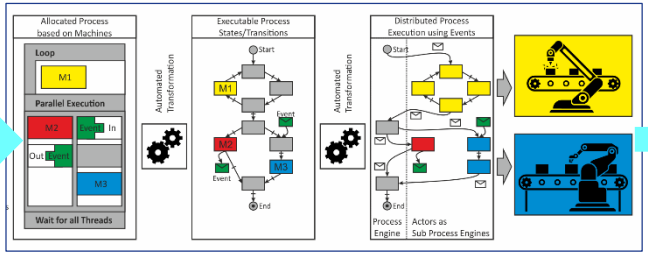
- Flexible Machines
- Collaboration and Coordination on the modular Shop Floor
- Handling the Systems Engineering of Distributed & Complex Systems
- Goal-oriented / Cognitive Decision Making for Optimization (efficiency, time & resources, product quality, flexibility, etc.)
- Symbolic & Distributed Artificial Intelligence (abstraction, logic, multi agent systems)

Transition of goal-oriented decisions into explicit machine controls

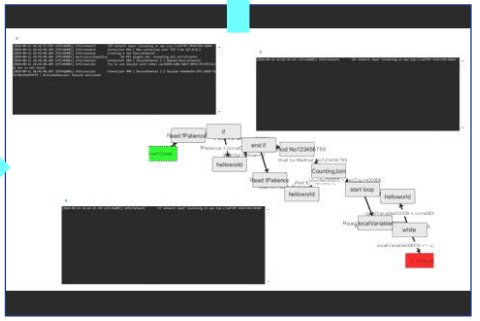
Flexibility:: Collaborating Machines



Modelling :: Abstraction and Complexity



Logic :: Processes and Intelligent Agents



Decision Making :: Process Optimization

Work in Progress for Production Process Interoperability

- Automated Process Planning
  - Incl. Replaning
  - extremely hard
    - Intermediate approach: Abstract Production Processes vs. Concrete Realisations
- Automated Process Scheduling
  - NP-hard
  - Re-Scheduling in combination with process replaning
- Processes for Heterogeneous Systems: Human Robot Collaboration / Operator 4.0
- Services required for automated planning and execution
  - Autonomous Actors / Agents & Self-organisations (interaction protocols & communication)
  - Yellow Pages / Directory Facilitator / Discovery / Model Mapping
  - Heartbeat / Lifecycle Support
  - Interoperability Support
  - Development / Debugging Support
  - …

Georg Weichhart

- Senior Scientist & Head of Team
  Flexible Production Systems
  PROFACTOR GmbH
  Im Stadtgut A2 | 4407 Steyr-Gleink | Austria
  Mob. +43 664 60 885-355
  Georg.Weichhart@Profactor.at | www.profactor.at
- Lecturer
  Communications Engineering – Business Informatics
  Johannes Kepler University Linz
  Georg.Weichhart@jku.at www.jku.at
- Chair
  International Federation on Automatic Control (IFAC)
  Technical Committee Enterprise Integration and Networking tc.ifac-control.org/5/3