Panel on INTELLI/InManEnt: Intelligent Production Agents

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Topic: Intelligent Production Agents

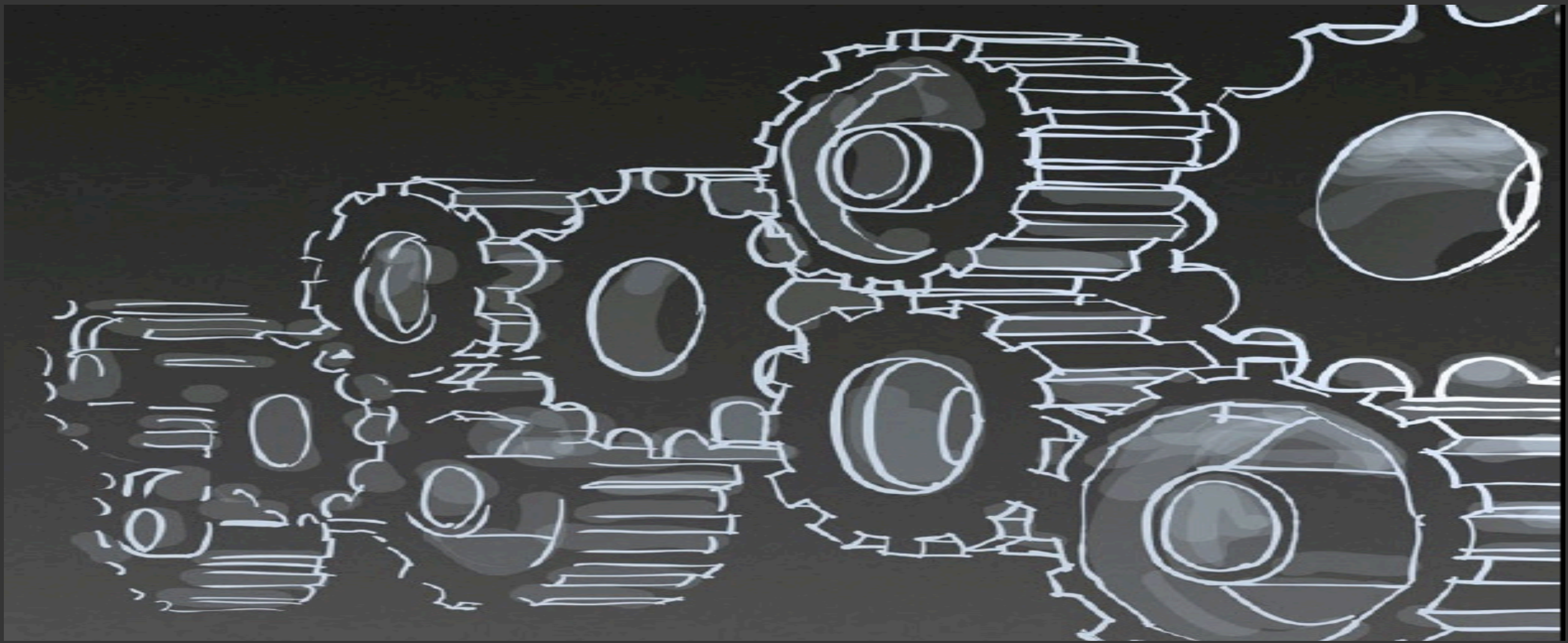
St. Julians, Malta

Panelists

- Norbert Link, University of Applied Sciences - Karlsruhe, Germany
- Oleksandr Sokolov, Nicolaus Copernicus University, Poland
- Ingo Schwab, University of Applied Sciences - Karlsruhe, Germany
- Leo van Moergestel, Utrecht University of Applied Sciences, The Netherlands
- Gil Gonçalves, Faculdade de Engenharia da Universidade do Porto, Portugal

Moderator: Gil Gonçalves

Intelligent Manufacturing Environments



Manufacturing companies are subject to constant changes in their operational environment, due to new regulations, economic up/downturns, environmental issues and technological innovation.

Being capable to respond to these continuous and most of the times disruptive changes, demands for reconfigurability, flexibility, adaptability and agility.

"Intelligent Production Agents" present challenges related with new production paradigms and concepts, new knowledge based approaches, and life cycle sustainability of products and production systems.

- Norbert Link: Mutual Optimisation
- Oleksandr Sokolov: Agents communication and cooperation under uncertainty environment
- Ingo Schwab: How to Represent and Use Process Knowledge; Ideas from Machine Learning and Statistics
- Leo van Moergestel: Extending the role of product agents to the whole life cycle of a product
- Gil Gonçalves: Changeability in Production Control Systems

Changeability in Production Control Systems

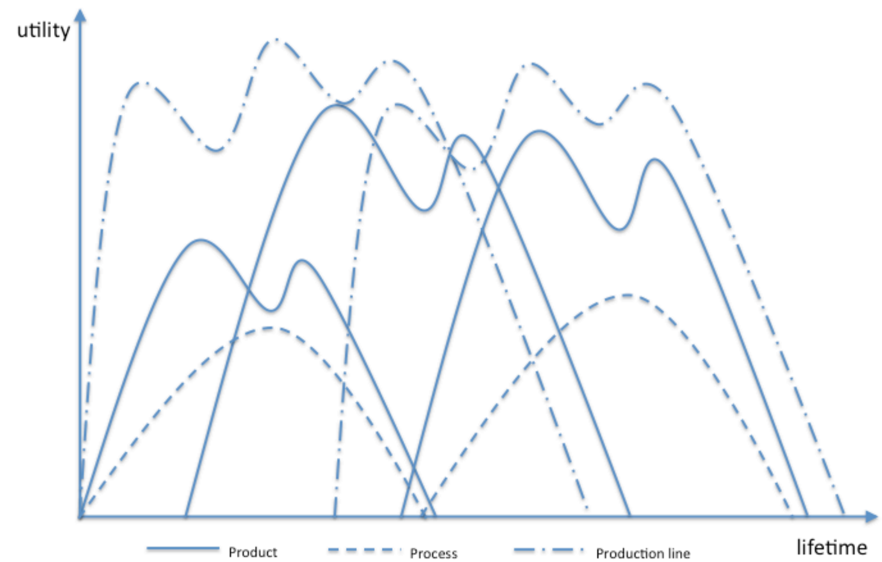
European industry is active in all manufacturing fields, making Europe one of the strongest outfitters and operators of factories. Industrial processing machinery and production systems cover a wide range of products destined to specific purposes in downstream manufacturing sectors and, as such, demand for these is closely linked to new products or product renovation in the downstream manufacturing sectors.

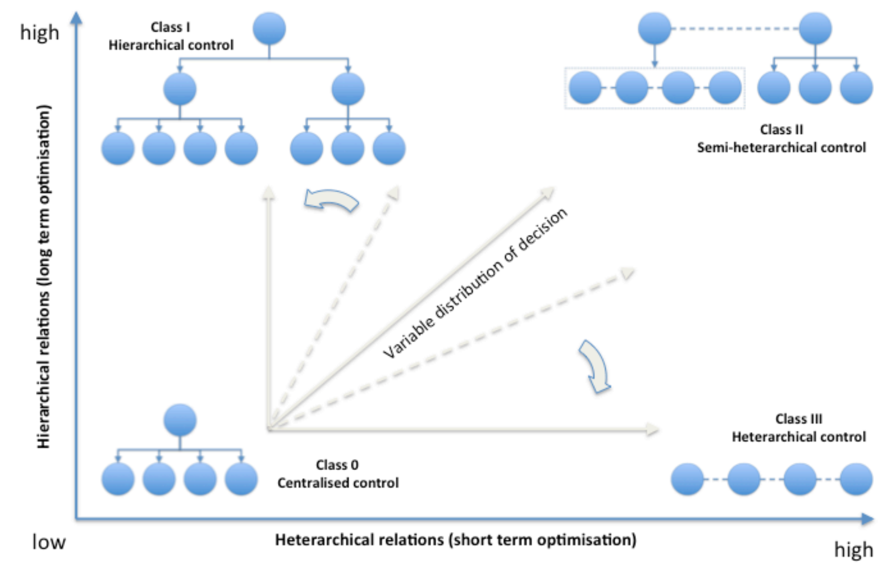
Customization and make to order in downstream sectors, leads to smaller lot sizes, higher variability of products and reduced product life cycles.

Changeability in Production Control Systems

Rapid changing product portfolios and technologies requires production systems that are easily upgradeable, and into which new technologies and functions can be easily integrated.

This creates the need for novel manufacturing control systems able to cope with the increased complexity required to manage product variability and disturbances, and to implement agility, flexibility and reactivity in customized manufacturing.



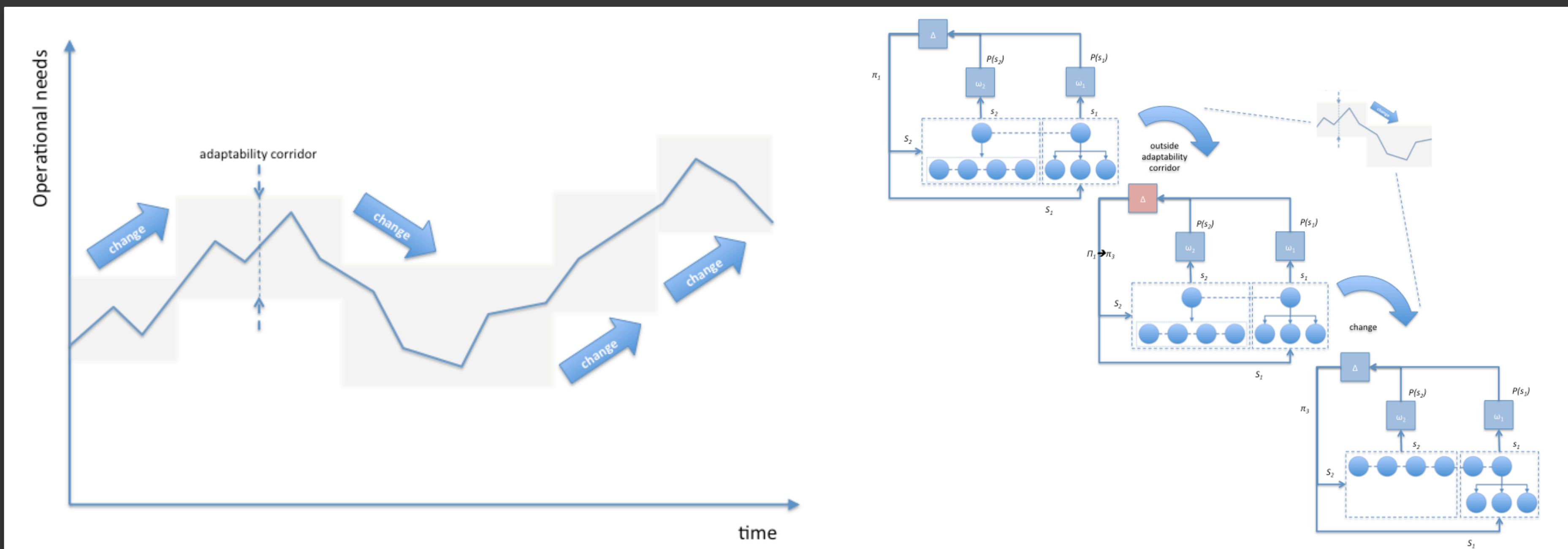


Facing these challenges requires highly flexible, intelligent and self-adaptive production systems, equipment and control systems, which can react to continuously changing demand, can be smoothly brought into operation, and can extend equipment life cycle.

Changeability in Production Control Systems

Self-adaptive production systems and equipment, can fast adjust within adaptability corridors, at multiple levels with low effort. But in some cases the boundaries of the changeability corridors must be crossed.

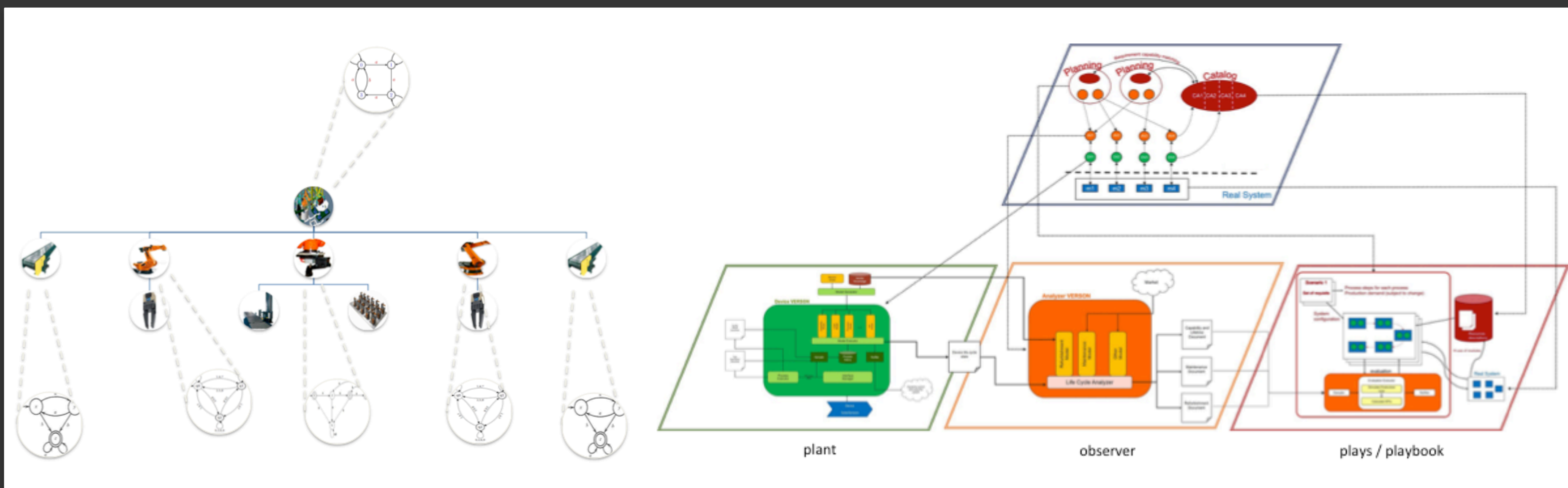
Changes may take place at the physical (hard) level or at the logical/control (soft) level.



The changeability function analyses the behaviour of the system and in case the current operational needs fall outside the adaptability corridor of the current configuration decides on a new configuration to use (may imply an increase/decrease of capacity or functionality).

Changeability in Production Control Systems

Multiple control architectures can be defined and analysed during the design phase of the production system (off-line mode)
This way the time to react to "change events" can be reduced and based on a selection of the most adequate configuration amongst the existing ones
(similar to the selection of the most adequate play from a playbook).



During the running phase (on-line mode), new configurations can be added and obsolete configurations removed (learning process).
This guarantees the dynamics of the configuration repository (playbook) and ensures its adequacy for the control of the system.

Summary of the "Intelligent Production Agents" panel

Pre-requisites to production agents intelligence: situation perception, acquisition and representation of process and self-state knowledge, reasoning system to derive optimal process execution from the knowledge and the encountered situation, and language and communication skills.

Agent communication under uncertainty: languages and communications skills able to deal with stochastic and uncertain environments

Knowledge representation: machine learning and statistics as basis for a reasoning system to derive process execution

Product agents to extend product life cycle: acquisition and representation life cycle use and self-state, possible re-use of the whole product or its parts

Changeability to extend system life cycle: adaptability and automation/autonomy of the systems and its capacity to respond to modifications in the operational needs and/or rules of engagement

Number of industrial applications: still very limited, lack of reference architectures and standards

I-RAMP³
Intelligent Network Devices for fast Ramp-up

How to Represent and use Process Knowledge
Some Ideas from Machine Learning and Statistics
(very short presentation…)

Ingo Schwab

Hochschule Karlsruhe – Technik und Wirtschaft
Institut für Angewandte Forschung (IAF)

19.10.2015

Hochschule Karlsruhe
Technik und Wirtschaft
UNIVERSITY OF APPLIED SCIENCES

IAF
Institut für
Angewandte Forschung

Question: How to adjust the parameters of a machine/ process line that it works well?

- Process chain optimization.

paran Solution? Try every combination of the parameters?

http://thumb

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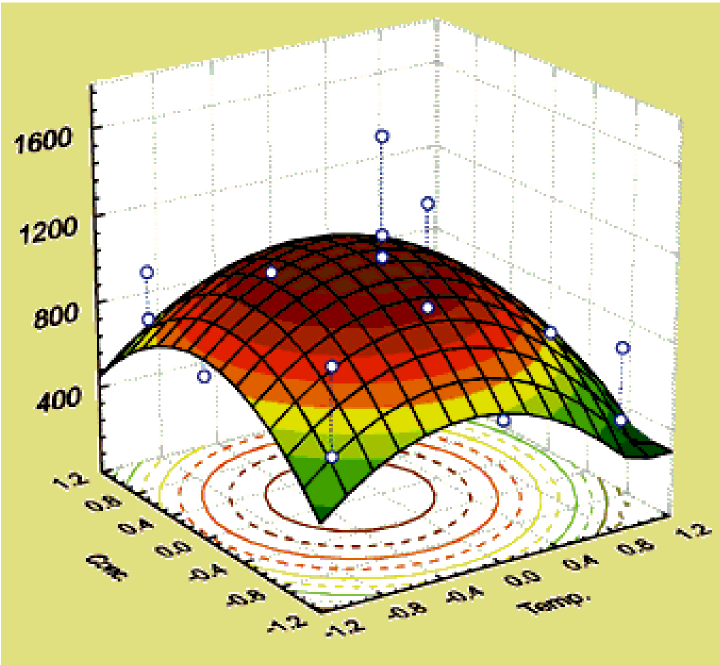
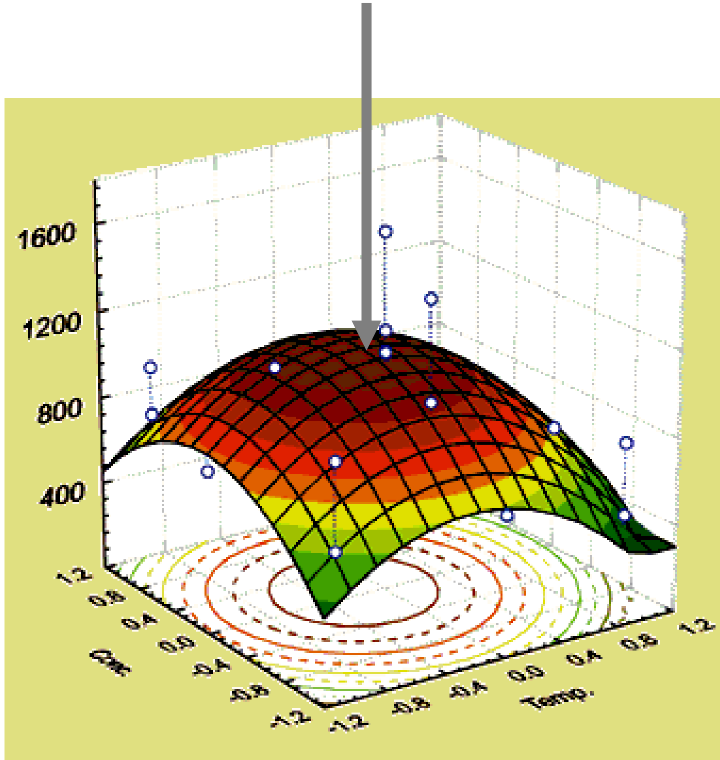
(Simple) example

Regression task.
Curve(-fitting) of the measurements (white dots).



interpolate Optimum



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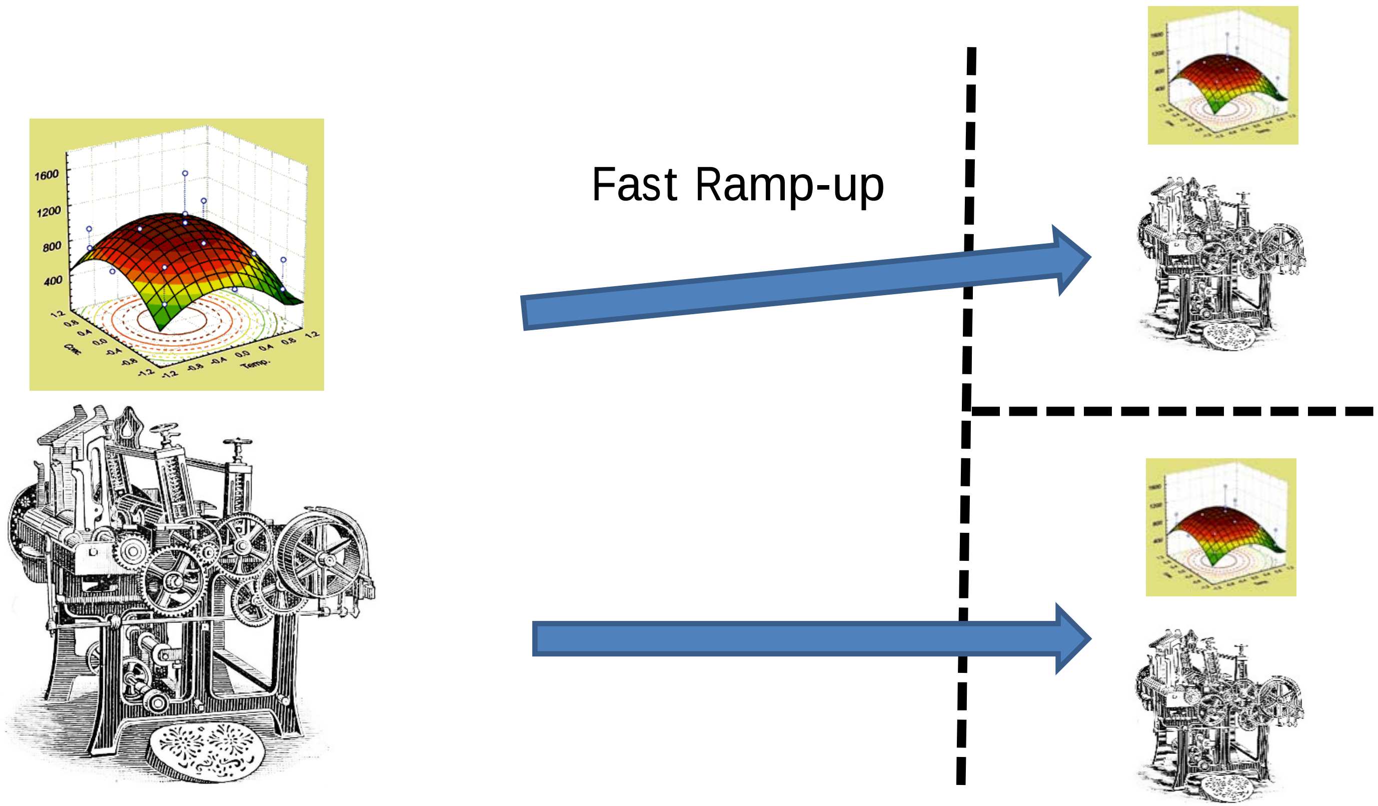
Another idea: transfer the knowledge from one machine to another.
Adjust the parameter with a learned model.



Summary of the goals:

Ramp-up Phase

- Zero ramp-up time for known tasks
- Reduced experimental effort for change to unknown tasks
- Fast ramp-up after exchange of device components

Production Phase

- Fast-driven execution (no specification of parameters)
- Zero time of change to product variants (known tasks)
- Zero time for exchange of devices

Easy task? Or research topic?

So far: Everything seems to be easy and straightforward.

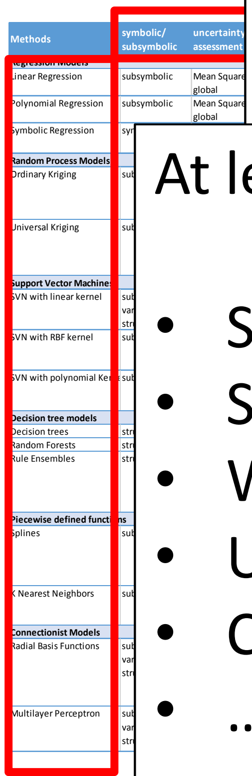
But: Talk Hao Wang, Ingo Schwab, Michael Emmerich: Comparing Knowledge Representation Forms in Empirical Model Building

Easy task? Or research topic?

So far: Everything seems to be easy and straightforward.

But: Talk Hao Wang, Ingo Schwab, Michael Emmerich: Comparing Knowledge

Representat



At least 15 different learning algorithms are used in practice.

At least 14 different properties of the models.

- Structure fixed by the framework/user
- Structures learned
- Which Parameters are fitted from data
- Uncertainty assessment
- Computational effort
- …

Questions?

Extending the role of product agents to the whole life cycle of a product

Leo van Moergestel

Agent-based Manufacturing

- A product agent will guide the manufacturing of a single product
- The production software infrastructure is a multiagent system
- The product agent creates a production log.

What happens when a product has been made?

- Transport
- Use
- Repair, maintenance
- Recycling

- All controlled by a remote or embedded agent.

Internet radio

- Made by end-user specification
- Should be capable to clone itself
- The product agent is the guardian angel of the product

Agents communication and cooperation under uncertainty environment

Oleksandr Sokolov

Nicolaus Copernicus University,
Torun, Poland

Contents

- State value
- Conflict resolution

Agent structure and basic functions

- Agent
  - Data
  - Behavior
    - Action based on utility
      - Probability
      - Predicate
      - Game
      - Planner
    - Decision making
      - Theorem prover
        - Environment
        - Another agent
      - Temporal logic
        - Beleive
        - Desire
        - Intention
      - Modal logic
    - Agreement
      - Auction
      - Pareto efficiency
      - Rationality
      - Guaranteed success
      - Negotiation
        - One-to-one
        - One-to-many
        - Many-to-many

Intelligent agents *continuously* perform three basic functions:

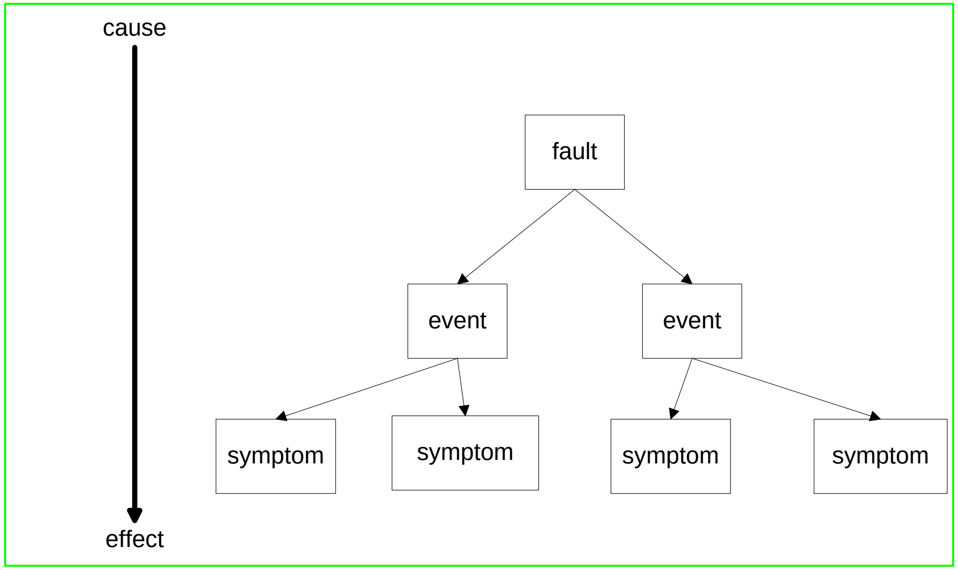
- *perception* of *dynamic conditions* in the *environment*;
- *reasoning* to *interpret* perceptions;
- *solve problems*.

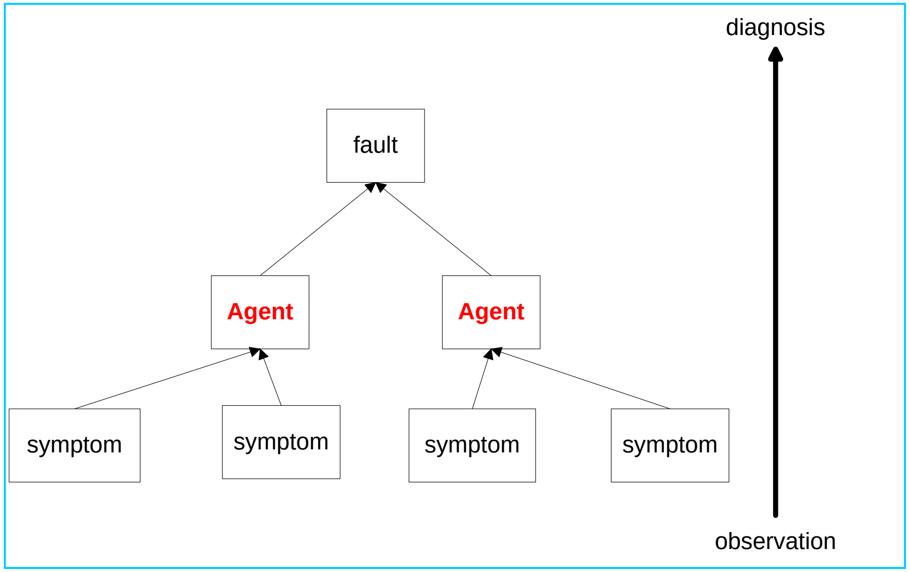
Remark. The ***complex models of simple entities*** *(real variables,levels,resources)* *we barter for the* ***simple model of complex entities*** *(agents)****!***
It is possible first of all due to modern computers productivity.

State Estimation from the Symptom-Fault Relationship

physical system: from faults to symptoms

diagnosis system: from symptom to faults





The main mission of 'events' in diagnostic task is to perceive the symptoms and recognize caused faults.

Additional advantages of using intermediate layer:

- spatially distributed diagnosis,
- activities of events,
- possibility 'to speak' each other.

Symptom-fault agent's model

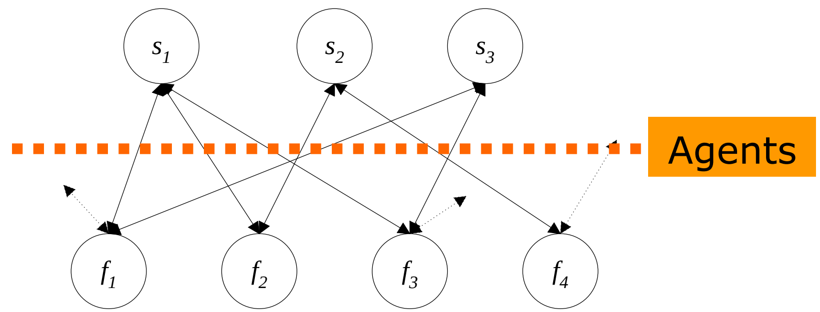
We use $F = \{f_l\}_{l=1}^{N_F}$ and $S = \{s_m\}_{m=1}^{N_S}$ to denote the finite sets of all possible faults and symptoms, respectively.

$$\psi : S \rightarrow F \qquad (1)$$

Mappings (1) are widely presented as a ***binary diagnostic matrix***

Let us introduce the set of agents $A = \{a_i\}_{i=1}^{N_A},\ N_A \leq$

S / F	f_1	...	f_{N_F}
s_1	0	...	0
...	0	...	1
s_{N_S}	1	...	1



Sa1/Fa1	f_1	...	***FMa1***
s_1	0	...	0
...	0	...	1
sNa1	1	...	1

Sa2/Fa2	f_1	...	***FMa2***
s_1	0	...	0
...	0	...	1
sNa2	1	...	1

San/Fam	f_1	...	***FMam***
s_1	0	...	0
...	0	...	1
sNan	1	...	1

(Each agent is responsible for several (greater then zero) faults and one fault can be recognized by several (greater then zero) agents).

Example of diagnostic problem

Let us consider three-tank system and its fault diagnosis matrix

$$A_1 \frac{dL_1}{dt} = F - Q_{12} = F - \alpha_{12} S_{12} \sqrt{2g(L_1 - L_2)},$$

$$A_2 \frac{dL_2}{dt} = Q_{12} - Q_{23} = \alpha_{12} S_{12} \sqrt{2g(L_1 - L_2)} - \alpha_{23} S_{23} \sqrt{2g(L_2 - L_3)},$$

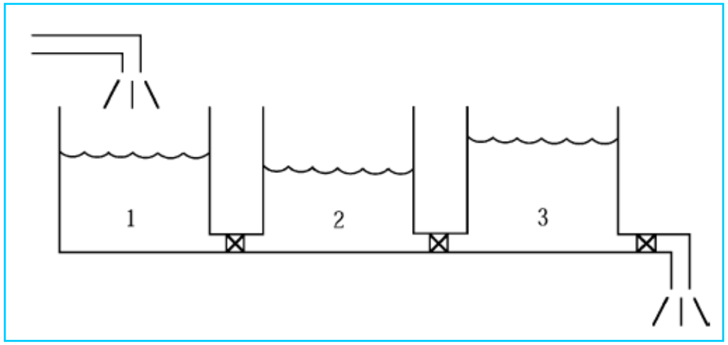
$$A_3 \frac{dL_3}{dt} = Q_{23} - Q_3 = \alpha_{23} S_{23} \sqrt{2g(L_2 - L_3)} - \alpha_3 S_3 \sqrt{2gL_3},$$

S/F	f_1	f_9	f_{10}	f_{11}	f_{12}	f_{13}	f_{14}
s_1	1						
s_2	1	1			1		
s_3		1	1			1	
s_4			1	1			1
s_5	1			1	1	1	1

Let us assume that fault detection is realized with the use of five residuals generated on the grounds of the physical equations of the dynamical system. These residuals generate the symptoms s1,s2,s3,s4,s5.

Diagnostic signal	Detection algorithm	Decision algorithm
s_1	$r_1 = F - \hat{F}$	$\lvert r_1 \rvert < K_1$
s_2	$r_2 = F - \alpha_{12} S_{12} \sqrt{2g(L_1 - L_2)} - A_1 \frac{dL_1}{dt}$	$\lvert r_2 \rvert < K_2$
s_3	$r_3 = \alpha_{12} S_{12} \sqrt{2g(L_1 - L_2)} - \alpha_{23} S_{23} \sqrt{2g(L_2 - L_3)} - A_2 \frac{dL_2}{dt}$	$\lvert r_3 \rvert < K_3$
s_4	$r_4 = \alpha_{23} S_{23} \sqrt{2g(L_2 - L_3)} - \alpha_3 S_3 \sqrt{2gL_3} - A_3 \frac{dL_3}{dt}$	$\lvert r_4 \rvert < K_4$
s_5	$r_2 = F - \alpha_3 S_3 \sqrt{2gL_3} - A_1 \frac{dL_1}{dt} - A_2 \frac{dL_2}{dt} - A_3 \frac{dL_3}{dt}$	$\lvert r_5 \rvert < K_5$

Example of agents representation of binary diagnostic problem



Unit	Agent	List of faults
Tank Z_1	a_1	f_2, f_9, f_{12}
Tank Z_2	a_2	f_3, f_{10}, f_{13}
Tank Z_3	a_3	f_4, f_{11}, f_{14}
Pump	a_4	f_1, f_5, f_6, f_7, f_8

f_k	Fault description
f_1	fault of the flow sensor F
f_2	fault of the level sensor L_1
f_3	fault of the level sensor L_2
f_4	fault of the level sensor L_3
f_5	fault of the control path U
f_6	fault of the control-valve
f_7	fault of the pump
f_8	lack of medium
f_9	partial clogging of the channel between the tanks Z_1 and Z_2
f_{10}	partial clogging of the channel between the tanks Z_2 and Z_3
f_{11}	partial clogging of outlet
f_{12}	leaking from the tank Z_1
f_{13}	leaking from the tank Z_2
f_{14}	leaking from the tank Z_3

S/F	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}	f_{11}	f_{12}	f_{13}	f_{14}
s_1	1				1	1	1	1						
s_2	1	1	1						1			1		
s_3		1	1	1					1	1			1	
s_4			1	1						1	1			1
s_5	1	1	1	1							1	1	1	1

Fuzzy Relation cs. Crisp Relation

S/F	f_1	f_2	f_3	f_4
s_1			1	
s_2	1	1		
s_3		1	1	1
s_4			1	
s_5	1	1		

S/F	f_1	f_2	f_3	f_4
s_1	0.7	0.6	0.4	0.2
s_2	0.8	0.6	0.2	0
s_3	0.7	0.6	0.4	0.1
s_4	1	0	0.3	0
s_5	0.8	1	0.4	0

Inverse problem of diagnosis

$$F \circ B = S$$

$$F \circ R = S$$

$$S_O = \{s_2, s_3, s_5\}$$

S=[0.7, 0.6, 0.4, 0.2, 0]

$$\sigma_{full} = f_2 \vee (f_1 \wedge f_4) \vee (f_2 \wedge f_1) \vee (f_2 \wedge f_4) \vee (f_2 \wedge f_1 \wedge f_4)$$

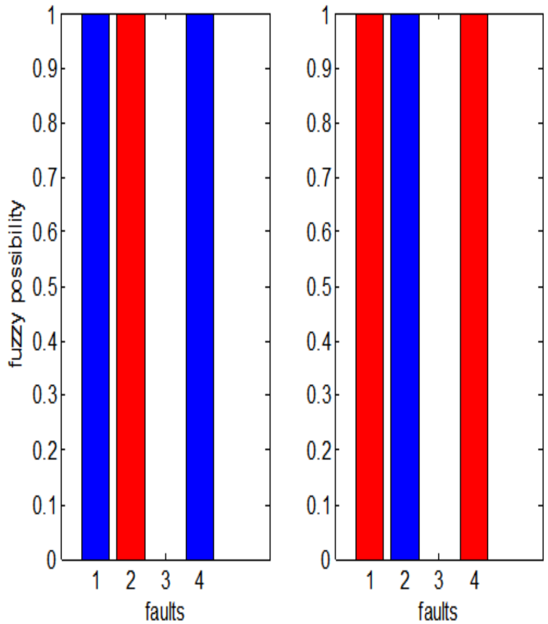
Crisp Solution

n=5; %j - symptoms
m=4; %i - faults
R=[1 0 1 0 0;
1 1 1 0 0;
0 1 0 1 1;
0 1 0 0 0];
S=[1 1 1 0 0];
Now
F^G =

1 1 0 1

and
F^L =

0 1 0 0
1 0 0 1



Let the binary diagnosis matrix be as follows

S/F	f_1	f_2	f_3	f_4
s_1			1	
s_2	1	1		
s_3		1	1	1
s_4			1	
s_5	1	1		

Let $S_O = \{s_2, s_3, s_5\}$ is observed set of symptoms .
Then we have $\sigma = f_2 \vee (f_1 \wedge f_4)$,
and $D(S_O) = 2$, $C_1(S_O) = \{2\}, C_2(S_O) = \{1,4\}$,
$\sigma_{full} = f_2 \vee (f_1 \wedge f_4) \vee (f_2 \wedge f_1)$
$\vee (f_2 \wedge f_4) \vee (f_2 \wedge f_1 \wedge f_4)$

We have the same result.

Fuzzy Solution

Let

R=[0.7 0.6 0.4 0.2 ;
0.8 0.6 0.2 0 ;
0.7 0.6 0.4 0.1;
1 0 0.3 0];

S=[0.7 0.6 0.4 0.2];

Then

F^G =

1.0000 0.7000 1.0000 0.7000

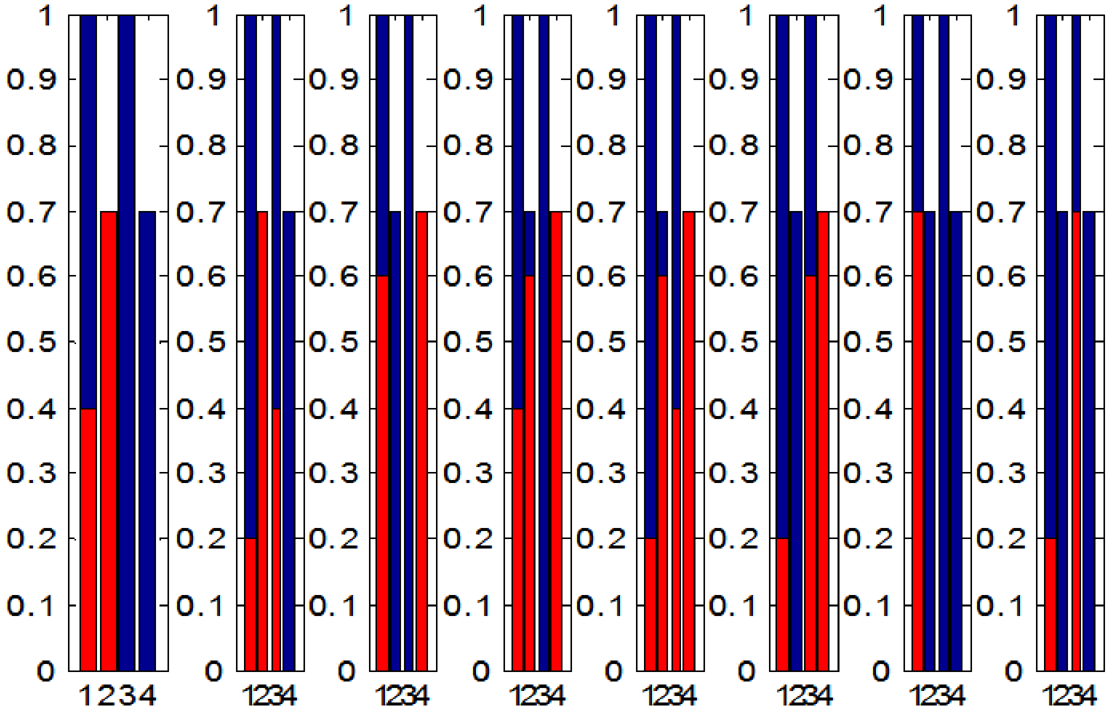
and

F^L =

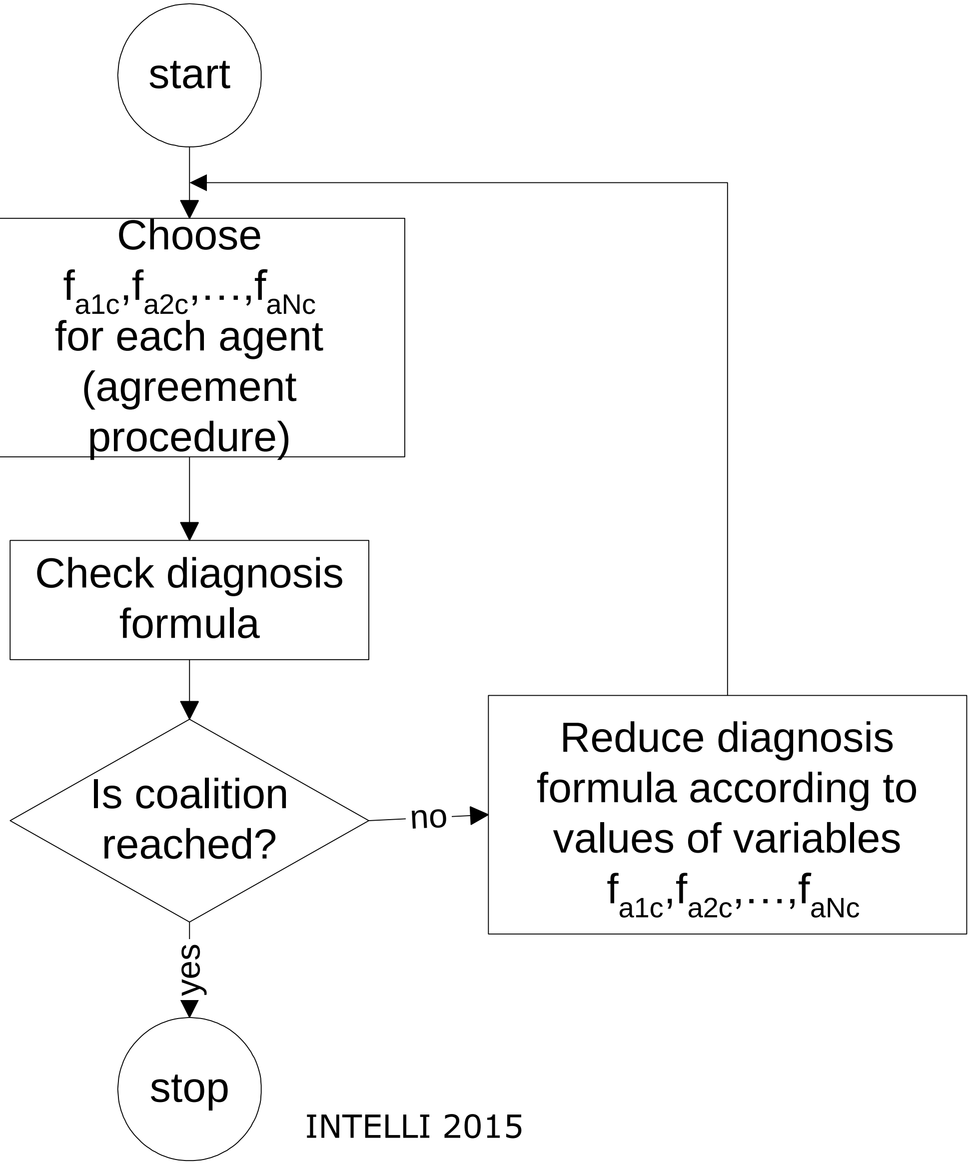
[

0.4000	0.7000	0	0
0.2000	0.7000	0.4000	0
0.6000	0	0	0.7000
0.4000	0.6000	0	0.7000
0.2000	0.6000	0.4000	0.7000
0.2000	0	0.6000	0.7000
0.7000	0	0	0
0.2000	0	0.7000	0

]



Agents Cooperation Algorithms



Cooperation at Partial Observability Conditions

We now introduce a model of modal logic as

$$M = \left\langle W, R_1, \ldots, R_{N_A} \right\rangle$$

where:

- $W = \left\{ w_i \right\}_{i=1}^{N_W}$ is a finite, non-empty set of possible worlds that reflect possible faults; one of these worlds is named as *current* and reflect current state of fault diagnosis;
- $R_i, i = \overline{1, N_A}$ is a relation that i^{th} agent set for possible worlds for its faults.

Algorithm

a) Generate the set of possible states of the world S.

b) Generate partial information set for each agent and collect them into the common knowledge

$$\{P_1(s), P_2(s), \ldots, P_N(s)\}$$

c) Starting from one agent to begin to making decision until the one-element true information set became for some agent

d) The agent with one-element true information set recognize the true state.

S = {a=f1, b=f2, c=f3,…},

$$\sigma_{full} = f_2 \vee (f_1 \wedge f_4) \vee (f_2 \wedge f_1) \vee (f_2 \wedge f_4) \vee (f_2 \wedge f_1 \wedge f_4) \vee \ldots$$

		Set of Faults							
		a	b	c	d	e	f	g	h
Agents	1	I	I	I	I	H	H	H	H
	2	I	I	H	H	I	I	H	H
	3	I	H	I	H	I	H	I	H

Sequential Iteration Procedure

Let fault a is true

S = {a,b,c,d,e,f,h}

All agents: Fault *h* is impossible

$$P_1^t = \{\{a,e\},\{b,f\},\{c,g\},\{d,h\}\}$$
$$P_2^t = \{\{a,c\},\{b,d\},\{e,g\},\{f,h\}\}$$
$$P_3^t = \{\{a,b\},\{c,d\},\{e,f\},\{g,h\}\}$$

Agent1: Fault *d* is impossible

$$P_1^{t+1} = \{\{a,e\},\{b,f\},\{c,g\},\{d\},\{h\}\}$$
$$P_2^{t+1} = \{\{a,c\},\{b,d\},\{e,g\},\{f\},\{h\}\}$$
$$P_3^{t+1} = \{\{a,b\},\{c,d\},\{e,f\},\{g\},\{h\}\}$$

Agent2: Faults *b* and *d* are impossible

$$P_1^{t+2} = \{\{a,e\},\{b,f\},\{c,g\},\{d\},\{h\}\}$$
$$P_2^{t+2} = \{\{a,c\},\{b\},\{d\},\{e,g\},\{f\},\{h\}\}$$
$$P_3^{t+2} = \{\{a,b\},\{c\},\{d\},\{e,f\},\{g\},\{h\}\}$$

Agent3: Fault *a is true*

$$P_1^{t+3} = \{\{a,e\},\{b\},\{f\},\{c,g\},\{d\},\{h\}\}$$
$$P_2^{t+3} = \{\{a,c\},\{b\},\{d\},\{e,g\},\{f\},\{h\}\}$$
$$P_3^{t+3} = \{\{a\},\{b\},\{c\},\{d\},\{e\},\{f\},\{g\},\{h\}\}$$

Problems

- Communication in fuzzy environment
- Using of Type 2 Fuzzy Logic
- Different strategies of cooperation of agents

Thank you very much for your attention!

Puzzle of the Hats

Three agents (say, girls) are sitting around a table, each wearing a hat. A hat can be either red or white, but suppose that all agents are wearing red hats. Each agent can see the hat of the other two agents, but she does not know the color of her own hat. A person who observes all three agents asks them in turn whether they know the color of their hats. Each agent replies negatively. Then the person announces ‘At least one of you is wearing a red hat’, and then asks them again in turn. Agent1 says No. Agent2 also says No. But when he asks Agent 3, she says Yes