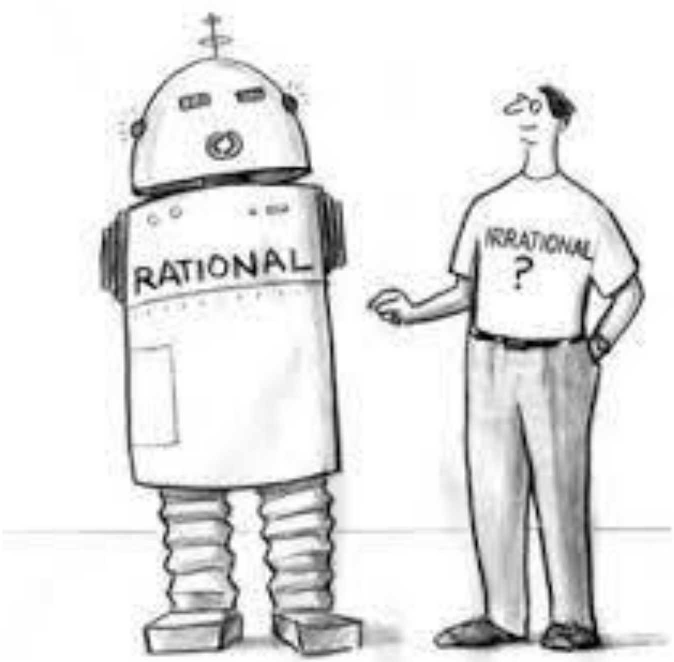
Ambient Intelligence

Vorlesung 10 – Artificial intelligence in AmI systems



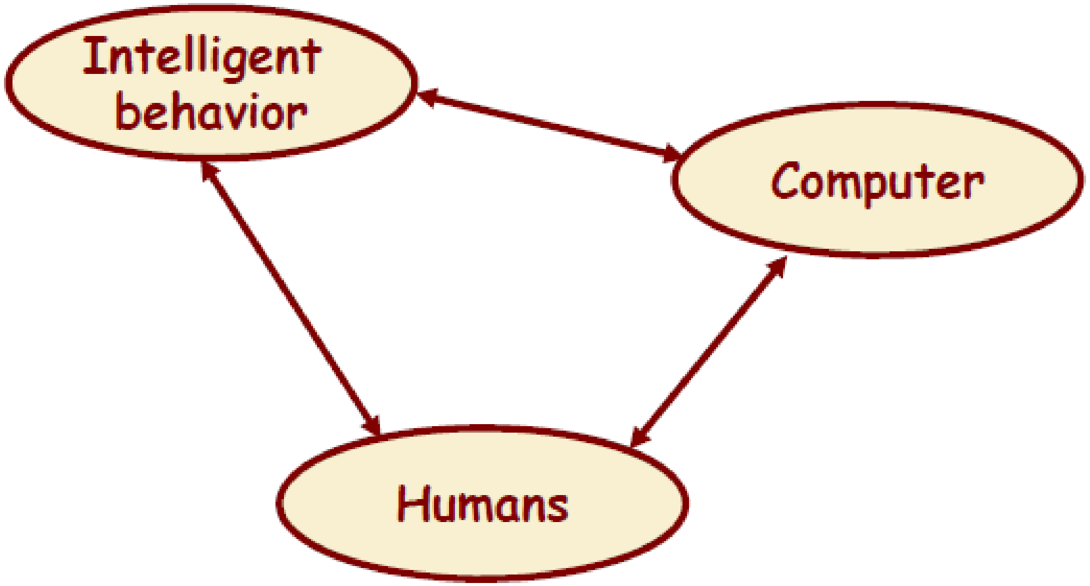
Agenda

- What is AI?
- Artificial intelligence in AmI
- Types of Artificial Intelligence
- Forms of Reasoning
- The user in learning systems
- Trends in intelligent environments

This lecture is highly influenced by lectures presented by Jean-Claude Latombe and Joschka Boedecker

What is AI?

- AI is the reproduction of human reasoning and intelligent behavior by computational methods



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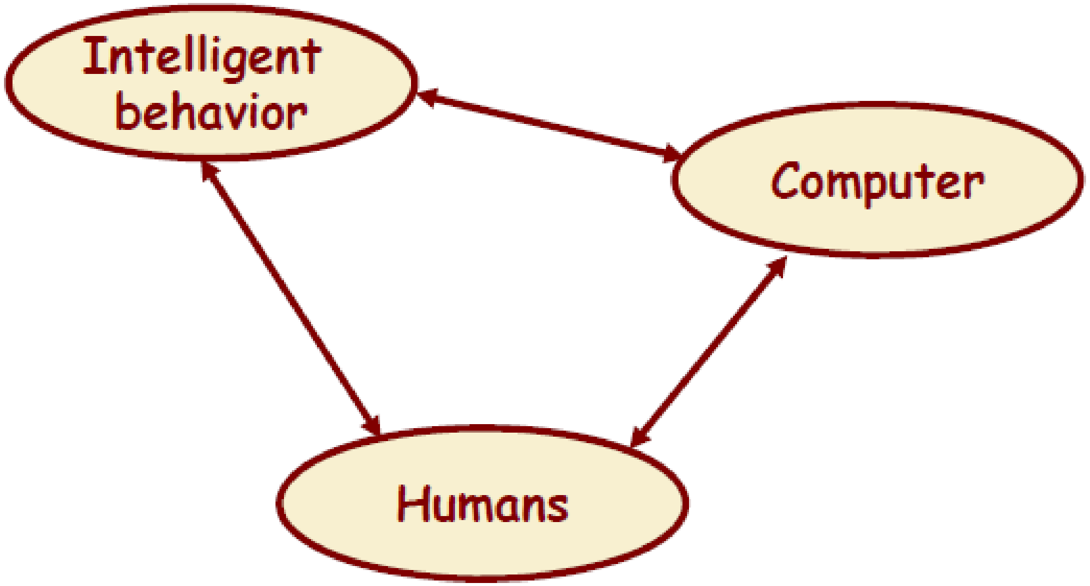
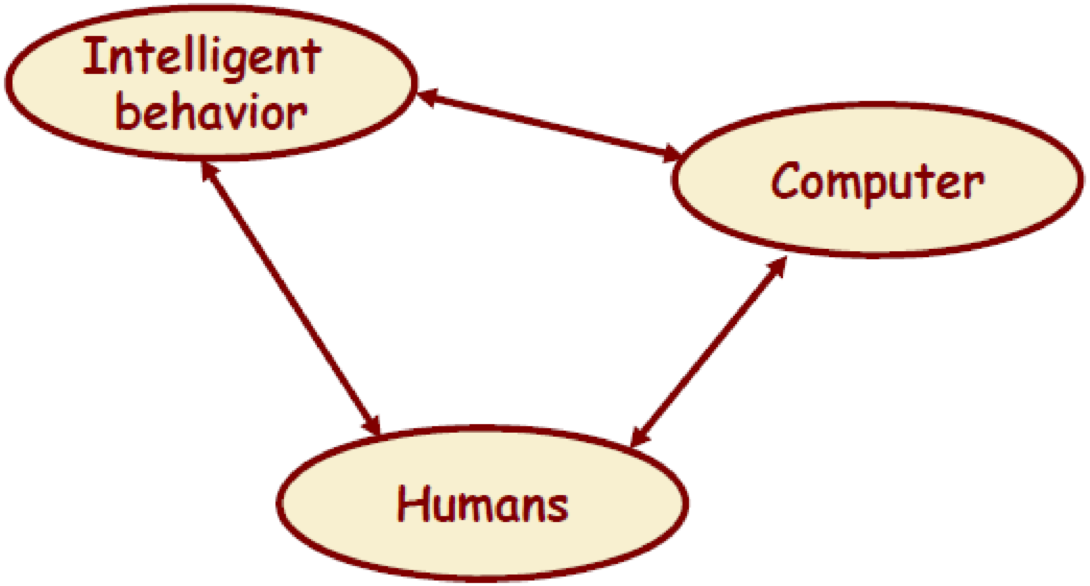


What is AI?

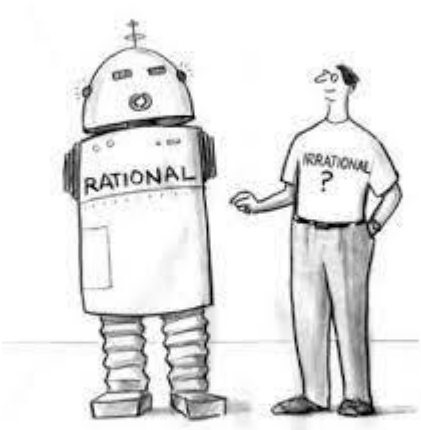
- AI is THE ATTEMPT TO REPRODUCE human reasoning and intelligent behavior by computational methods

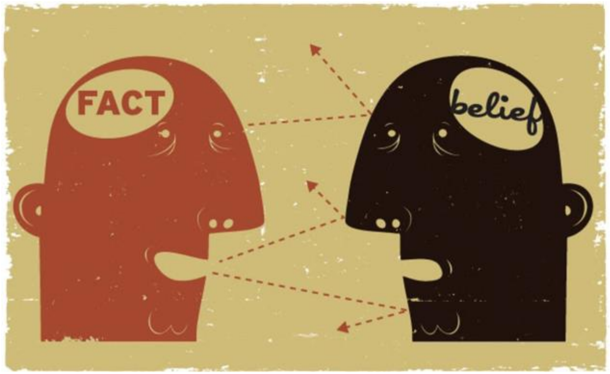


What is AI?

- The attempt to make computers more “intelligent"
- The attempt to better understand human intelligence

- Four approaches:
  - Is it about thought thinking . . .
  - . . . or acting?
  - Oriented towards a human model (with all its defects) . . .
  - … or normative (how should a rational being think/act)?





What is AI?

Act like humans	**Act rationally**
Think like humans	**Think rationally**

- Example: Turing Test
- Take a task at which people are better at and build a computer system that does it automatically
- … not much interesting for AI
- …… because let’s face it, humans do not act the best :)

What is AI?

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Act like humans	Act rationally
Think like humans	Think rationally

- Here, how the computer performs tasks does matter (The reasoning steps are important)
- What cognitive capabilities are necessary to produce intelligent performance?
    - Not important: Being able to solve problems correctly
    - Important: Being able to solve problems like a human would
        - Cognitive science and cognitive psychology
        - Also important for human-machine interaction

What is AI?

Act like humans	**Act rationally**
Think like humans	**Think rationally**

- Now, the goal is to build agents that always make the “best” decision given what is available (knowledge, time, resources)
- “Best” means maximizing the expected value of a utility function
    - Here, impact of self-consciousness, emotions, desires, love for music, fear of dying …

What is AI?

Act like humans	**Act rationally**
Think like humans	**Think rationally**

- What are the laws of thought?
- How should we think?
  - The logical approach
  - Problems:
    - Presentation of problem descriptions using a formal notation
    - Computability

What is AI?

Act like humans	**Act rationally**
Think like humans	**Think rationally**

- Rational agents (or rational actors)
  - A rational agent acts so as to achieve its given goals, under the assumption that its impressions of the world and its convictions are correct
  - Rational thinking is a prerequisite for rational acting, although it is not a necessary condition
    - What to do when we must make a decision faced with insufficient information?

Can Machines Act/Think Intelligently?

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- Yes, if intelligence is narrowly defined as information processing
  - My car can decide that a situation is dangerous and automatically breaks
- Maybe Yes, maybe No, if intelligence is not separated from the rest of “being human”
  - I know that the person pretending that he wants to jump in front of the car is a friend who usually do these stupid silly things…
  - Or even worse, I’m having a bad day and I’m not as focused as usual, so I do not notice the situation…

Agenda

- What is AI?
- Artificial intelligence in AmI
- Types of Artificial Intelligence
- Forms of Reasoning
- The user in learning systems
- Trends in intelligent environments

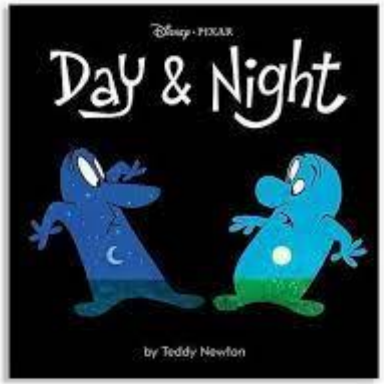
What AI we need in AmI?

- Mainly rational thinking and acting…
  - Its slightly cold and it's predicted to get colder tonight, let’s start the fireplace before it gets colder

- Maybe sometimes act like humans… sometimes
  - You do not want your smart home system to tell you “I will keep you cold tonight because lately you’ve been acting different with me!”
  - But maybe you want your music system to change its mood sometimes and play some music that you do not commonly listen to

AI in AmI
Motivation

- Ambient Intelligence
- An AmI system should adapt to changing circumstances
  - Change of environment
  - Change of users
  - Change of the system
- Adaptation of the system during runtime
  - Configuration or adaptation



AI in AmI
Motivation – 1

- Example - Mrs. Mayer's son has moved nearby and now comes over much more often.

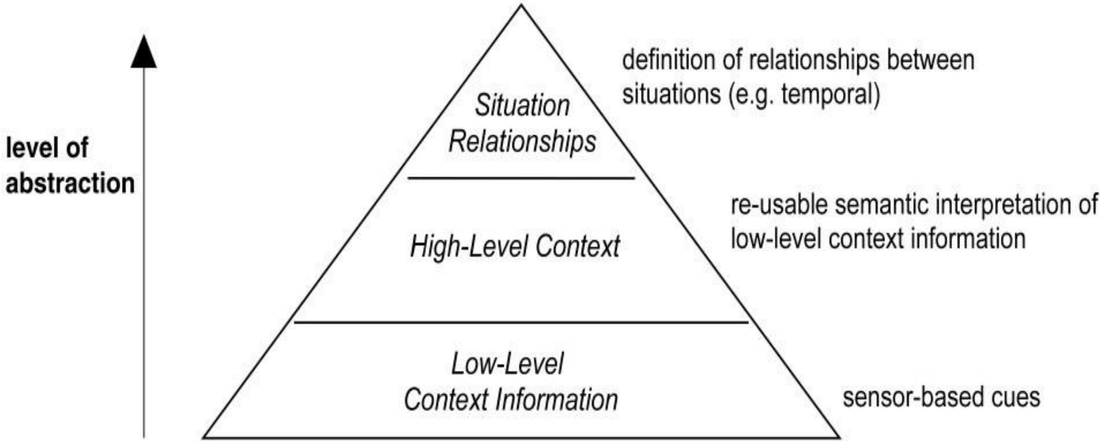
  - Configuration - Mrs. Mayer adjusts the rules of the home so that it also supports her son.
  - Adaptation - the AmI environment learns from the context that another person is frequently in the vicinity and adapts to this.

AI in AmI
Motivation – 2

- Example - a new sensor for measuring air quality is installed in the environment.
  - Configuration - the user teaches the system to find it and convert its data into rules
  - Adaptation - the system finds the new sensor independently and searches for suitable rules

Ai in AmI
Context Awareness & Reasoning

- From low-level context to situations



- Reasoning creates new context information from existing context
- Reasoning creates an understanding of the context

AI in AmI
Context Awareness & Reasoning

- **Activities**
  - Higher-order context that has a reference to the user
  - E.g. Mrs. Mayer is peeling potatoes

- **Activities of Daily Living (ADL)**
  - Activities of daily living
  - Frequent reference to activities within the living environment

AI in AmI
Context Awareness & Reasoning

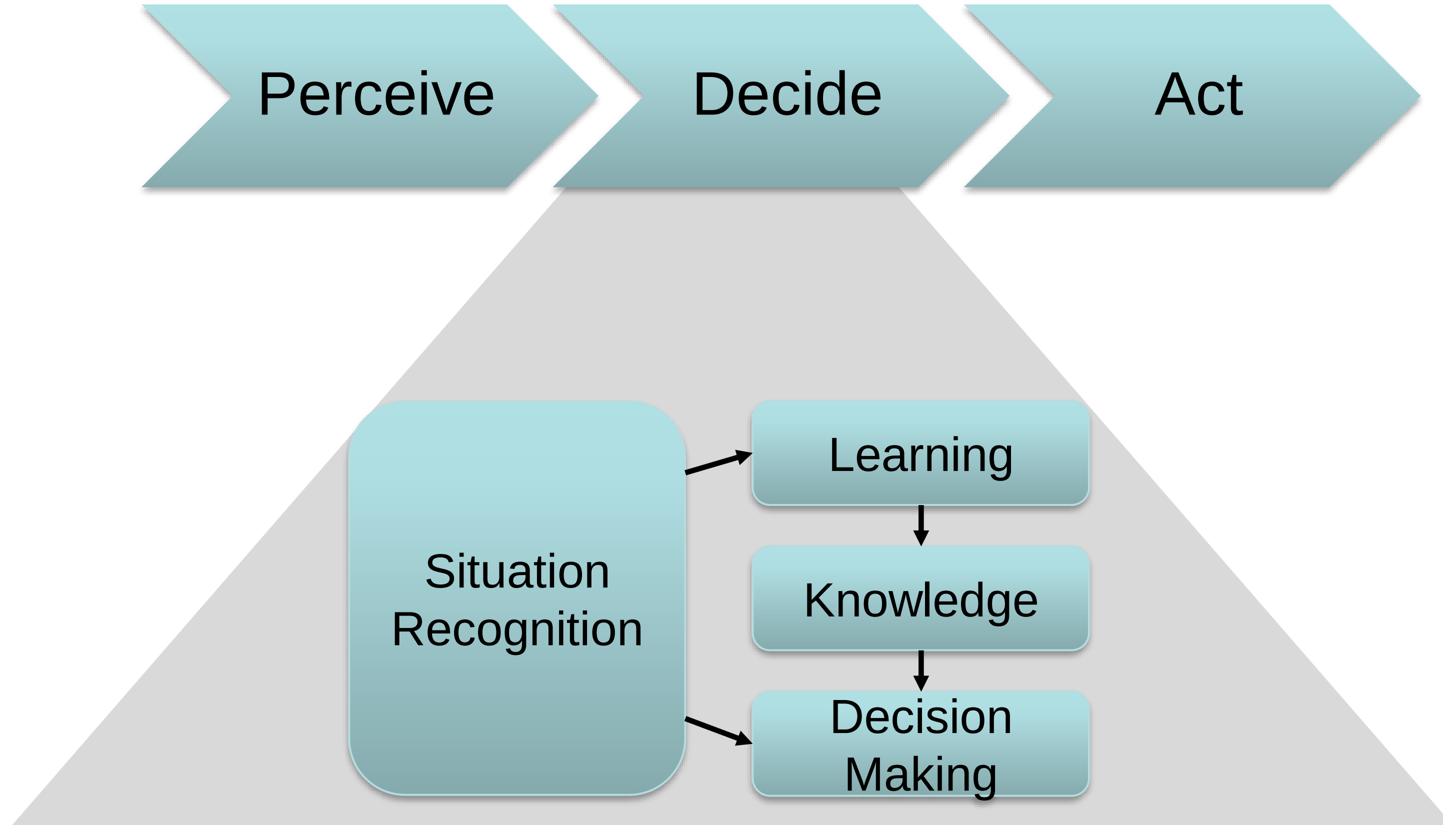
- **Situations** are similar to **activities** - but induce them with further information
  - Time of situation - certain situations have different meanings at different times
  - Duration of the situation - can have different length
  - Frequency of situation - can occur with variable frequency
  - Sequences of situations - can occur in certain sequences with other situations

AI in AmI
Context Awareness & Reasoning

- Situations properties

Eigenschaften	Erklärung
Generalizability	Level of abstraction, e.g. media consumption is more generic than watching TV
Composition	Situations can often be subdivided, e.g. cooking consists of several individual situations
Dependency	Situations can be interdependent, so that situation A can only take place after situation B has started
Opposition	Situations can be mutually exclusive
Time occurance sequence	Situations can be time dependent

AI in AmI
Perceive, Decide, Act



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Main types of artificial intelligence in AmI
Overview

- Rule-based systems
  - Expert knowledge is directly introduced into the system
  - Logic-based rules
- Supervised Learning
  - Expert knowledge as the basis of machine learning
  - Classification based on given data
- Unsupervised Learning
  - System learns patterns without expert knowledge
  - E.g. cluster recognition

Main types of artificial intelligence in AmI
Rule-based systems

- Foundation - knowledge can be discretized
- Ontologies enable a structured representation of knowledge
- Spatial and temporal dependencies are often the basis in situation recognition

IF *at_kitchen_on* ***AND*** *later no_movement_detected*

THEN *assume the occupant has fainted*

Main types of artificial intelligence in AmI
Rule-based systems

- Example of a rule for "Person sleeps”
  - ***If*** *bed_in_use* ***AND*** *light_is_off* ***AND*** *10min_no_actions*
    THEN *person_is_sleeping*

- Fuzzy logic can help to act with non-precise context

Main types of artificial intelligence in AmI
Supervised Learning

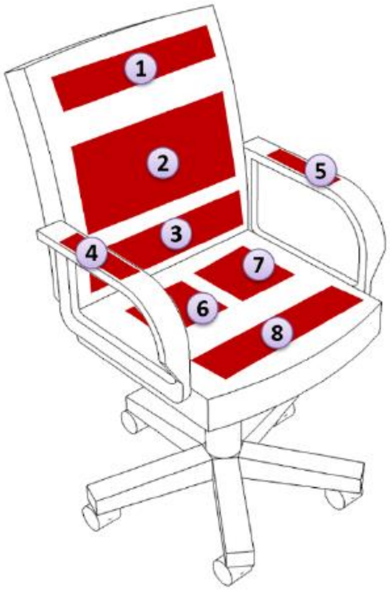
“ A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P if its performance at tasks in T, as measured by P, improves with experience E. ”

- Tom M. Mitchell

- Knowledge is available in exemplary form
- With one part of the knowledge a system is trained (Training Set)
- With another part of the knowledge this is tested (Test Set)

Main types of artificial intelligence in AmI
Supervised Learning

- Example: intelligent office chair with eight capacitive sensors
  - Determination of sitting position (healthy sitting)
  - Data is collected together with sitting position
  - 80% of the data is used as training data
  - 20% of the data is used as test data
  - Training of a Support Vector Machine … for example



Main types of artificial intelligence in AmI
Unsupervised Learning

- Large data set available
- No (or very fuzzy) assignment of knowledge
- System searches independently for possible patterns
- Example: System searches for clusters of frequent activities
  - Whenever person cooks dish x, windows are opened shortly afterwards
  - System builds new rule to control air quality

Main types of artificial intelligence in AmI
Situational Awareness

Few precise sensors, few situations → Inaccurate sensors → More imprecise sensors, complex situations

Rule-based systems

Supervised Learning

Unsupervised Learning

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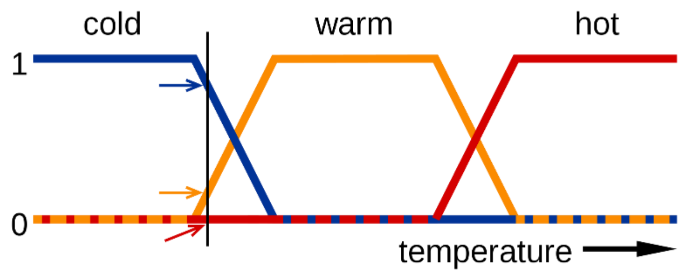
Forms of reasoning
Fuzzy Logic

- Mapping of fuzziness in data
- Moving away from fixed values



Boolean	Fuzzy
AND(x,y)	MIN(x,y)
OR(x,y)	MAX(x,y)
NOT(x)	1 – x

Forms of reasoning
Fuzzy Logic

Forms of reasoning
Fuzzy Logic

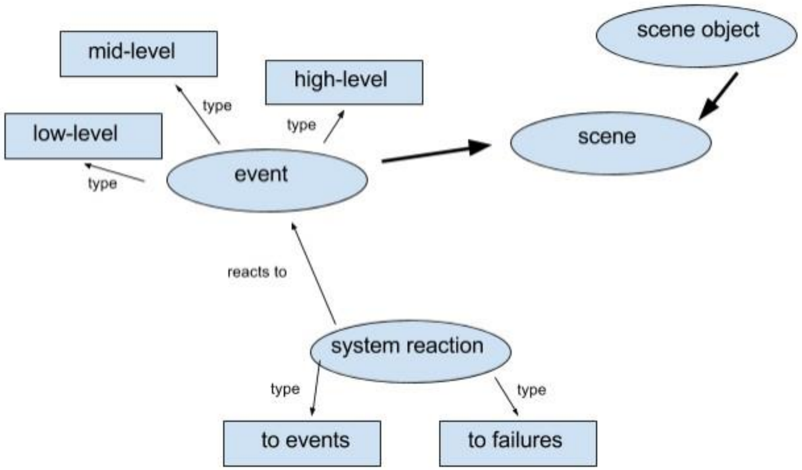
- Example - Refrigerator
  - Sensors for inside temperature, outside temperature, control compressor
- -----→ keep in mind that temperature is not discreet
  - Rule 1: If T_inside = cold and T_outside = warm, then compressor = weak
  - Rule 2: If T_inside = lukewarm and T_outside = hot, then compressor = strong
  - ... Rule n

Forms of reasoning
Ontology Reasoning

- Knowledge is represented in the form of ontologies

- Rules are based on this ontology

- Mapping of expert knowledge



Forms of reasoning
Ontology Reasoning

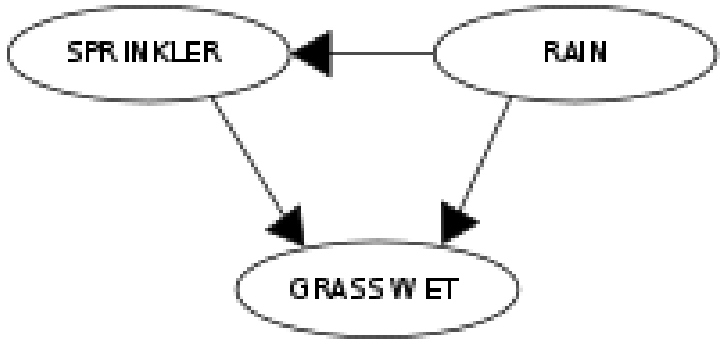
- Example - person sleeps

(?user rdf:type socam:Person), (?user, socam:locatedIn, socam:Bedroom), (?user, socam:hasPosture, ‘LIEDOWN’), (socam:Bedroom, socam:lightLevel, ‘LOW’), (socam:Bedroom, socam:doorStatus, ‘CLOSED’) -> (?user socam:status ‘SLEEPING’)

Forms of reasoning
Bayesian networks

-

	SPRINKLER	
RAIN	T	F
F	0.4	0.6
T	0.01	0.99

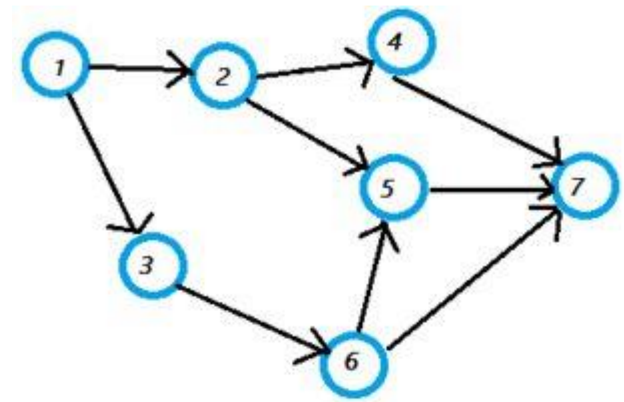


RAIN	
T	F
0.2	0.8

		GRASS WET	
SPRINKLER	RAIN	T	F
F	F	0.0	1.0
F	T	0.8	0.2
T	F	0.9	0.1
T	T	0.99	0.01

Forms of reasoning
Bayesian networks

- Directed Acyclic graph
- In the case of AmI
  - Nodes as context events
  - Links as causal connection
  - Situation can be inferred from tree traversal of the network



RAIN	SPRINKLER T	SPRINKLER F
F	0.4	0.6
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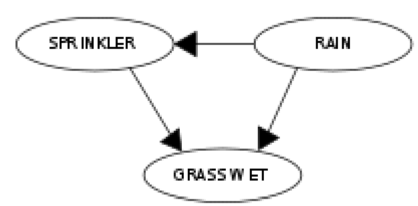
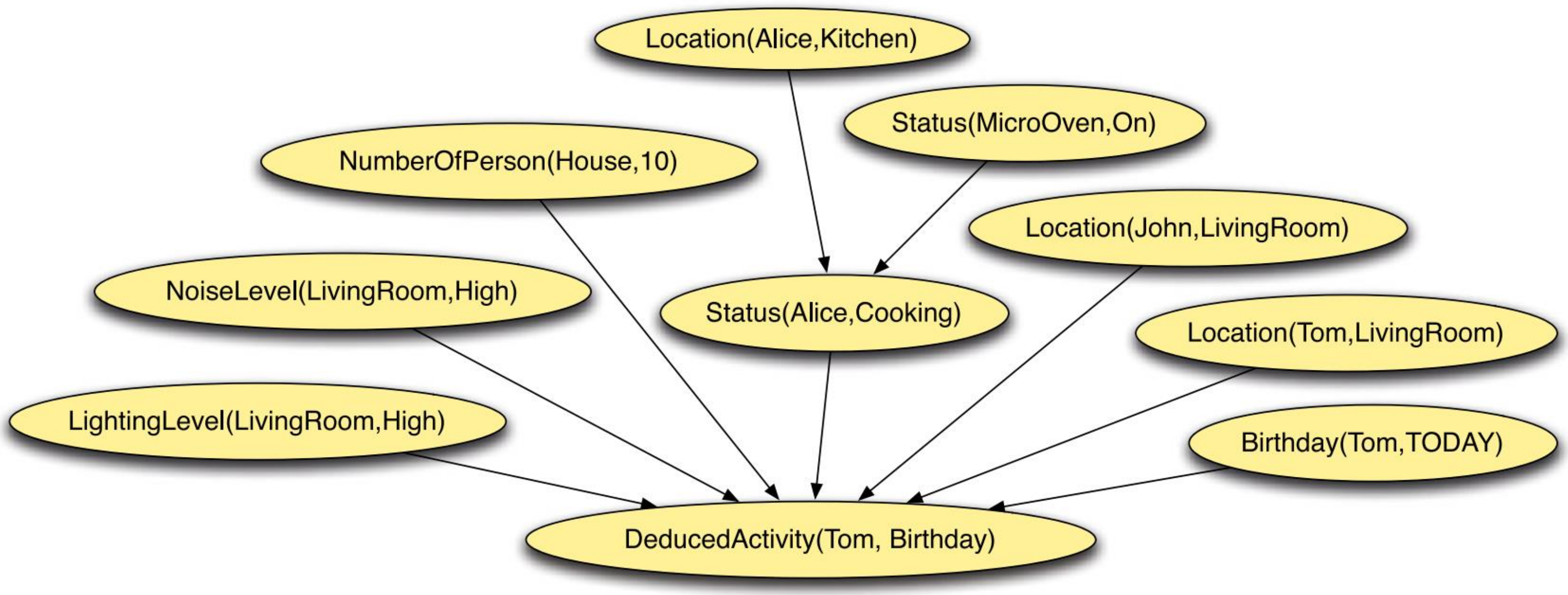


RAIN T	RAIN F
0.2	0.8

SPRINKLER	RAIN	GRASS WET T	GRASS WET F
F	F	0.0	1.0
F	T	0.8	0.2
T	F	0.9	0.1
T	T	0.99	0.01

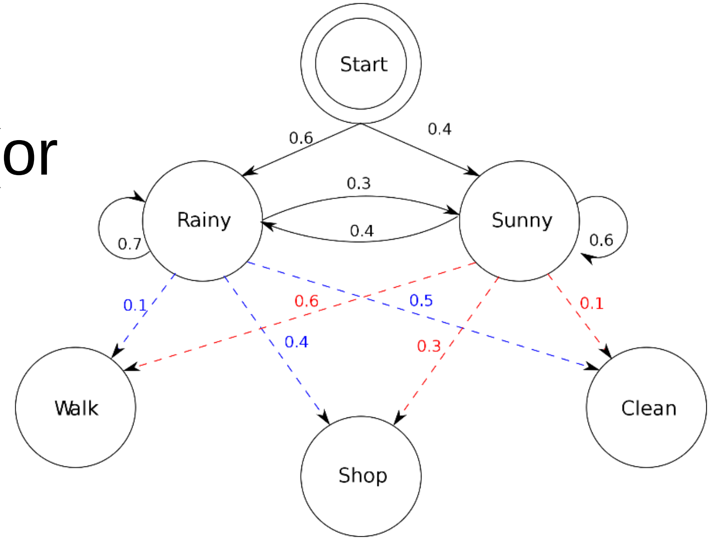
Forms of reasoning
Bayesian networks

- Example - Birthday party



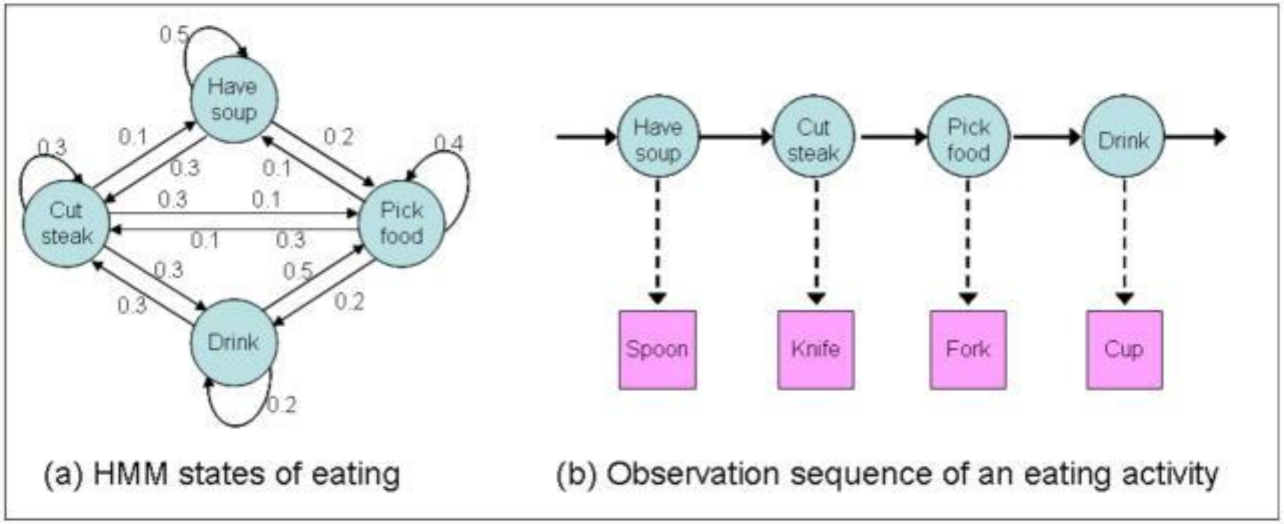
Forms of reasoning
Hidden Markov Modelle

- Dynamic Bayesian Networks
- Only a part of the states is observable
- Probabilities of transitions are known (or learned)



Forms of reasoning
Hidden Markov Modelle

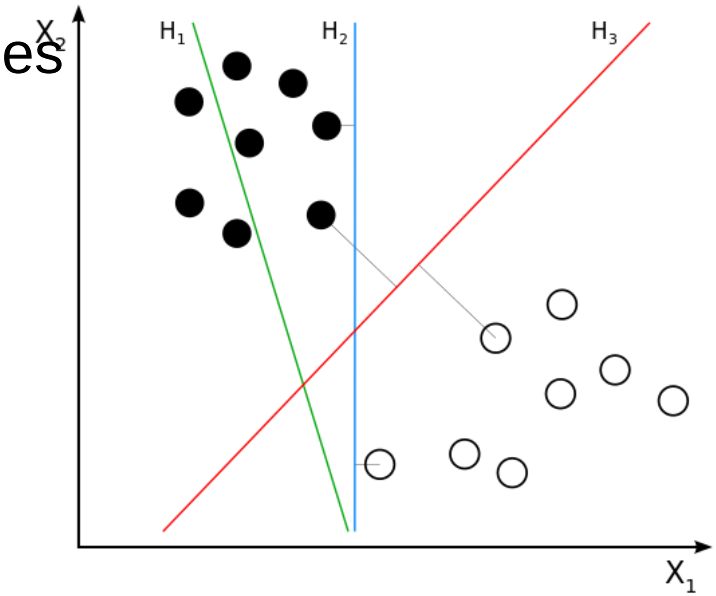
- Example - Activity detection



Kim E, Helal S, Cook D. Human Activity Recognition and Pattern Discovery. *IEEE pervasive computing / IEEE Computer Society [and] IEEE Communications Society*. 2010;9(1):48. doi:10.1109/MPRV.2010.7.

Forms of reasoning
Support Vector Machines

- Classification of objects or events
  - Subdivision so that class boundaries are as wide as possible.
  - H2 separates, but with narrow boundaries
  - H3 separates, with wide boundaries
- Higher dimensional data sets can be separated with hyperplanes

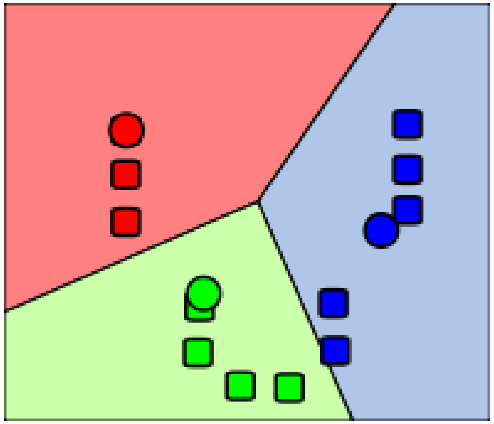


Forms of reasoning
Support Vector Machines

- example – Smart Couch
  - 8 sensors as input
  - 15 verschiedene Belegungen
  - You can use SVM or similar classifiers to classify between:
    - Empty/occupied
    - Setting/laying down
    - Person 1/ person 2
    - .
    - .

Forms of reasoning
k-Means Clustering

- Unsupervised Learning Method
- Division of a state space into clusters
- Assignment of new elements according to proximity to cluster center



- is the person doing the same thing he/she does every morning?

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The user in learning systems
Forms of influence

User

Data source

Operator

Adaption

The user in learning systems
Forms of influence

- Data source
  - The user's activities are the most important basis of the system's decisions
  - As an expert, the user can configure the systems
- Operator of the learned rules
  - The operator triggers many rules
  - She/he can give feedback on their success
- Adaptation of learning
  - The user can influence learning processes

The user in learning systems
Data sources

- Ground Truth
  - Data basis that is accepted as true
  - Frequently labeled data

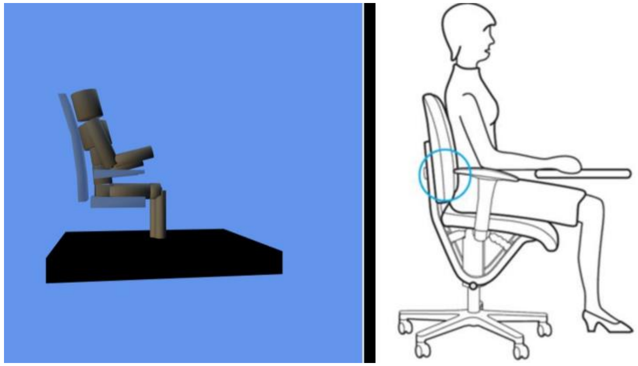
- User activities represent the "truth"

- Learning systems can be trained with these

The user in learning systems

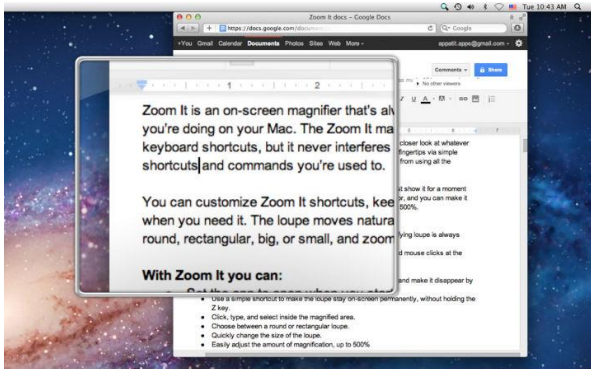
Data sources

- Smart Chair - Pose Recognition
- User plays different poses
- The assigned sensor values serve as a basis for pose recognition
- Adaptation of threshold values



The user in learning systems
Data sources

- Profile of the user
  - E.g. age, gender
  - System behavior
    - Accessibility tools
  - Preferences
    - System controls multiple applications according to individual preferences
    - Resolution, language, standard programs, themes, templates

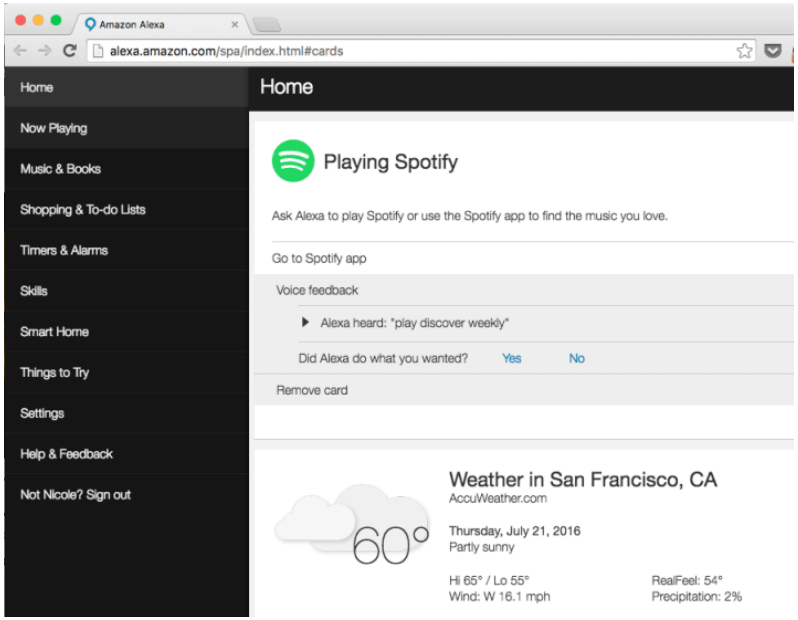


The user in learning systems
Operator of the learned rules

- Self-created rules
  - Custom configured rules are set
  - Can influence rule logic or parameters
- Framework for rules
  - Certain framework conditions for rules can be set by the operator
  - Scope of the learning system is limited
- Feedback
  - If rules are executed, the user is typically directly affected
  - System can ask for feedback

The user in learning systems
Operator of the learned rules

- Rule configuration by user
- For example, voice assistants
- Rules can be further used by the system



The user in learning systems
Operator of the learned rules

- Examples general conditions
  - "Never disturb me after midnight".
    - Unless it is a fire alarm

- Overriding settings that affect all other rules

The user in learning systems
Adaptation of learning

- Adjustment of control parameters
- Fuzzy sets
  - "cold", "mild", "warm".
  - Modification of the assigned value parameters and probabilities
- Parameter
  - Preferred room temperature: 21° instead of 20
- Profile
  - Person moves slower

The user in learning systems
Adaptation of learning

- Example 1 - Preferred room temperature
  - Thermostat has been turned up x times in the past n weeks
  - Adjust ambient temperature when person is present

- Example 2 - Person moves slower after a few years
  - Ambient lighting is activated longer (coming home scenarios)

The user in learning systems
Adaptation of learning

- Adaptation of the control behavior

- Profile
  - Person is visually impaired after accident

- Modality
  - screen in the corridor

The user in learning systems
Adaptation of learning

- Example 1 - Accident
  - Information about visual impairment added to profile
  - System redirects output to sound
  - System changes font sizes, contrast profiles ...
- Example 2 - new hardware
  - New hardware logs in with its functionalities
  - Output can be redirected to new hardware

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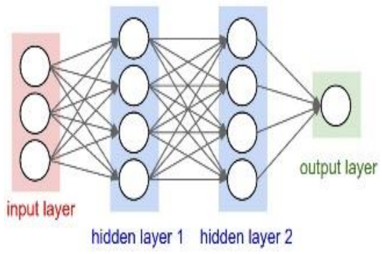
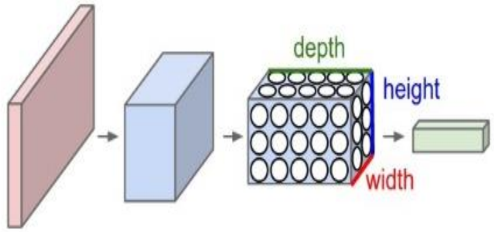
Trends in intelligent environments
Deep Learning

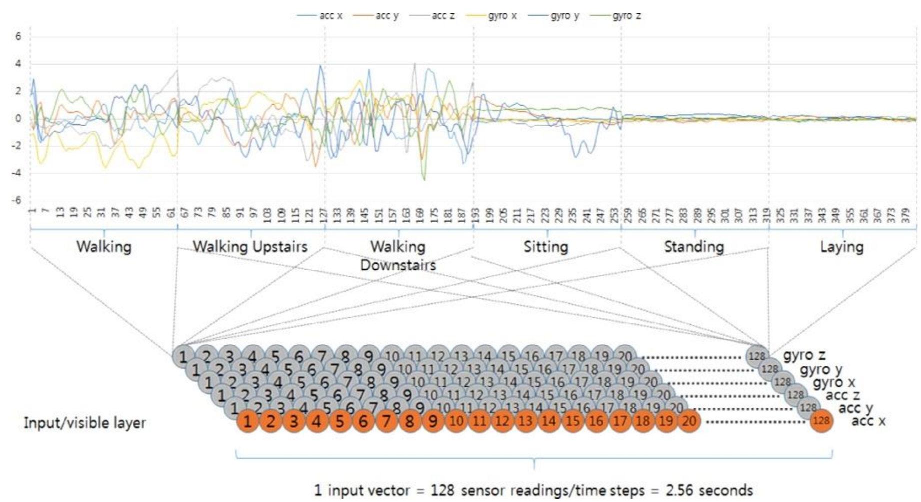
- Very high performance for many problems in computer vision
  - Object recognition, speech recognition, super-resolution, denoise, deblur, face recognition, ...

- Challenges
  - Black box - influence of parameters
  - System requirements





- Applications in situation recognition
- Temporal sequences in sensor data are used
- Example - sensors in smartphones



Trends in intelligent environments
Hybrid Reasoning

- Rule-based systems get problems with high complexity
- Learning-based systems cannot represent user preference and rapid changes well

- Combination of several methods to mitigate disadvantages of individual ones

- Example - Parameter Learning

- Basic rules are preconfigured by experts
- Learning procedures train the parameters of the rules

Trends in intelligent environments
Smart Speaker

- Assistance systems in the living environment
- Combination of speech recognition and rules
- Natural Language Processing
  - Code words offline (performance, privacy)
  - Transfer speech samples to server
  - Analysis and triggering of actions

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