Autonomous Robots

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I. Information Processing Structure for Service Robots

II. Implementation Examples

- A Learning on the Sensor-Motoric Level
- B Man-Machine Interface

III. Concluding Remarks

I. **Information Processing Structure for Service Robots**

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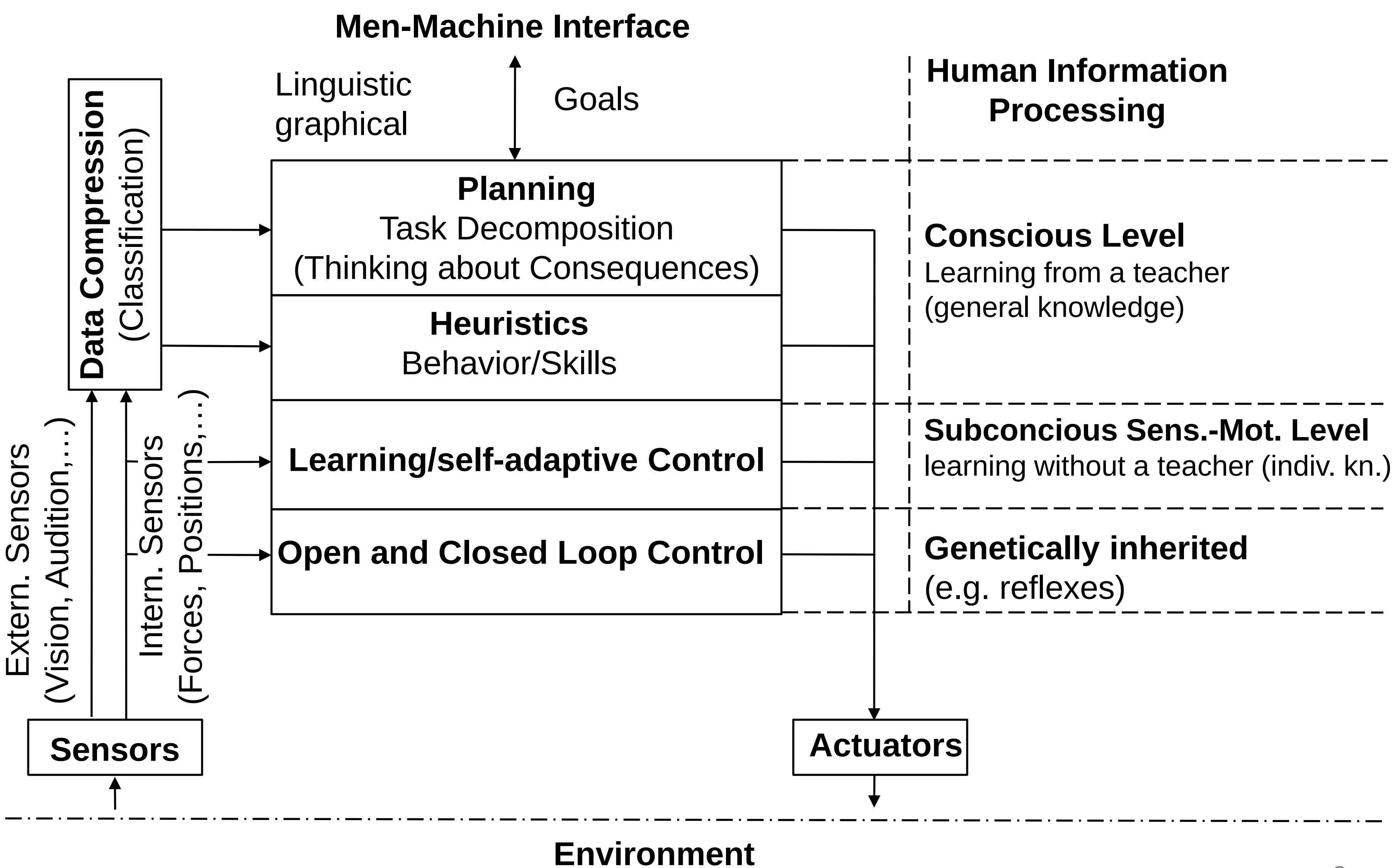
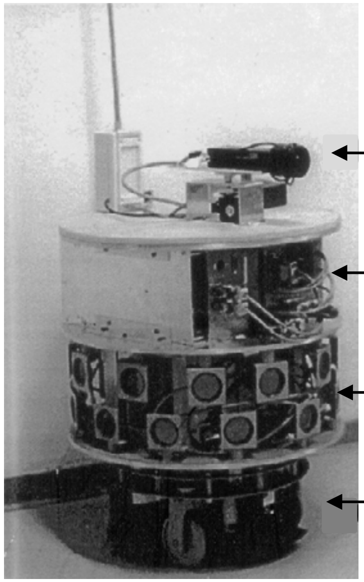

Men-Machine Interface
Linguistic graphical
Goals
Human Information Processing
Data Compression (Classification)
Planning
Task Decomposition
(Thinking about Consequences)
Heuristics
Behavior/Skills
Learning/self-adaptive Control
Open and Closed Loop Control
Conscious Level
Learning from a teacher (general knowledge)
Subconcious Sens.-Mot. Level
learning without a teacher (indiv. kn.)
Genetically inherited
(e.g. reflexes)
Extern. Sensors (Vision, Audition,…)
Intern. Sensors (Forces, Positions,…)
Sensors
Actuators
Environment

Example 2

Real experiments

Example 1

Simulation + Real experiments



Fixed Camera for environment mapping

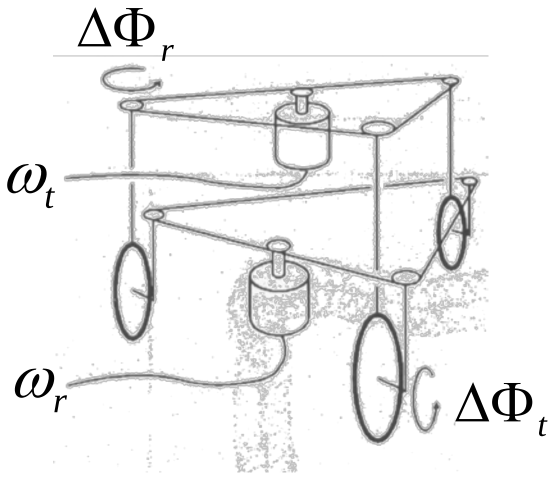
Onboard PC for robot control

Ultrasonic sensors

Odometric sensors

ALEF

Autonomes **LE**rnfähiges **F**ahrzeug



ALEF Kinematics

Input ω_r, ω_t angular motor velocities
Output x, y, α from $\Delta\Phi_r, \Delta\Phi_t$:

$$\Delta x = f_t \Delta\Phi_t \cos[\alpha(k-1)]$$
$$\Delta y = f_t \Delta\Phi_t \sin[\alpha(k-1)]$$
$$\Delta\alpha = f_r \Delta\Phi_r$$

(f_t, f_r = determined gear rations)

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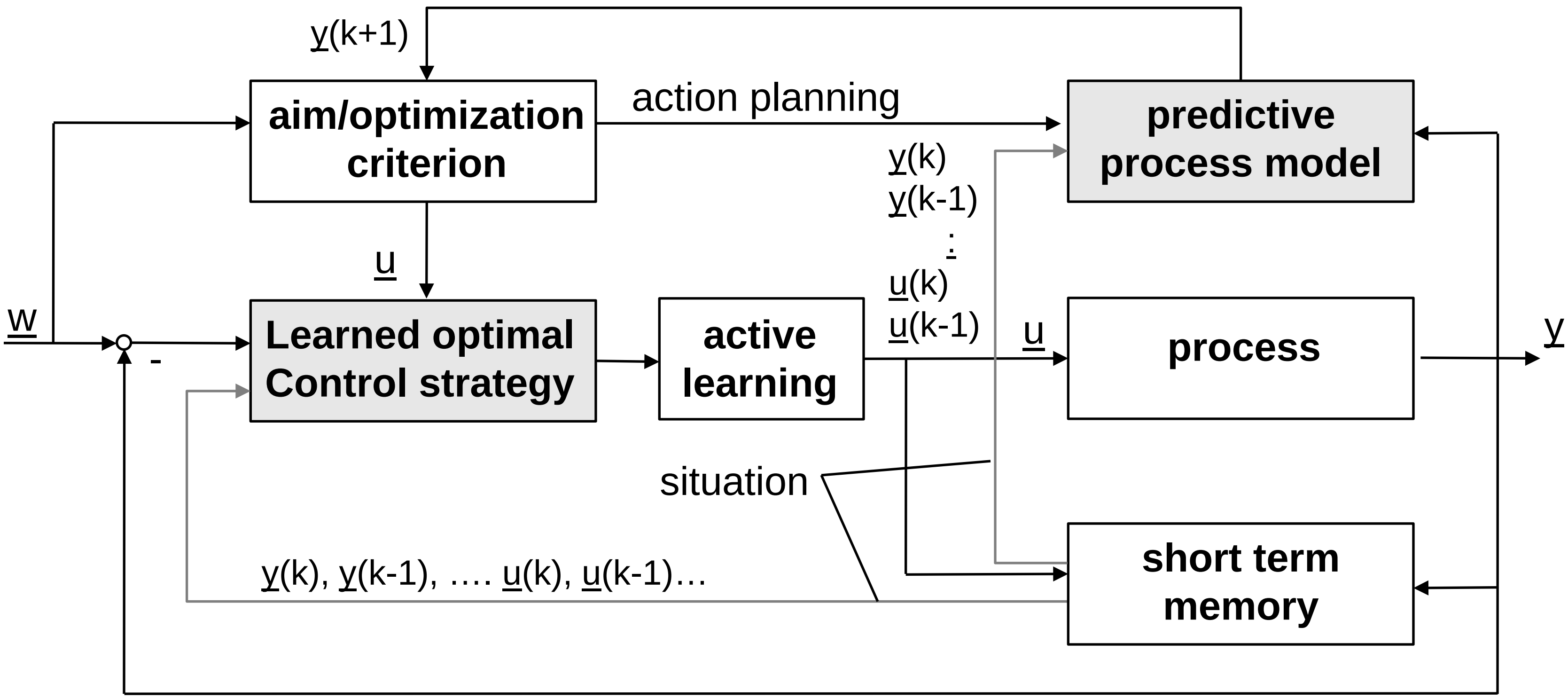
|Kurz 94| |Tolle, Kurz 98-International Journal of Intelligent Control and Systems|

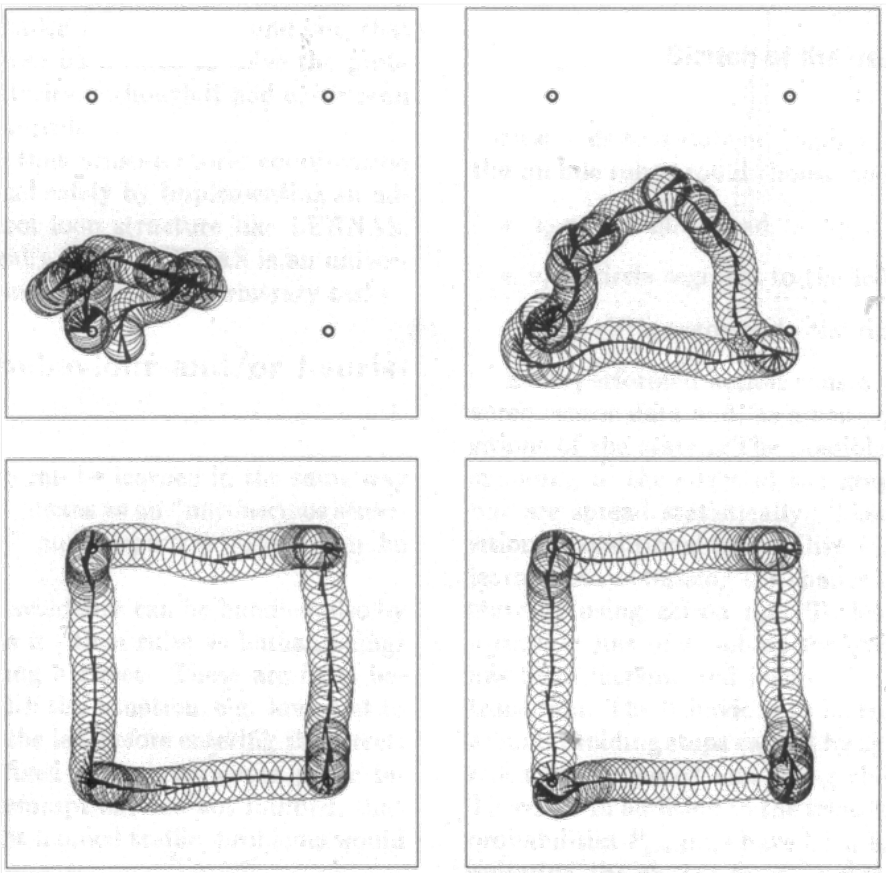
B Man-Machine Interface

III. Concluding Remarks



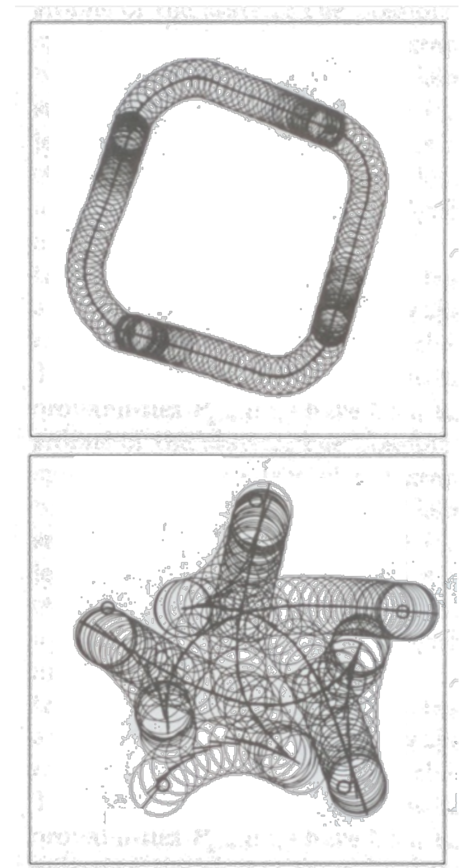
LERNAS a structure for self-adaptive (learning) nonlinear control for “fairly unknown“ complex nonlinear processes; “fairly unknown“ meaning, that only some qualitative knowledge on observability, controllability and process dynamics is required.

Grey boxes: Interpolating Memories



Simulated **Real**

Simulated - Kinematics



Optimization Criterion: ($\gamma =$ Direction error to target)

$$I(k)=\sum_{i=k}^{k+l} a_1\omega_t^2 + a_2\omega_r^2 + a_3\gamma^2 + \left[x(k+l)-x_{target}\right]^2 + \left[y(k+l)-y_{target}\right]^2$$

Front Wheel - Movable
Rear Wheels - Rigid Axle
Similar Optimization Criterion.

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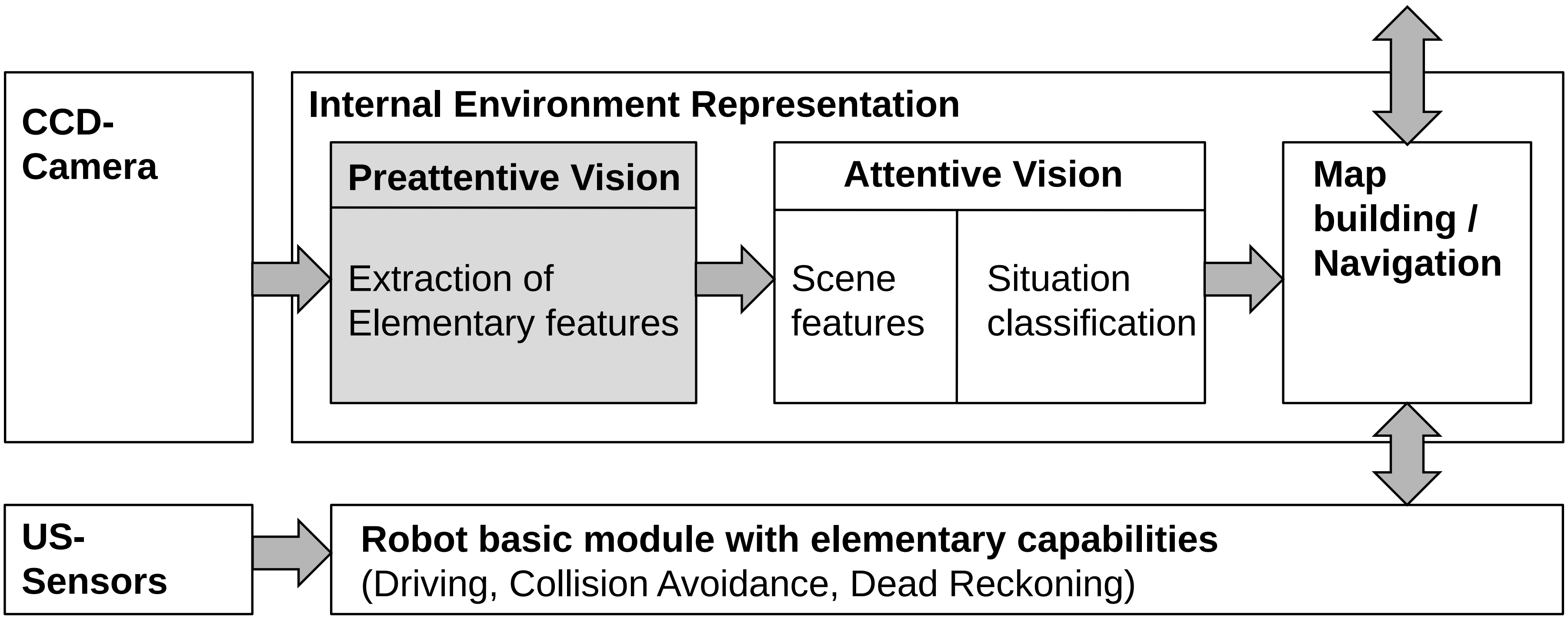
B Man-Machine Interface
|von Wichert 98||von Wichert 99 Control Engineering Practice|

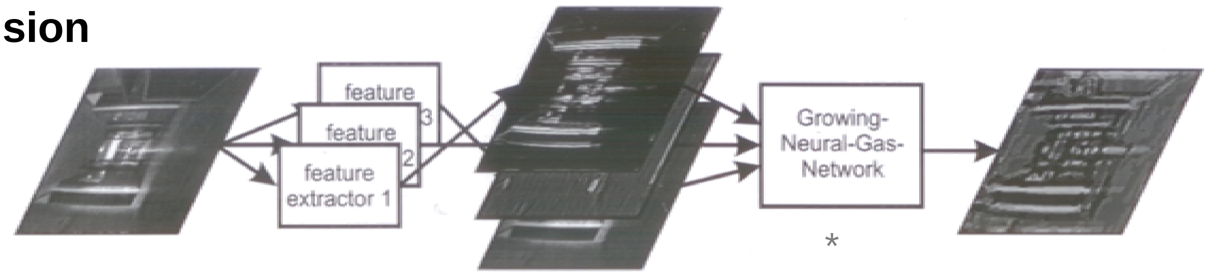
III. Concluding Remarks

Internal Environment Representation = Building the Interface at the Machine Level

Target: to reach a robust environment description on the basis of CCD-camera information and to build up some map of the environment autonomously



Preattentive Vision



Input image

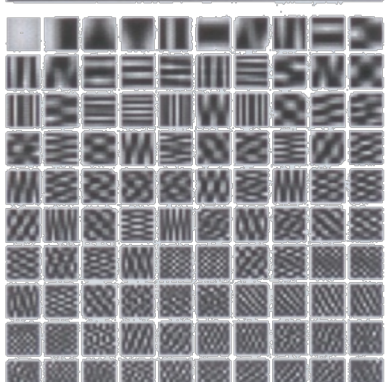
Multi channel basic feature description

Description by N elementary features s‘ (x,y)

Filtering example:

Self-adapting Principal component Feature extractors

Filters which are in accordance with the dominant horizontal and vertical structures



Classification example:

(9 Neurons)

Input image

Robust elementary features generated by GNG-Net- recombination of the multi channel description

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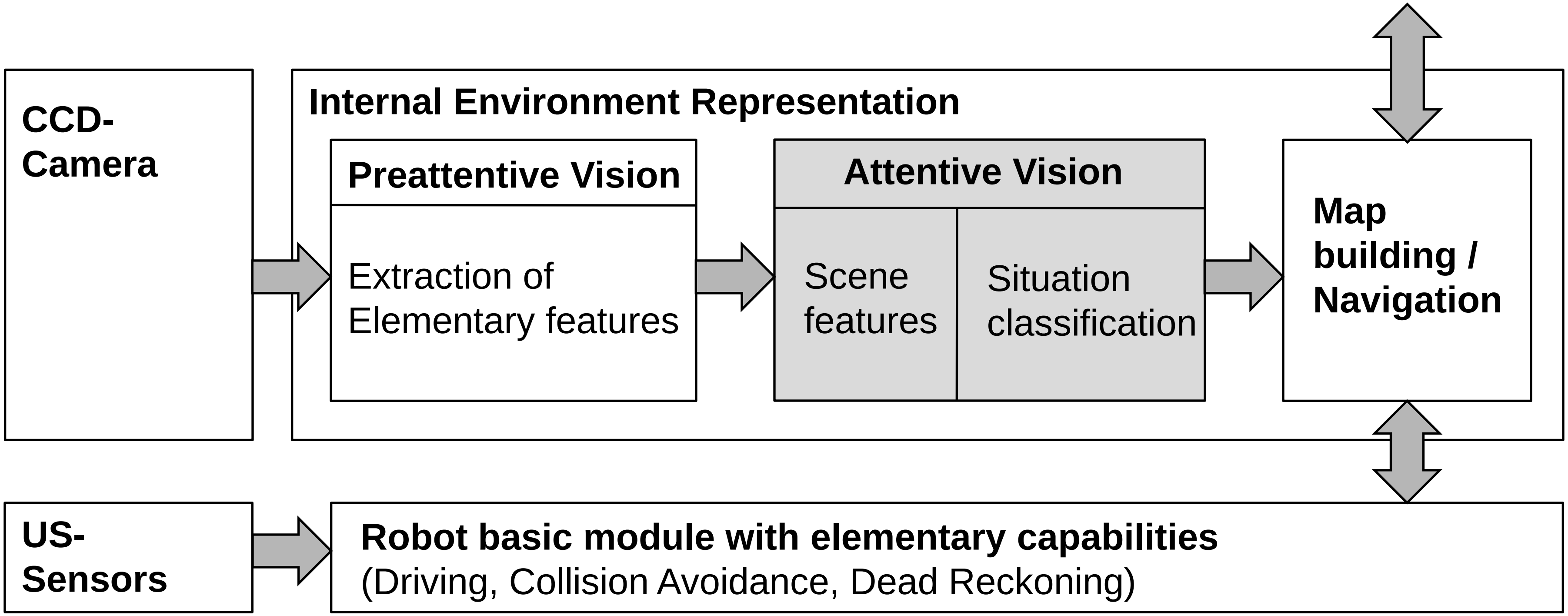


Attentive Vision – Scene Features

- The distribution of the elementary features is characterized by a number of geometric moments,

$$m_c^{p+q} = \sum_{l=0}^{L} \sum_{m=0}^{M} x^p y^q \delta(c - s'(x,y)) w(x,y)$$

which are combined into a scene feature vector. $\underline{x} = [m_1^{(0,0)} \cdots m_{N_c}^{(p_{\max}, q_{\max})}]$

- Defining a distance measure $\Delta = \left\| \underline{x} - \underline{x}_{ref} \right\|$ similarity can be judged.

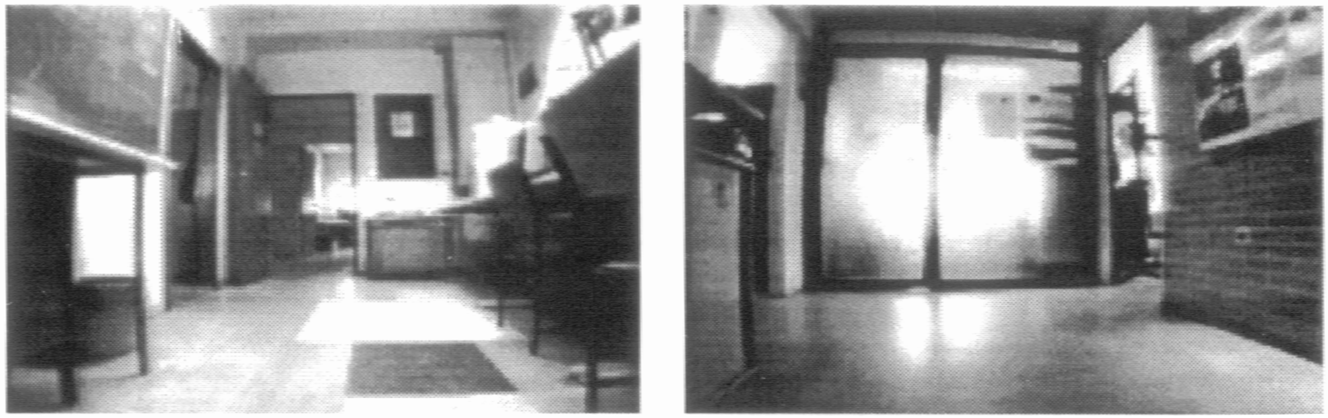
reference image

other images in order of similarity

Attentive Vision – Situation Classification (again by Growing-Neural-Gas-Networks)

Example of two classes:

„free space“



„narrow passage“

GNG – Reduction to 3 Neurons

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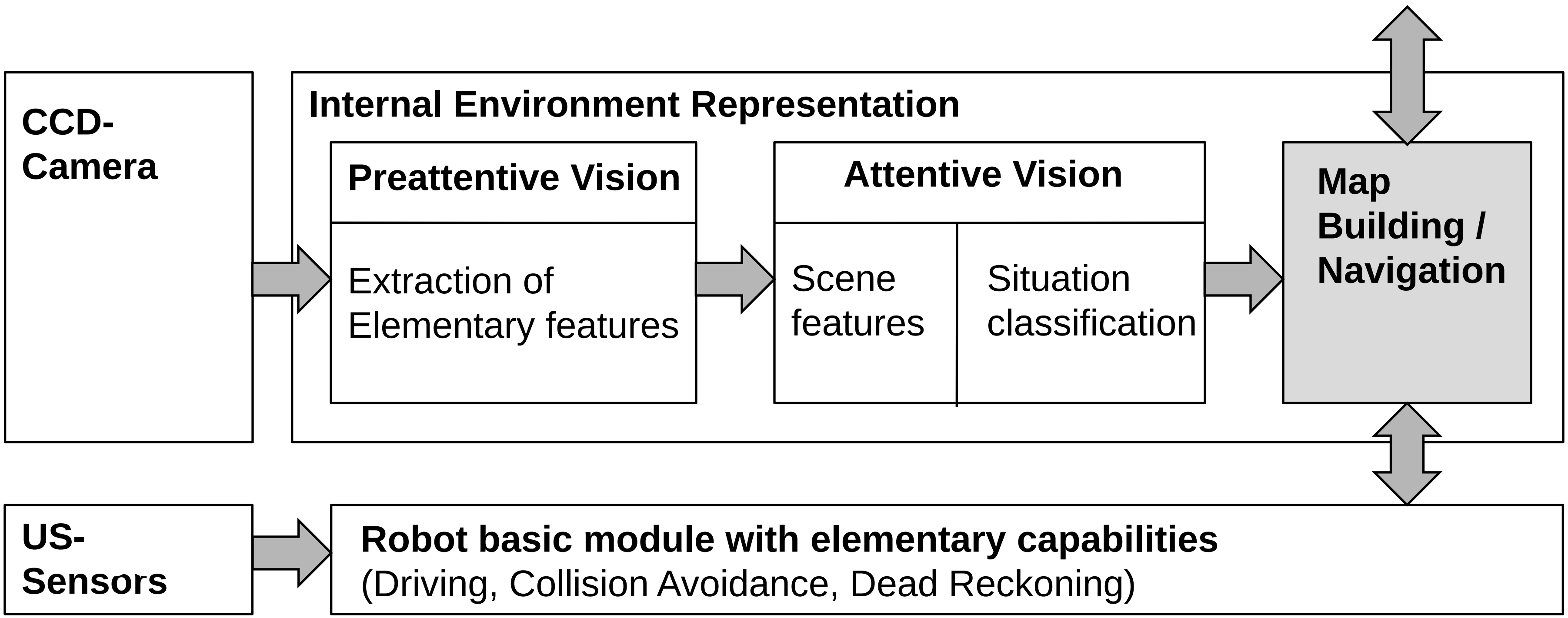

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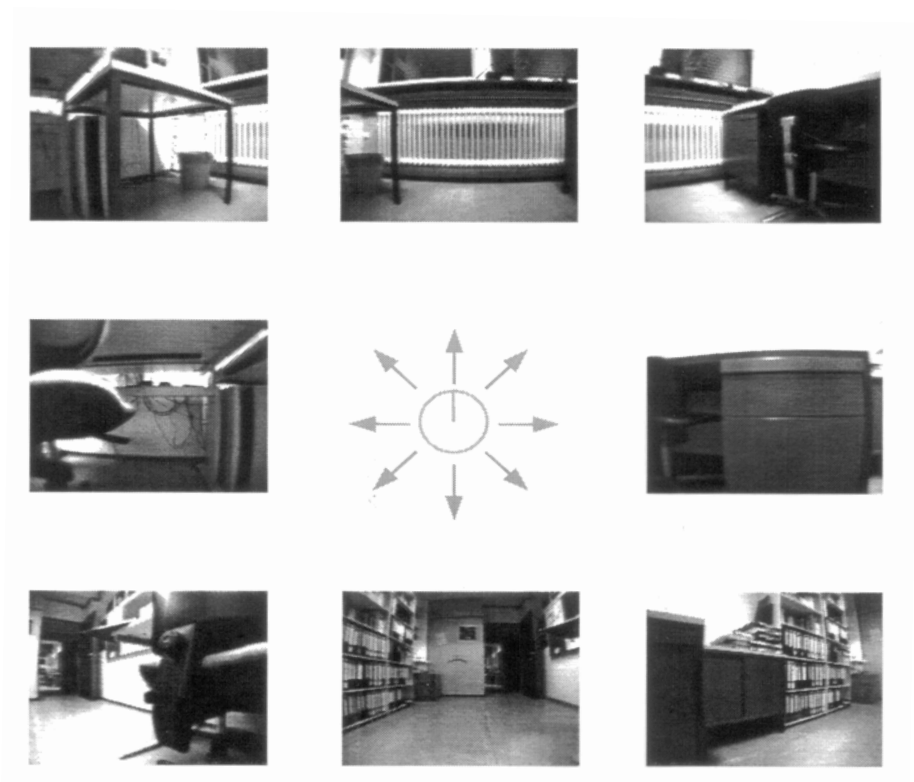
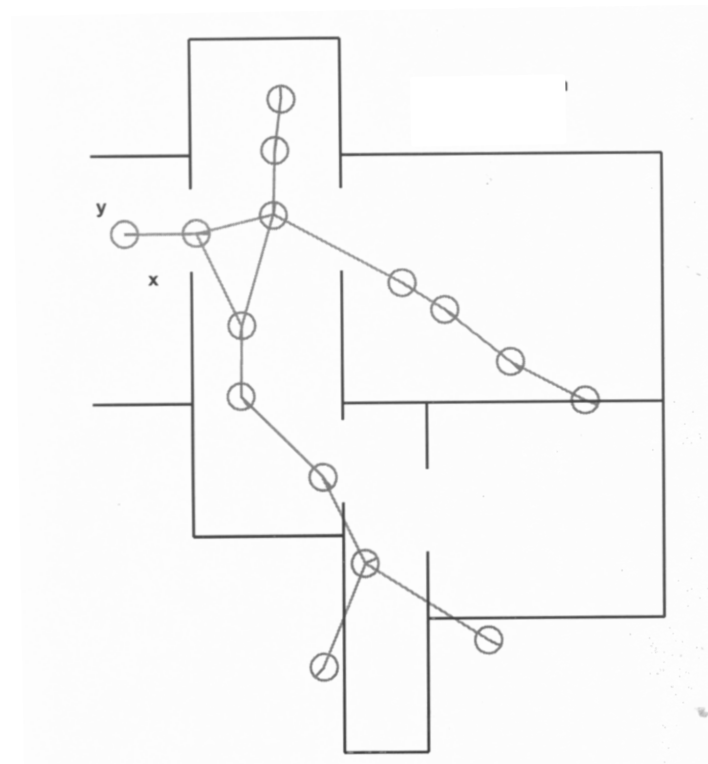
Map building

A topological map is built up by guiding the robot through the environment. Nodes are put either after a maximum distance or when the GNG classification identifies a new situation.

Dead reckoning measurements are used to give cartesian node positions - naturally faulty.



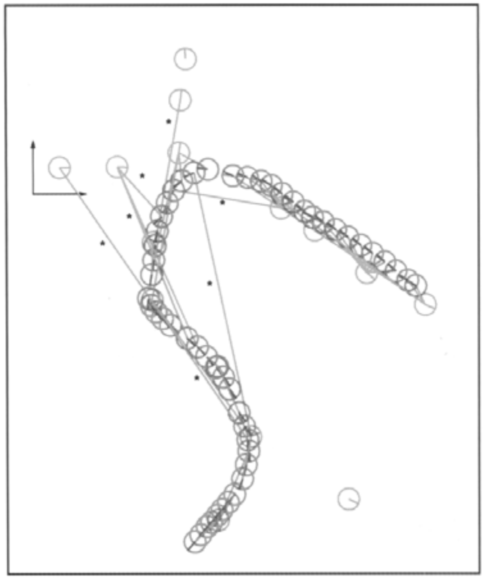
Example: Omnidirectional view in some node.



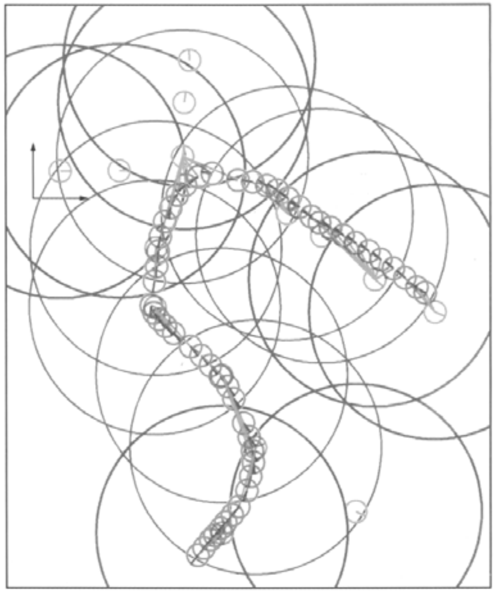
Map with cartesian position estimate and real floor plan.

Navigation:

Driving a given path on the basis of the map using the expected vision information in the driving direction. Cartesian position estimated by the dead reckoning system. (Target specification by an operator).



Path travelled on the basis of dead reckoning localization by connection of robot position with asumed position by one image: *=Erroneous localization



Errors can be removed by using three images and excluding images more than 2,5m away from estimated cartesian position.

External Environment Representation = Building the Interface for the user (Schemes)

interface to user

Communication Level

Representation Kit

Environment Representations

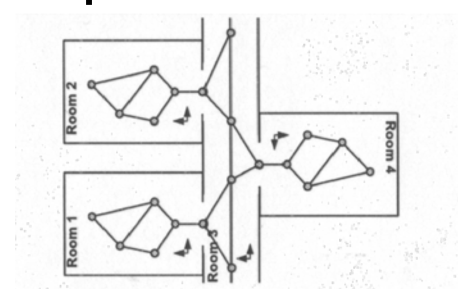
(movable) Objects Representations

Supervised Classifiers

Detection of inter-face situations

Object Recognition

Generation of Environment Concepts/Plans

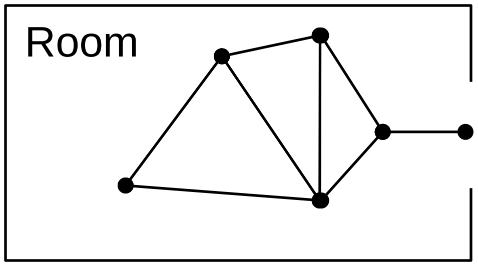


preprocessed sensor data

interface to internal representation

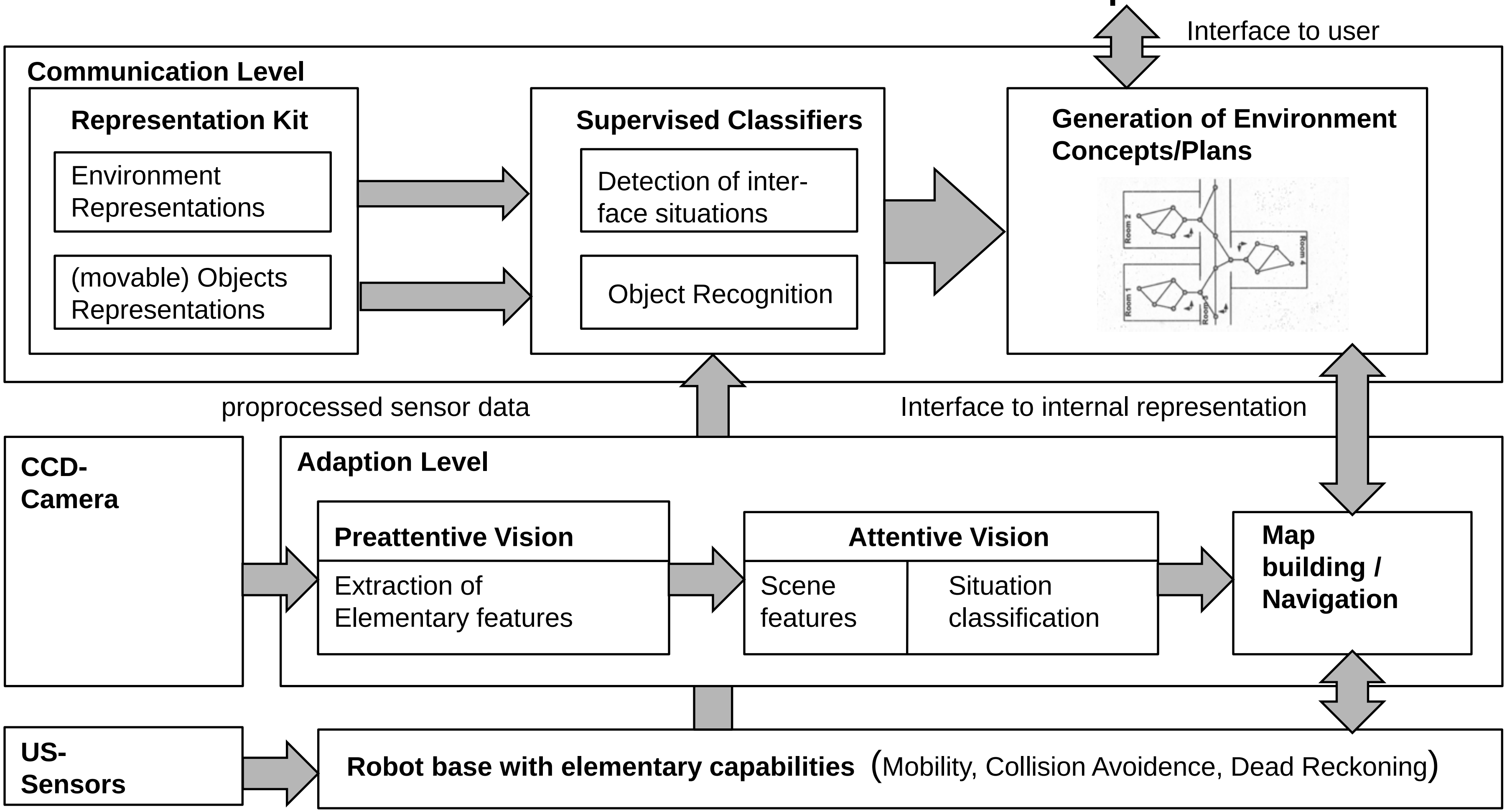
Representations (Schemes) are general descriptions with as well an easy conceptional and linguistic description for the robot user as an easy characterization/description possibility for the robots internal world representation:

e.g.: room – for the user a rectangle with on or more doors, for the robot a closed environment partition with one or more access possiblities

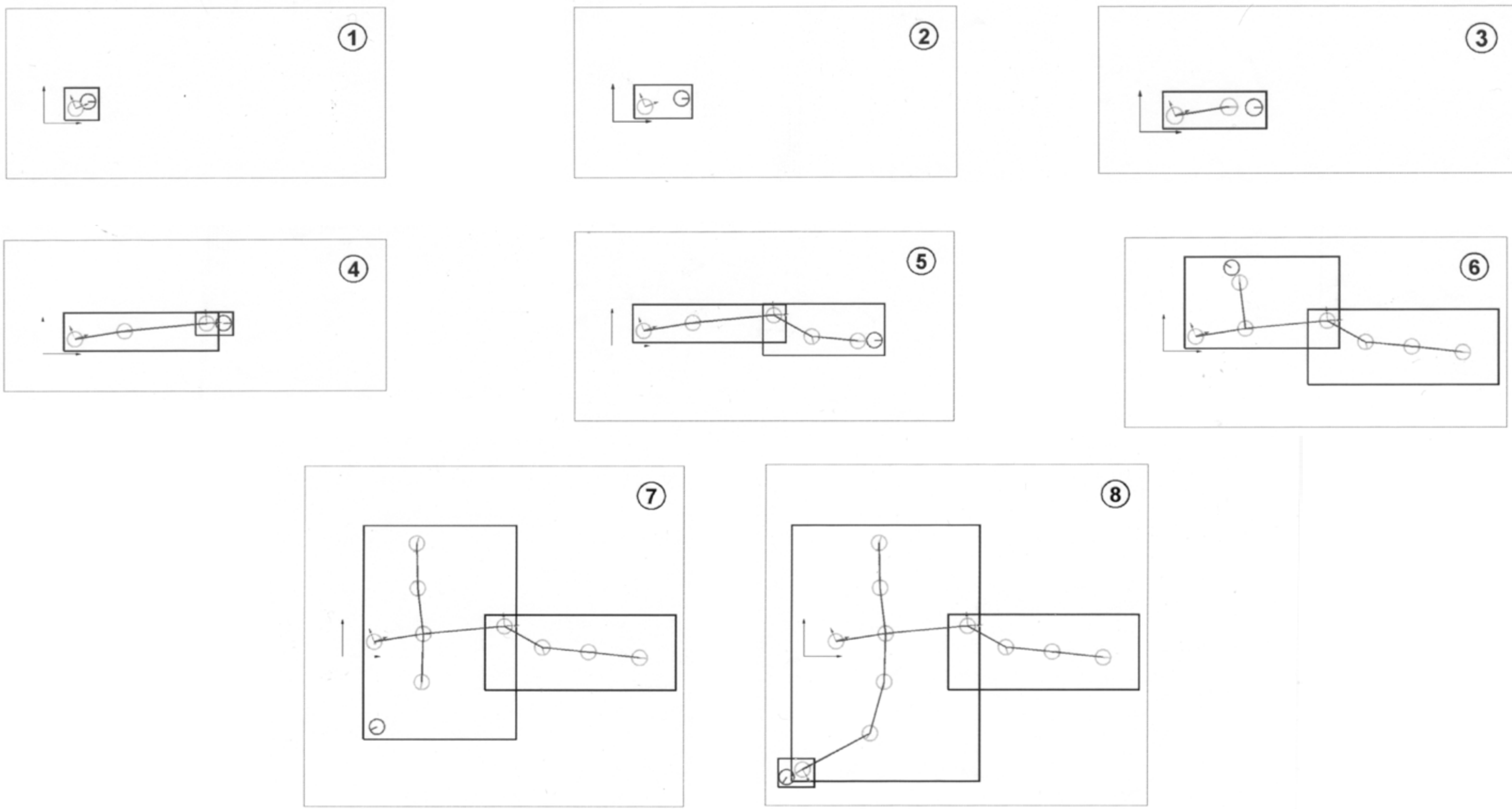


To build concepts from the internal map, knots are placed automatically when a small opening is passed – detected by the ultrasonic sensors

Men-Machine Interface = Combination of Internal and External Representations



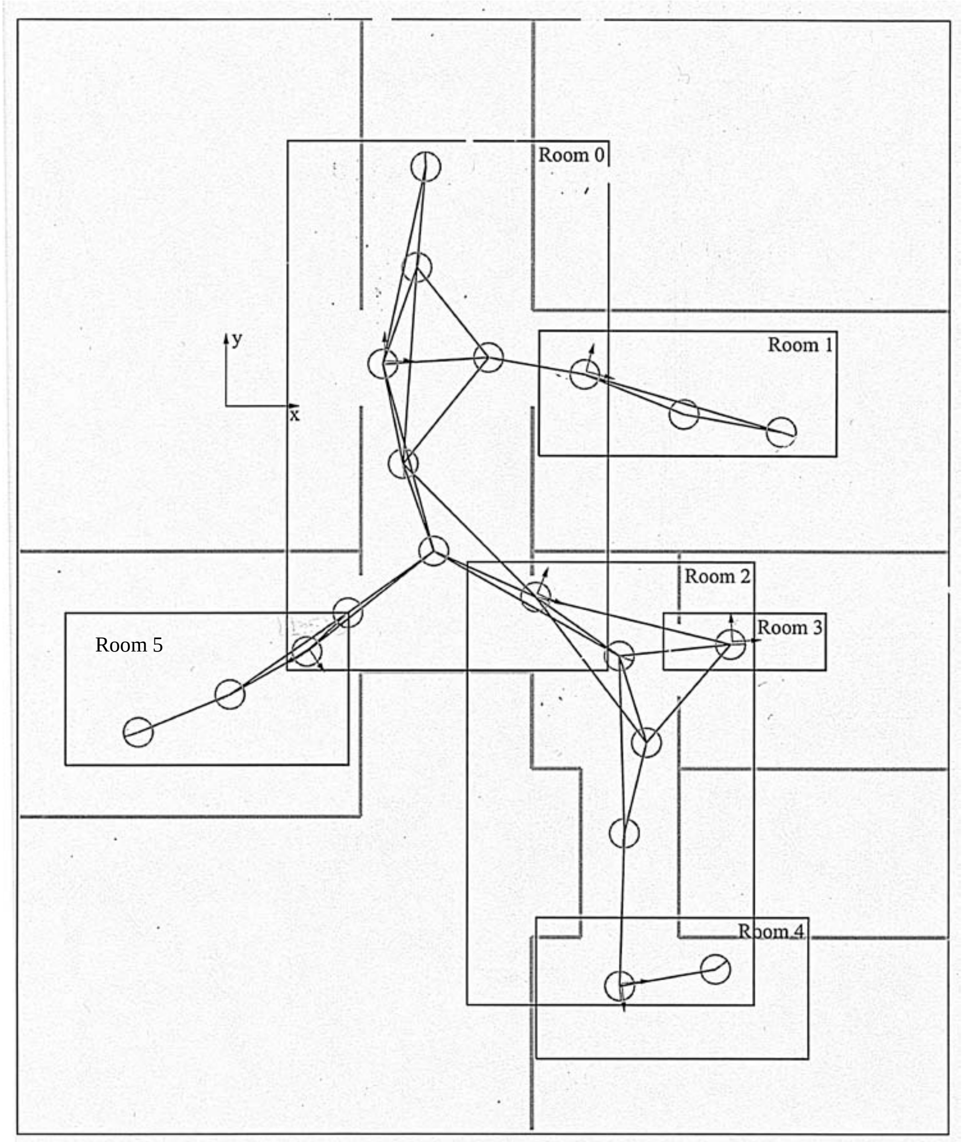
Example of the stepwise generation of a floor plan of our office by using the scheme room.



Result: Established map of our office environment

Possible Application:

Go from Room 5 to Room 4



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- **Amount of learning depends on the Task-Complexity of the considered Service Robot**
- **Men – Machine Interface**

? Proposed Structure similar to Human Information Processing Brain Structure

- left Hemisphere – unsupervised learning
  => ? self-generated internal conceptions
- right Hemisphere – supervised learning
  => ? (Language) General conceptions – e.g. chair

? Open: Exchange between Information Processing Levels

- Planning Level – Rule Based Level
- Rule Based Level – Sensomotoric Level
  (Conscious – Unconcious Level)
- Learned Behaviour – Reflex Level

Literature

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