Lecture Material given at

Söffker, D.; Ahle, E.: Idea, Conception, and Realization of Learning Abilities for Robot Control using a Situation-Operator-Model. Proc. of the Workshop on Automatic Learning and RealTime ALART05, University of Siegen, September 7-8, 2005, pp. 131-141.

Idea, Conception, and Realization of Learning Abilities for Robot Control Using a Situation-Operator-Model

Dirk Söffker and Elmar Ahle

UNIVERSITÄT DUISBURG ESSEN

Chair of Dynamics and Control
University Duisburg-Essen

Outline

- **Motivation**
- Initiating Ideas
- Conception of the Learning System
- Realization of the Architecture
- Conclusion and Future Work

Motivation

Main goals

- Building an autonomous learning system
- Learning from interaction with the environment
- Goals can be changed
- Goal-oriented interaction in a real world environment

Approach/Idea

- Structure the reality and map the structuring to the mental model to enable planning and learning
- Use the related Situation-Operator-Model (SOM) for the common representation

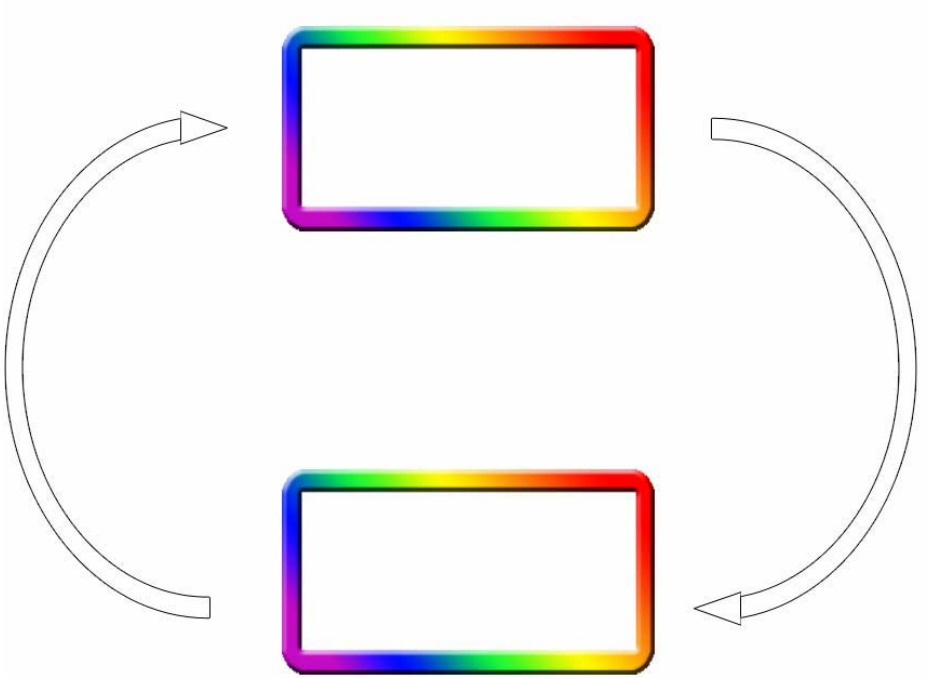
Outline

- Motivation
- **Initiating Ideas**
- Conception of the Learning System
- Realization of the Architecture
- Conclusion and Future Work

Interaction

Two-way reaction between players or systems

In the minimum two ‚systems' are interacting.



System – System
Human – Human
Human – System

> Human-Machine-Interaction
> Human-Machine-System

What is interaction?
How can the interaction be described?

Human-Machine-Interaction I

Example:
Supervision and
Control of
Railway Traffic,

here:
Hagen Electronic
Operating Center of the
Deutsche Bahn AG

Human-Machine-Interaction II

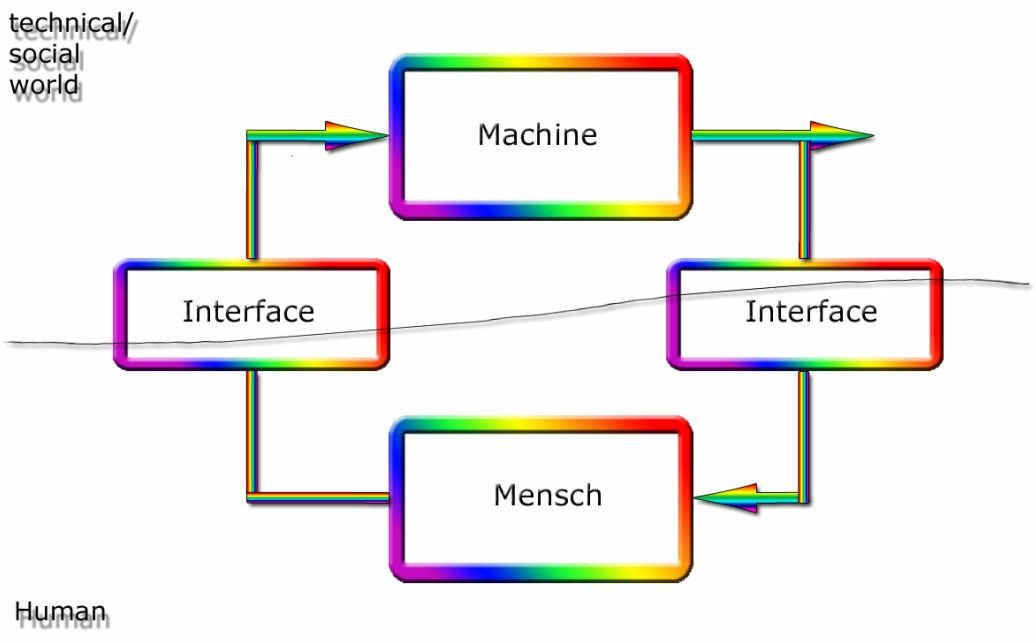
Example:
Supervision and
Control of
Railway Traffic,

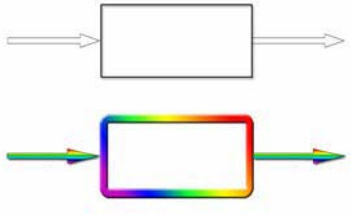
here:
Hagen Electronic
Operating Center of the
Deutsche Bahn AG

Example: Electronic Operating Center Hagen (German Railway)

Human-Machine-Interaction VI (and assumptions)

Causality ⇔ from the cause to the effect





i) final chain
ii) inner connections

Which is the adequate description? (techn./phsic. values > information)

Higher goals: - stability / dynamics - robustness - observability
- controllability -> automatic control

Qualitative Modeling Approach I

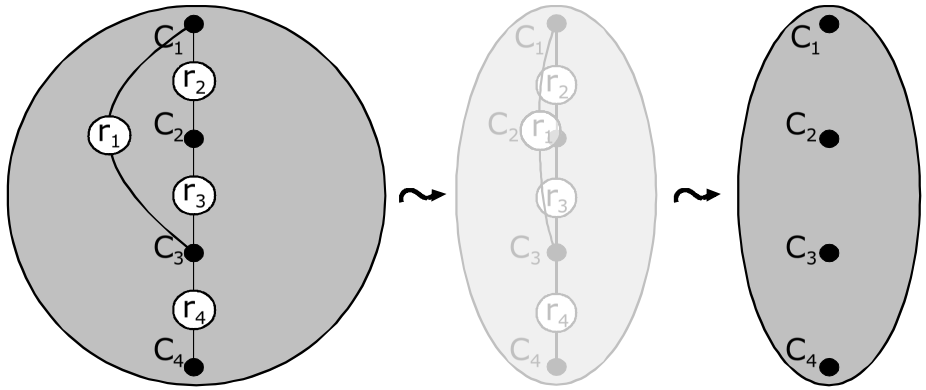
(structural variable systems)

Situation:

The term situation describes a fixed problem constellation and denotes the considered system.

The situation consists of an inner structure, which also allows the integration of time-variant values.

The graphical representation is realized by characteristic (C) and inner relations (R). Different detailed graphical representations are possible.



(Söffker, 1998f, 2001, 2003)

Qualitative Modeling II

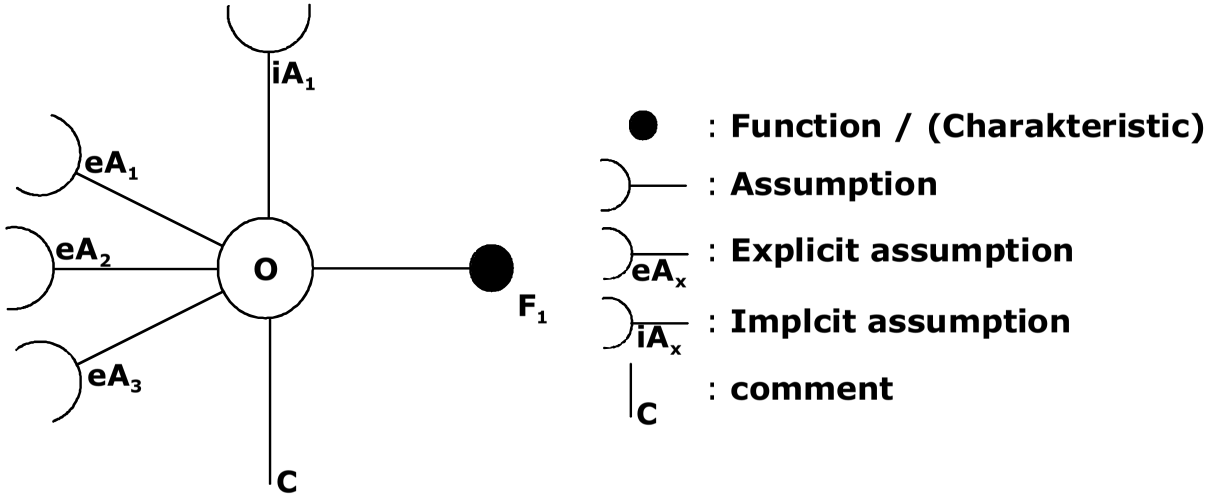
(structural variable systems)

Operator:

Operators are used to represent functional connections of real world facts. The connection can be passive (constitutional) or active ('ability to change something'). Operators represent/model outer world facts.

The function of an operator is denoted with (F), as 'input' the explicit and implicit assumption for realization of F (eA, iA) are used.

For detailed modeling known techniques will be used.
The SOM-technique is working as a meta-modeling approach.



(Söffker, 1998f, 2001, 2003)

Situation-Operator-Model

Assumption

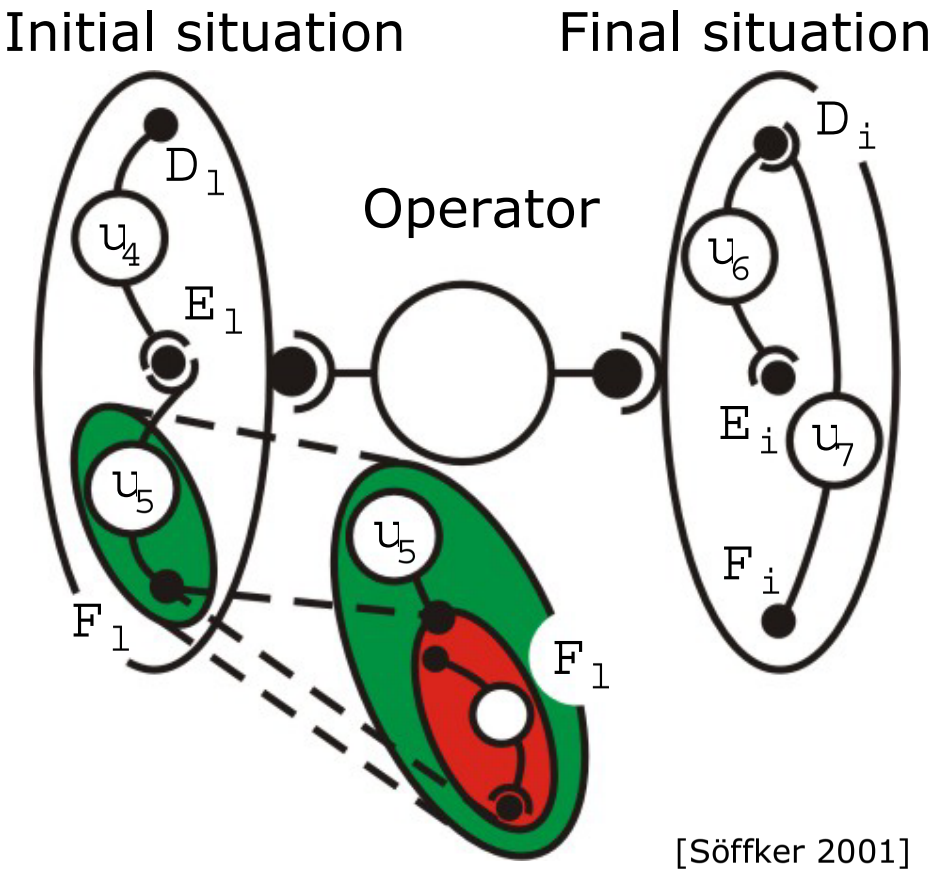
Changes and facts of the real world are understood as a sequence of scenes changed by actions.

Situation (model of scene)

- Characteristics D_1, E_1, F_1, D_i …
- Set of relations u_4, u_5 , u_6 , u_7 …
- Changed by operator

Operator (model of action)

- Function as result
- Explicit and implicit assumptions as input



[Söffker 2001]

➔Structuring used to model learning, planning, and execution process

Situation-Operator-Model

Learning

Assumptions to realize learning

- Problem-dependent structures of the real world scenes identified as structured situation-dependent characteristics and relations
- The real world is modeled by SOM that the relevant structure of the scenes and the situation are equal
- 'Time-independent' operators (active or passive) related to the problem structure are identified/learned

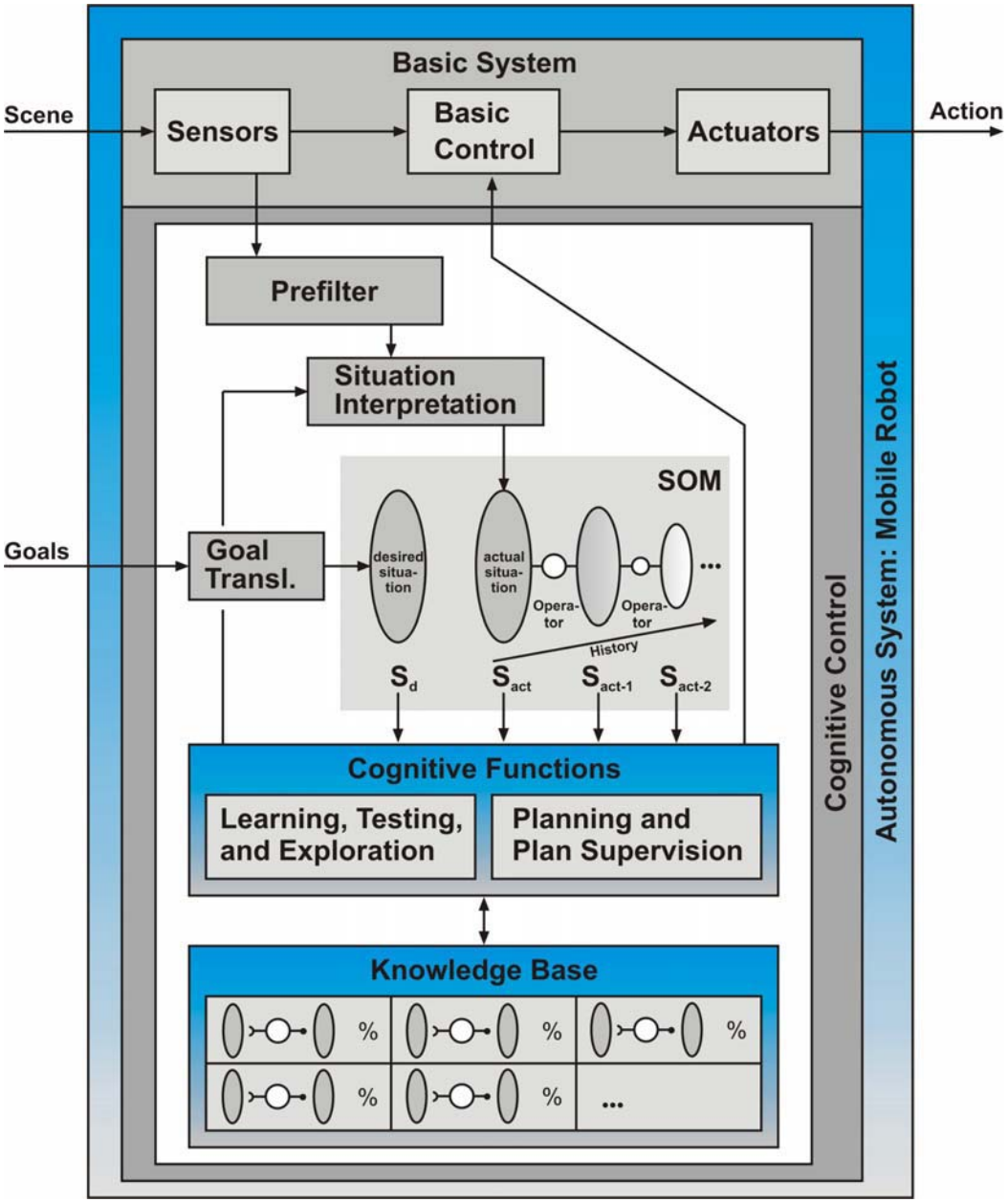
Outline

- Motivation
- Initiating Ideas
- **Conception of the Learning System**
- Realization of the Architecture
- Conclusion and Future Work

Architecture

Overview

- Basic system is implemented on the robot
- Translation to SOM description by situation interpretation module
- Higher cognitive capabilities are processed by the cognitive functions
- Experience is saved in the knowledge base
- Refining the knowledge base due to interaction and inference



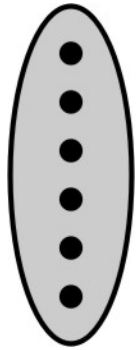
Architecture

From prefiltered to interpreted situation

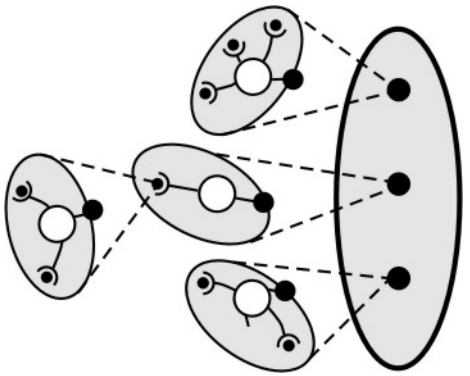
23 characteristics

14 relations

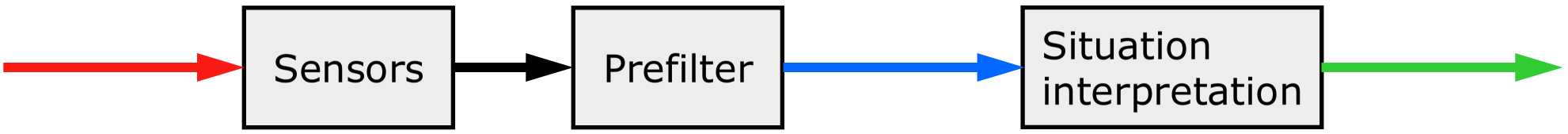
Scene



Prefiltered situation

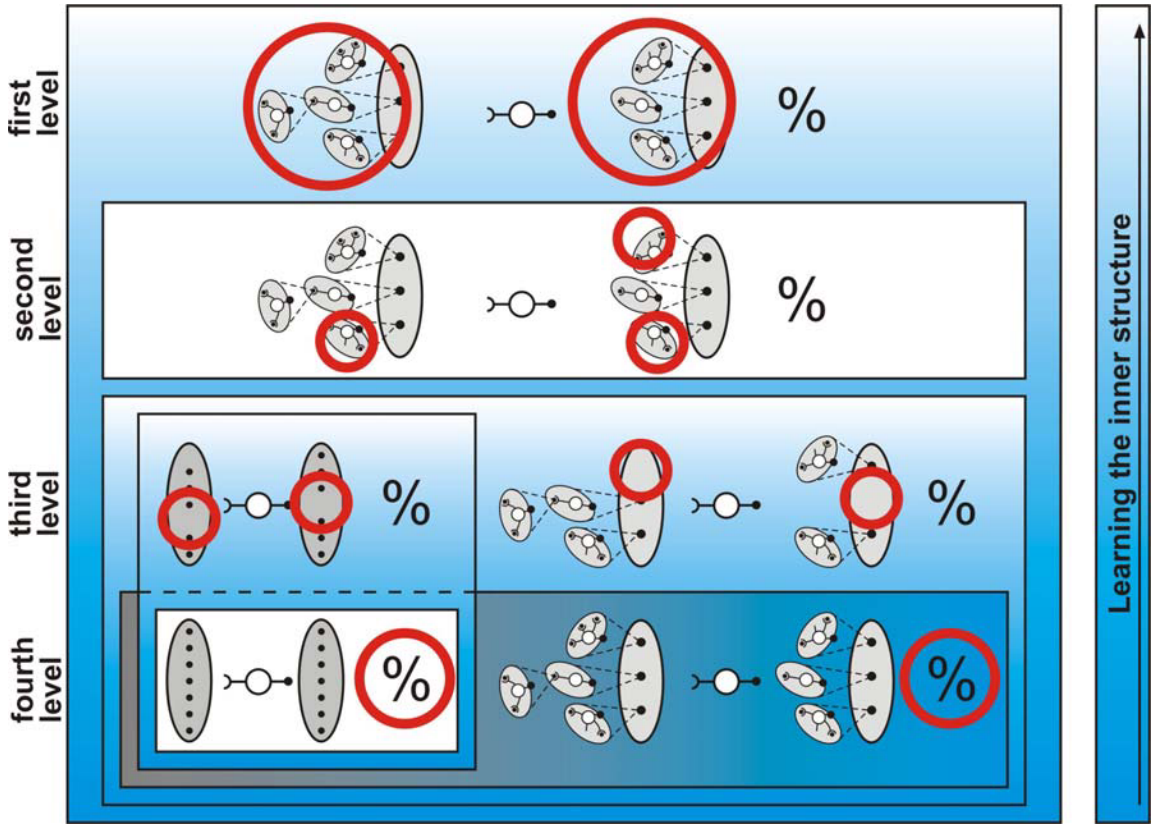


Interpreted situation



Learning

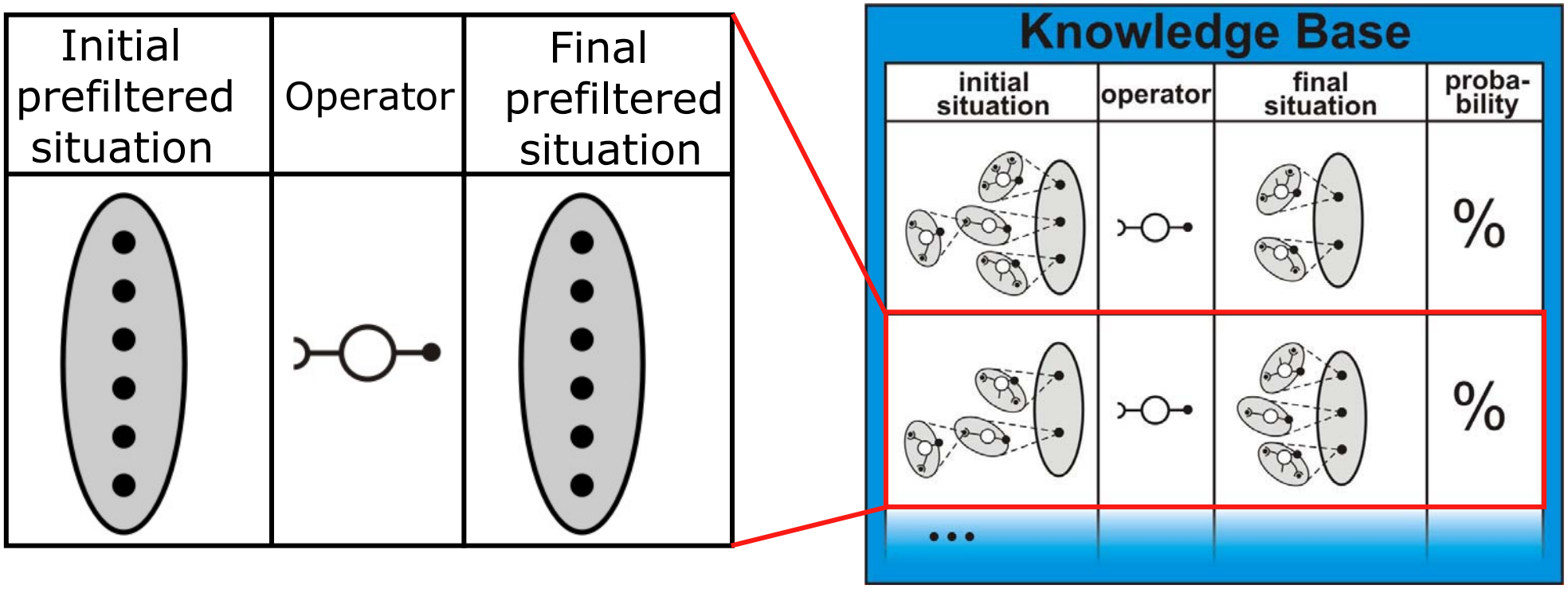
- Creation of new situation interpretations
- Adaptation of parameters of relations
- Inclusion and exclusion of characteristics
- Transition probabilities between situations



Learning

Updating knowledge base

- Knowledge base contains experiences
- System makes an observation
- Queries all experiences with the same operator



Learning

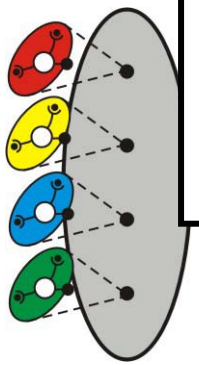
Example: Level 3 - Retraction

Initial scene	Operator	Final scene	Final situation

```
function search for object returns true or false
inputs:                 channel
local variables:        blob
blob:=false
for 20 steps and blob = false
   tilt camera to initial position
   for 12 steps and blob = false
      if blob on channel exists then blob:=true
      else tilt camera by 6°
   if blob = false then rotate robot by 10°
if blob = true then return true
else return false
```

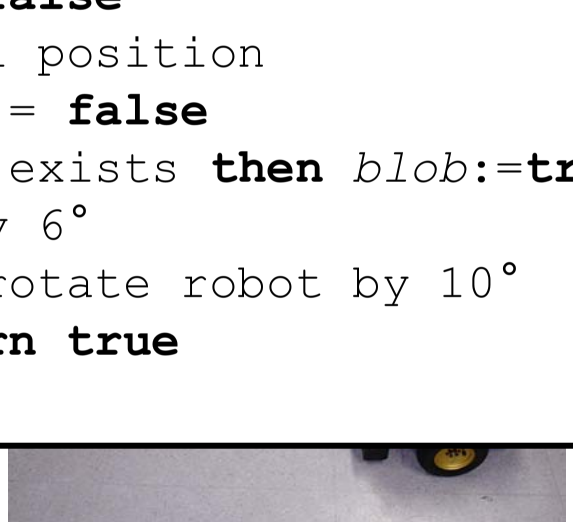
Initial

red [yes]



blue [no]

green [no]



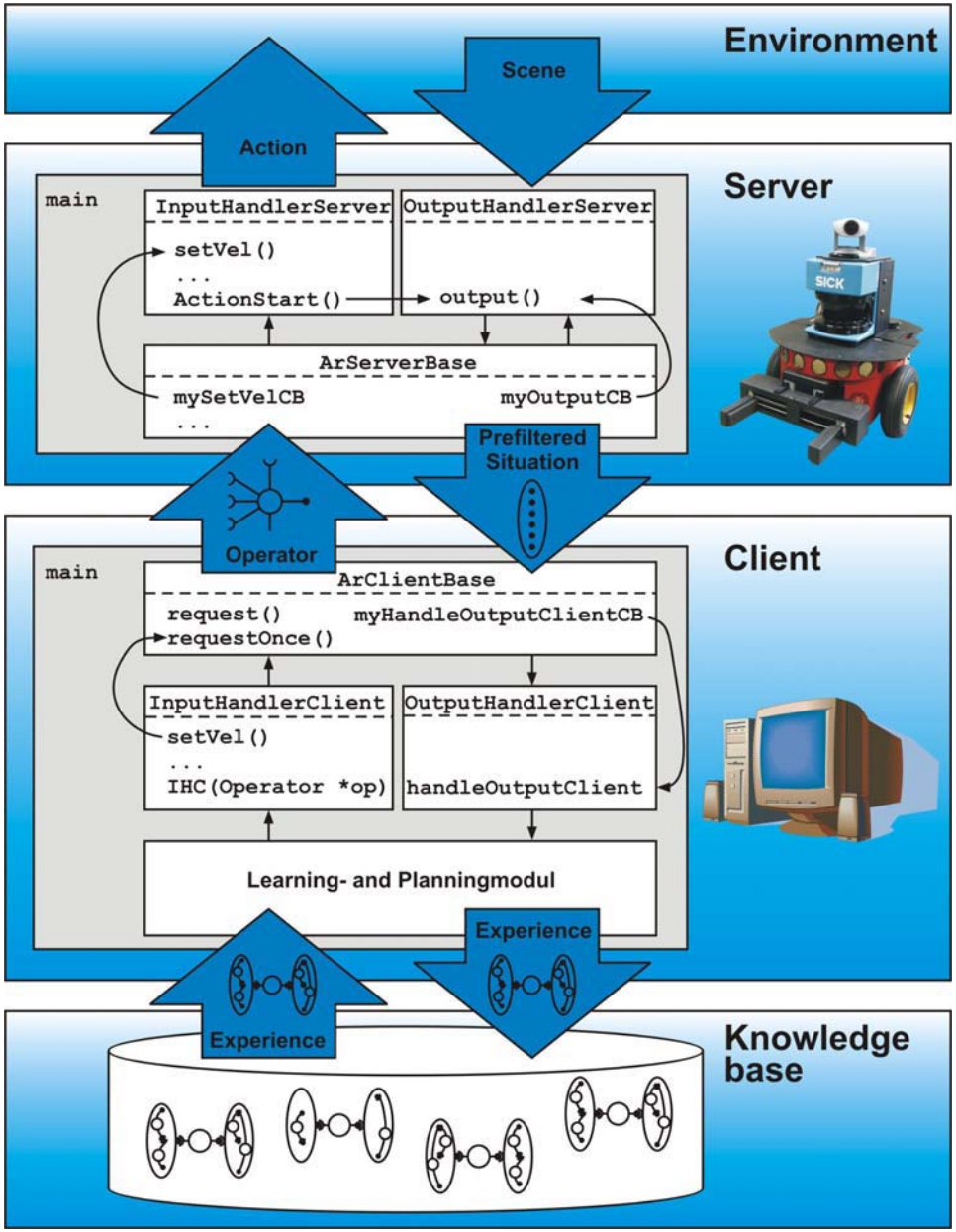
Outline

- Motivation
- Initiating Ideas
- Conception of the Learning System
- **Realization of the Architecture**
- Conclusion and Future Work

Realization

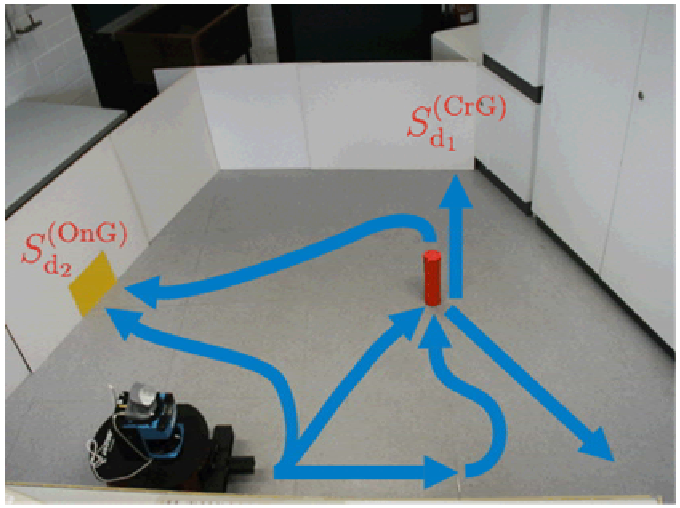
Client/Server Structure

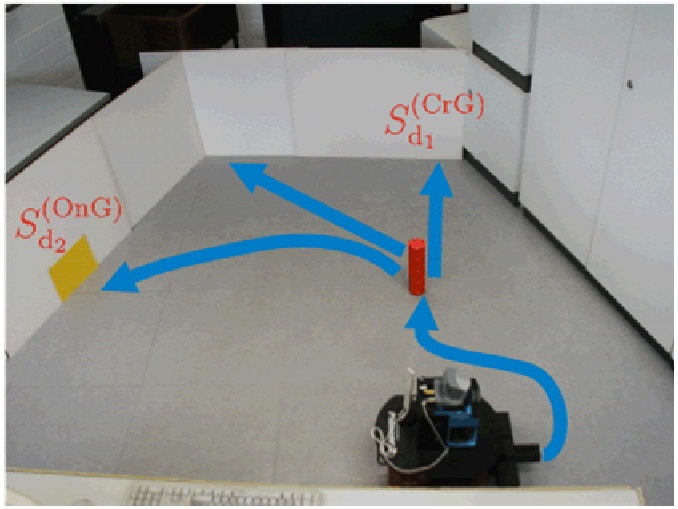
- Robot (server) perceives information from the environment by sensors
- Prefiltered situation is build and send to the client
- Goal-dependent selection of an operator by the planning module using database
- Operator is executed as action by the robot
- Interaction related knowledge is stored in database as experience



Realization

Test setup

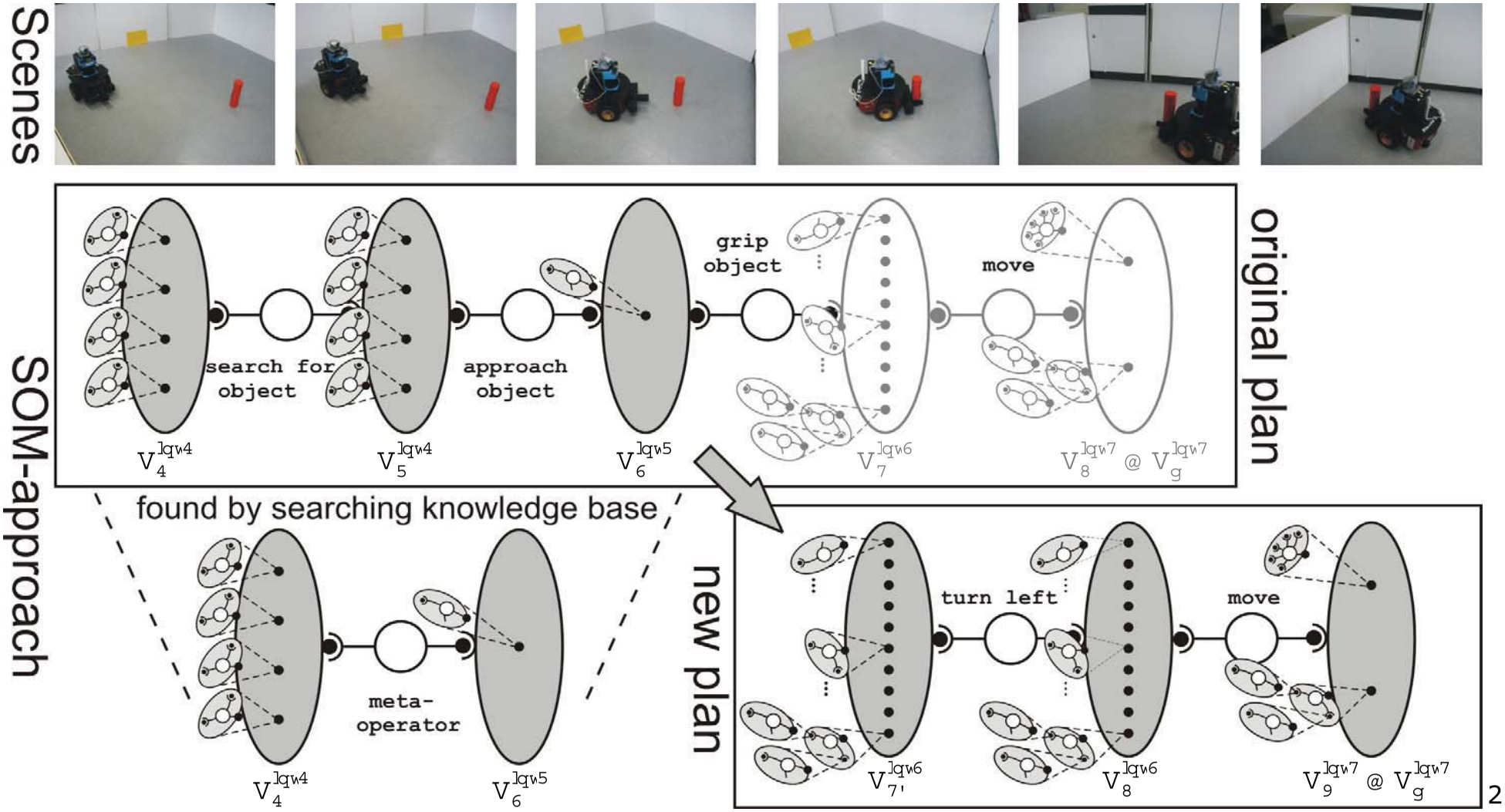




- Two given goals
- Given interpretation and operators
- 22 experiences
- 4 autonomous generated meta-operators

Realization

Test in lab environment



Realization

Test in lab environment

Outline

- Motivation
- Initiating Ideas
- Conception of the Learning System
- Realization of the Architecture
- **Conclusion and Future Work**

Conclusion

- Realization of a cognitive-based interactive system
- Learning, planning, and execution integrable in one architecture based on the representational level modeled with a Situation-Operator-Model
- Goal can be changed without changing database or architecture
- Different levels of learning realized conceptional

Future Work

- Full integration of planning and learning
- Creation of characteristics and situations by the system itself
- Integrating of localization and navigation software

Idea, Conception, and Realization of Learning Abilities for Robot Control Using a Situation-Operator-Model

Dirk Söffker and Elmar Ahle

UNIVERSITÄT DUISBURG ESSEN

Chair of Dynamics and Control
University Duisburg-Essen