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

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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
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**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
Causality $\Leftrightarrow$ from the cause to the effect

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

Higher goals: - stability / dynamics    - robustness    - observability
- controllability       $\rightarrow$ automatic control
**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.

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.

**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

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

[Söffker 2001]
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
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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

Scene

Sensors

Prefilter

Situation interpretation

23 characteristics

14 relations

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

<table>
<thead>
<tr>
<th>Initial prefILTERED situation</th>
<th>Operator</th>
<th>Final prefILTERED situation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Initial Prefiltered Situation" /></td>
<td><img src="image2" alt="Operator" /></td>
<td><img src="image3" alt="Final Prefiltered Situation" /></td>
</tr>
</tbody>
</table>

Knowledge Base

<table>
<thead>
<tr>
<th>initial situation</th>
<th>operator</th>
<th>final situation</th>
<th>probability</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image4" alt="Initial Situation" /></td>
<td><img src="image5" alt="Operator" /></td>
<td><img src="image6" alt="Final Situation" /></td>
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<tr>
<td><img src="image7" alt="Initial Situation" /></td>
<td><img src="image8" alt="Operator" /></td>
<td><img src="image9" alt="Final Situation" /></td>
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<td>...</td>
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</tr>
</tbody>
</table>
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

red [yes]

Initial

red [no]

blue [no]

green [no]
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- **Realization of the Architecture**
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Realization
Client/Server Structure

- Robot (server) perceives information from the environment by sensors
- Prefiltered situation is built and sent 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
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Realization

Test in lab environment

Scenes
Realization
Test in lab environment
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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
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