Applications of Artificial Intelligence

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Chapter 1:
Introduction and Survey

Survey of this course

Prerequesites of knowledge:

Discrete Mathematics (including applications), Programming I and II

helpful: Object oriented programming

Targets of this course:

Raising interest for AI applications and technology

Survey knowledge of most AI technologies

Knowledge of several application fields for AI

Which are the applications and technologies?

Wait a second …

What is AI ?

Turing‘s test

A software is intelligent, if a human cannot distinguish its behaviour from the behaviour of a human.

Application: Medical Diagnosis

Psychoanalysis: Eliza

1966: Joseph Weizenbaum, MIT

Computer performs a psychoanalysis session and acts „as one thinks a psychoanalysist would act“.

- **passed Turing‘s test with a lot of people**
- **built-in language assembler and composer**
- **response rules**

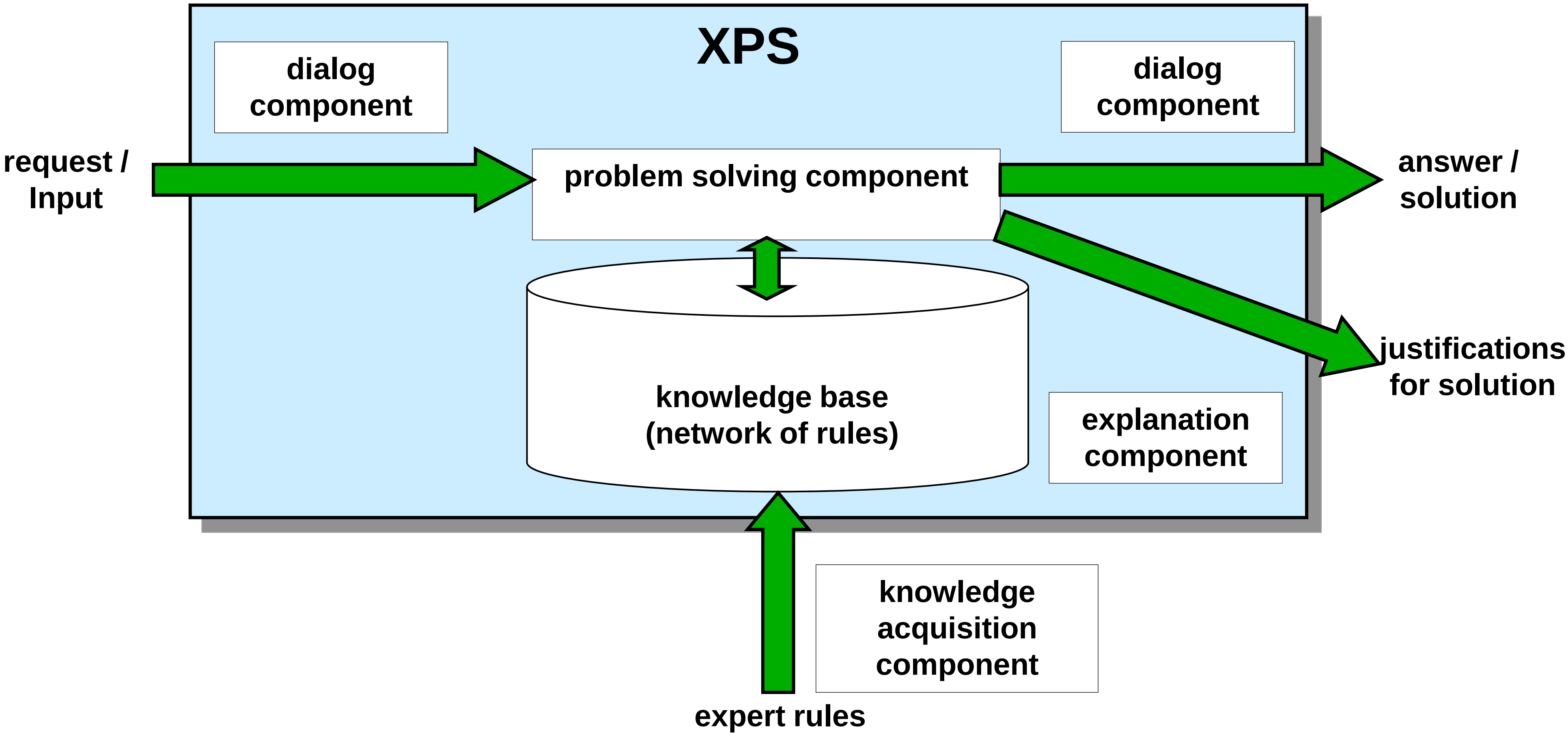
Medical Diagnosis: Mycin

1972: University of Stanford

- **for diagnosis and treatment of infectional deseases**
- **worked with probabilistic rules**
- **got high hit scores**
- **little acceptance among physicians due to distrust to computers**

Base Technology: Expert System

Expert System Architecture



Application: Technical Diagnosis

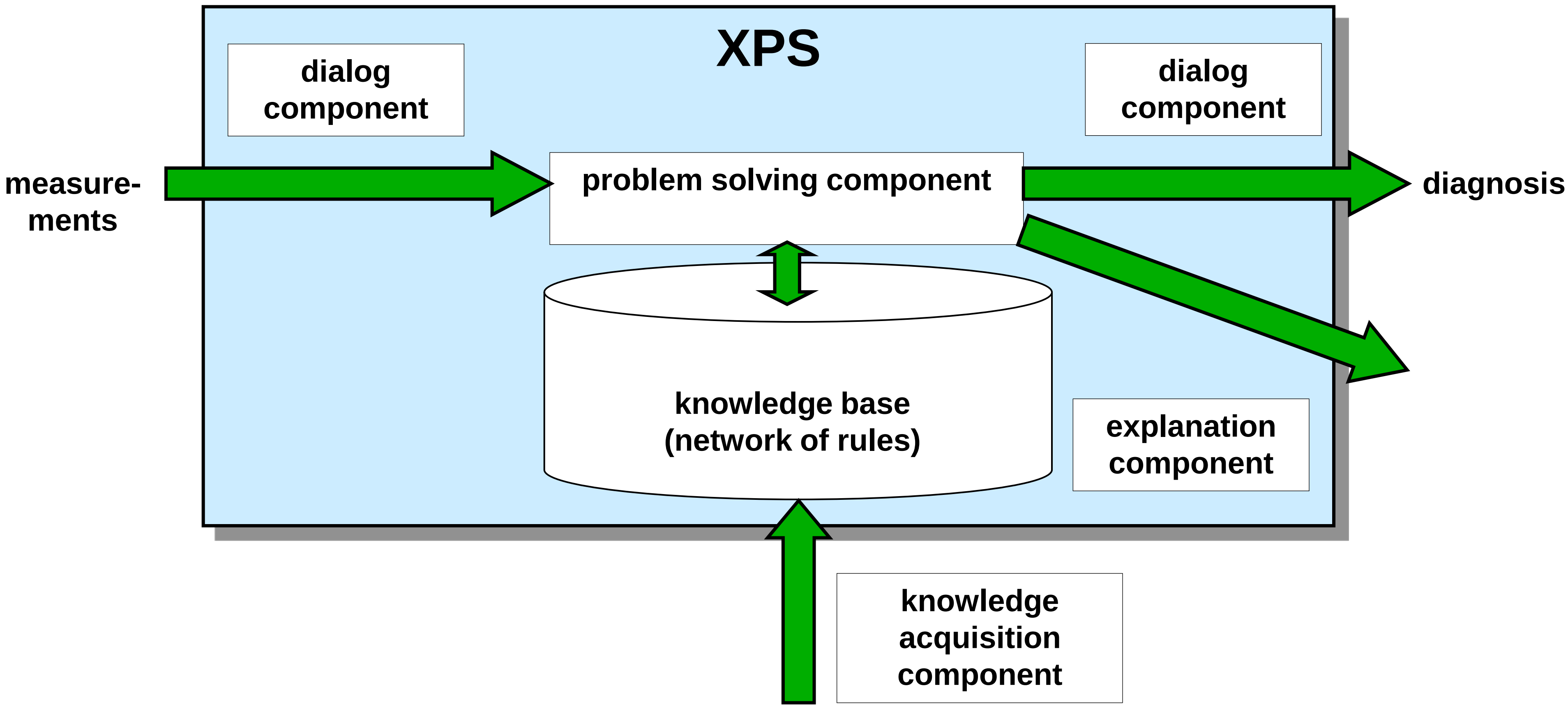
What is technical diagnosis?

Input:
- Technical system (e.g. car, train)
- Observations (e.g. measurements, fault codes, driver‘s complaint), out of order.

Task:
Detect,
- for which reasons the system is out of order
- exactly enough to recover the proper function of the system.

Application: Technical Diagnosis

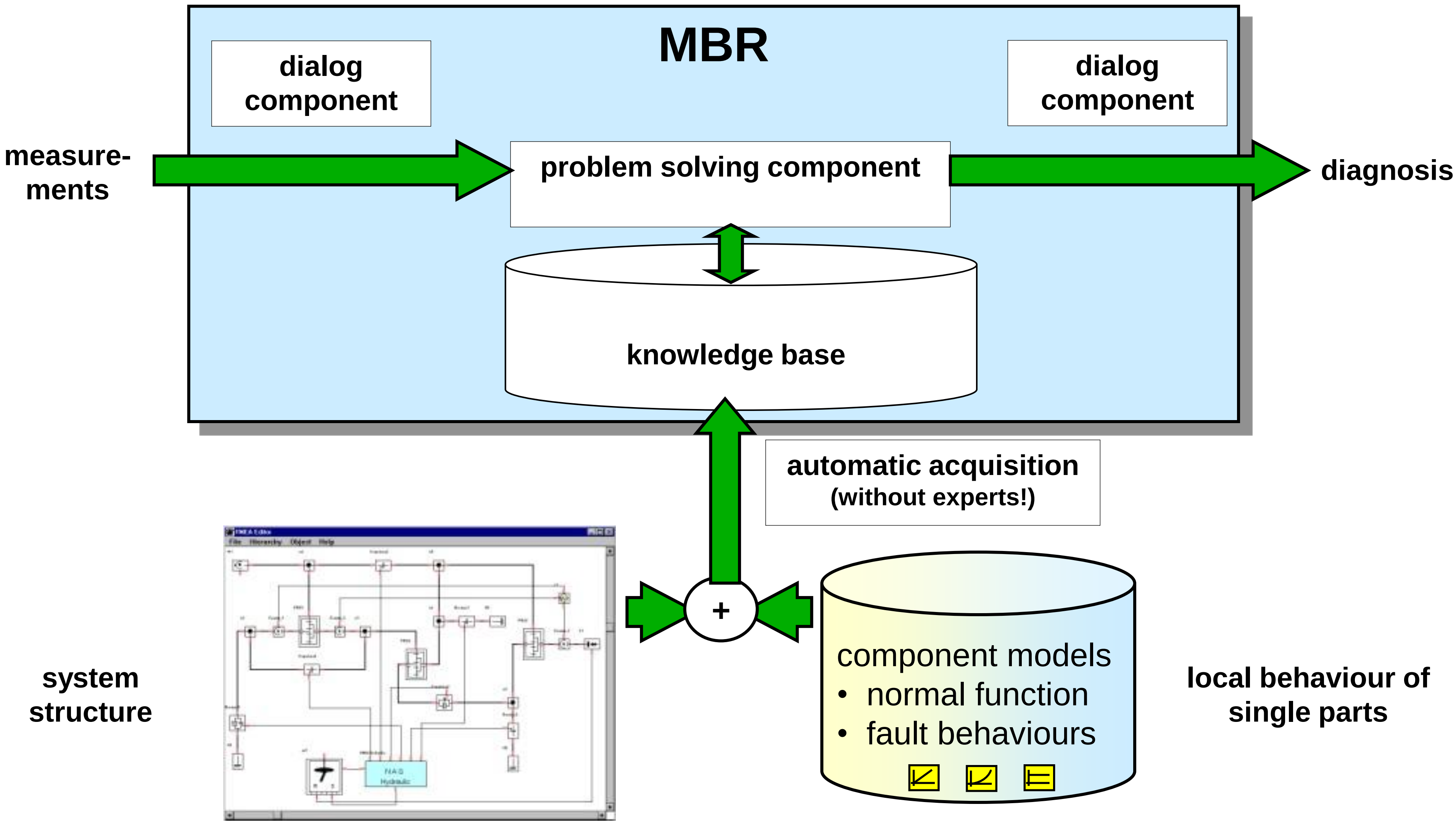
1970-1980s: diagnosis = heuristic classification



knowledge about structure and function:
specific symptom ⇒ specific diagnosis

Application: Technical Diagnosis

1990s: diagnosis = model-based reasoning



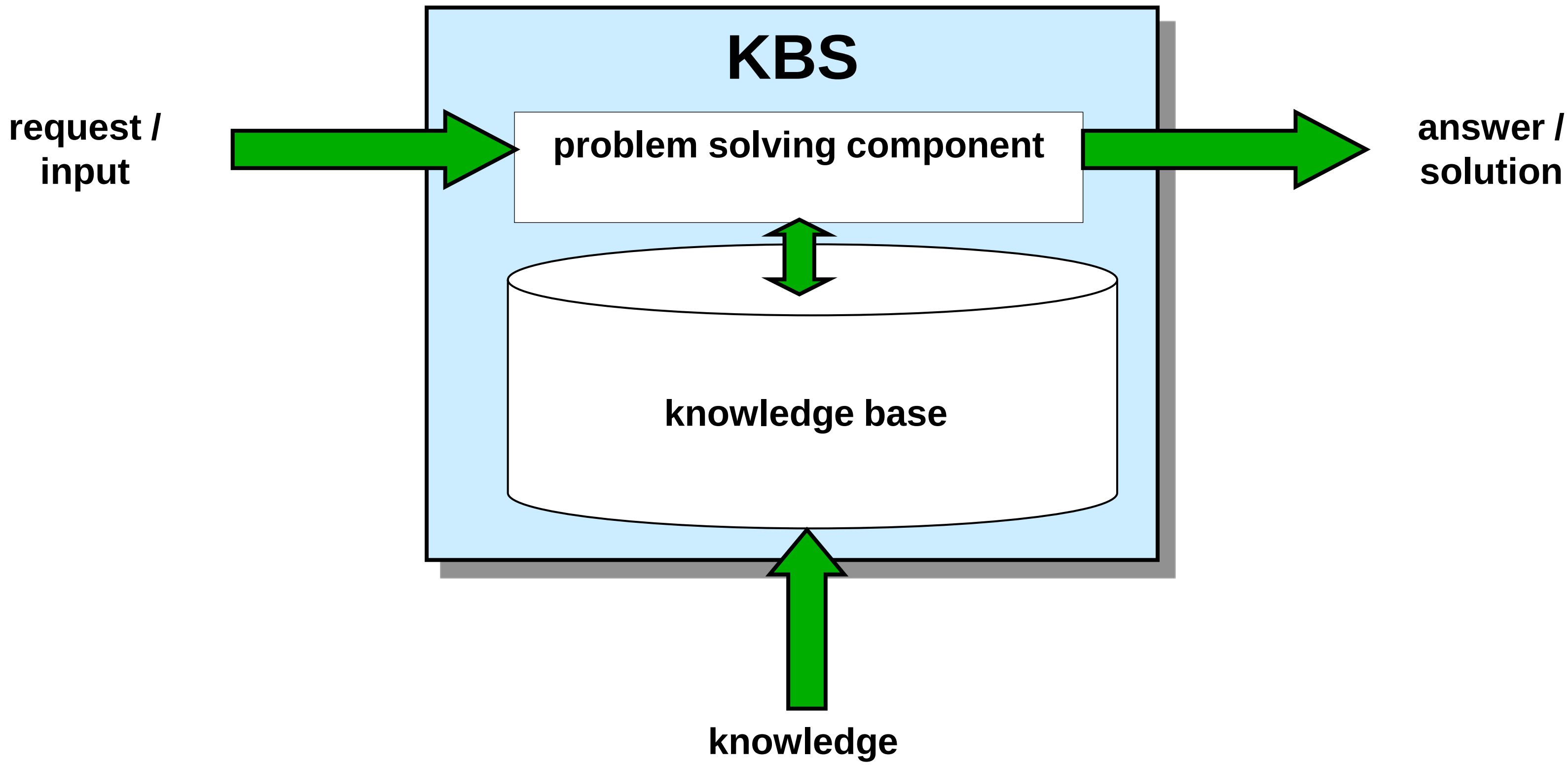
Base Technology: Knowledge-Based Systems

knowledge + problem solving component = KBS

data processing rules

Architecture KBS

(joint generalisation of XPS and MBR)



Application: Image recognition

Goals:

- Identifying persons of a certain group (gender, appearance, attitude, etc.)
- Identity control for admission / authorisation
- Identifying certain persons if they are in a certain area
- Forensic analysis
- Identifying street signs
- Identifying arbitrary objects for certain purposes
- …

Base Technology: Machine Learning (CBR)

Knowledge Acquisition Technique: Training by examples

1. approach: vector-based using a similarity measure

- classical approach already used in the early days of AI
- modern method: Support Vector Machines

2. approach: Neural networks

- modern method: deep learning

➡ ***Machine learning techniques are a current hype due to impressing success stories***

➡ ***This why nowadays many people identify AI with Machine Learning***

➡ ***“Algorithms” in this context are understood the algorithms how to adjust the parameters of the neural network from the training samples***

Note!

- Neural network algorithms are purely statistical and have no causal justificatíon
- Algorithms investigated in “Algorithmics” do always have a causal justification which can be proven.

Applications using Machine Learning:

Recent graduation theses supervised by iw:

Master Thesis Shwetha Mohan Kumar**:** *Computation of Delays in the Public Transportation of Hamburg*, WS2021/22

Master thesis Thimo Tollmien: *Optimizations of Delay Predictions in Local Public Transport Using Deep Learning*, SS 2018

➡ ***traffic advice, big data***

Master thesis Frederik Schnoege: *Einsatz von Natural Language Processing im IT Support*, SS 2020

➡ ***semantic categorisation***

Bachelor thesis Henning Brandt: *Implementation of a model for determining the concentration of organic molecules in a multicappilar gas chromatograph using machine learning,* WS 2019/20

➡ ***technical diagnosis***

Bachelor thesis Dennis Maas: *Transformation invariant bar code recognition using neural networks*, SS 2019

➡ ***logistics***

Bachelor thesis Michel Belde: *Improvement of a consulting app for the sales department using image recognition*, WS 2018/19

➡ ***sales***

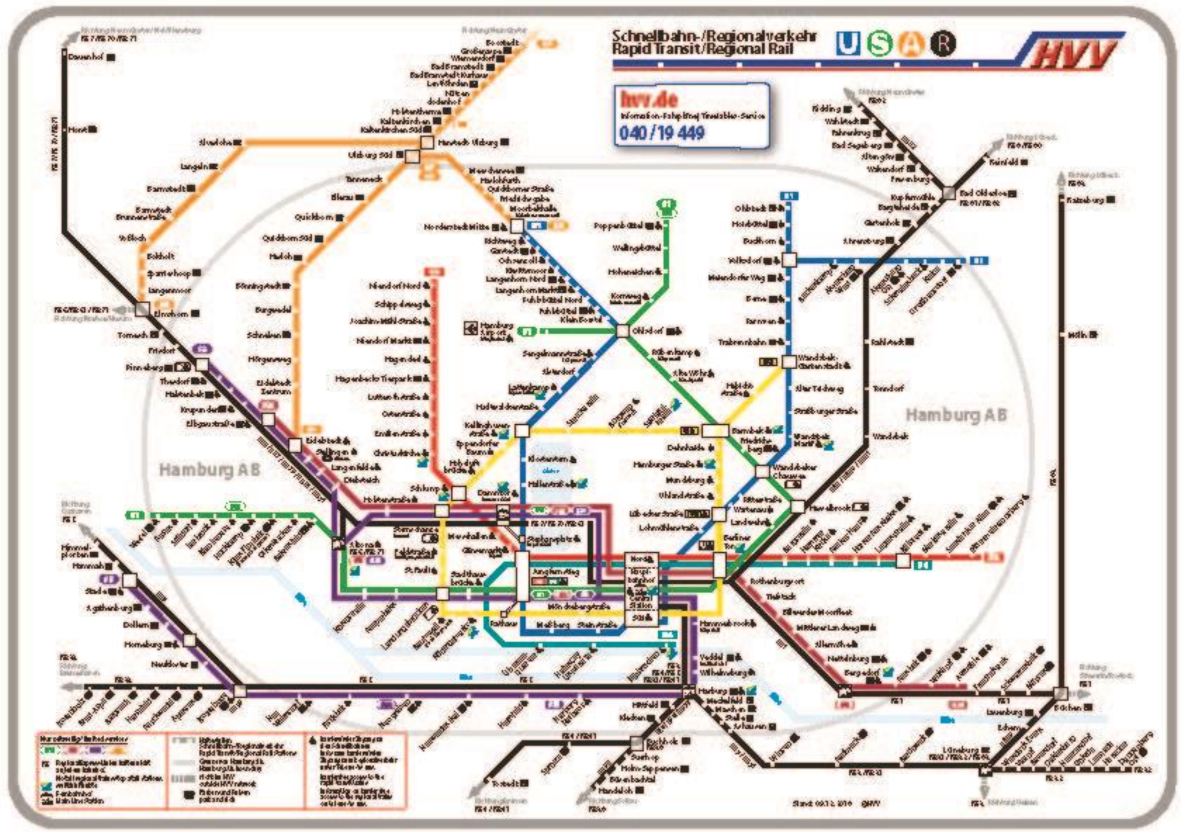
Bachelor thesis Lasse Karls: *Graph-based feature extraction to improve machine learning in predicting the business affiliation of a Signal Iduna customer,* WS 2018/19

➡ ***customer maintenance***

Application: Passenger Information System

Task:

For two points A and B, find the shortest path between A and B using exclusively segments of the traffic network.



Solution:

Dijkstra‘s algorithm
(cf. Discrete Mathematics, ch. 7, graph theory)

A* algorithm

➡ **several seminars, projects and graduation theses at FH Wedel on routing**

Optimisation with further heuristics (e.g. Geofox system für Hamburg Transportation Network)

Optimisation with preprocessing (e.g. Hafas for German Railways)

Application: Passenger Information System

Passenger information for HVV with smartphones:

Development and implementation of actual prototypes:

- iPhone
- Android smartphones

Diploma thesis Sebastian Hammes (eos-uptrade, SS 2010)

- results used in HVV App

Bachelor thesis Henning Reimer (HBT, SS 2010)

- results used in Geofox App

Master thesis Josias Polchau (HBT, SS 2014)

- Innovation award of Rotary Club Wedel

Speed-up of routing computation:

This is NOT typical AI !

Master thesis Nicolas Mönch: *Shortest paths in dynamic graphs*, WS 2015/16

Bachelor thesis Christian Binder: *Optimisation of a public transport routing algorithm, SS 2017*

Master thesis Lukas Müller: *Hierarchical Algorithms in Public Transport*, SS 2018

Application: Passenger Information System

does not contain AI techniques as defined in a classical way

Mobile passenger assistant:

A „navigation device“ for public short-distance traffic

Master thesis by Josias Polchau (SS 2014)

Funktion	Nutzen	Realisierungsaufwand	
Informationen zur aktuellen Fahrt			**implemented**
Aktualisierung der Route			**implemented**
Erinnerungen			**implemented**
Verbesserung der Fußwegnavigation			
Füllstands-Anzeige			
Stau-Karte			**implemented**
Anzeige: Einstieg vorne/hinten		derzeit nicht möglich	
Fahrradmitnahme		derzeit nicht möglich	
Routenpause			
Lautsprecheransagen		derzeit nicht möglich	

Example for a typical AI solution in this context:

Master thesis Thimo Tollmien: *Optimizations of Delay Predictions in Local Public Transport Using Deep Learning*, SS 2018

Application: Road Navigation

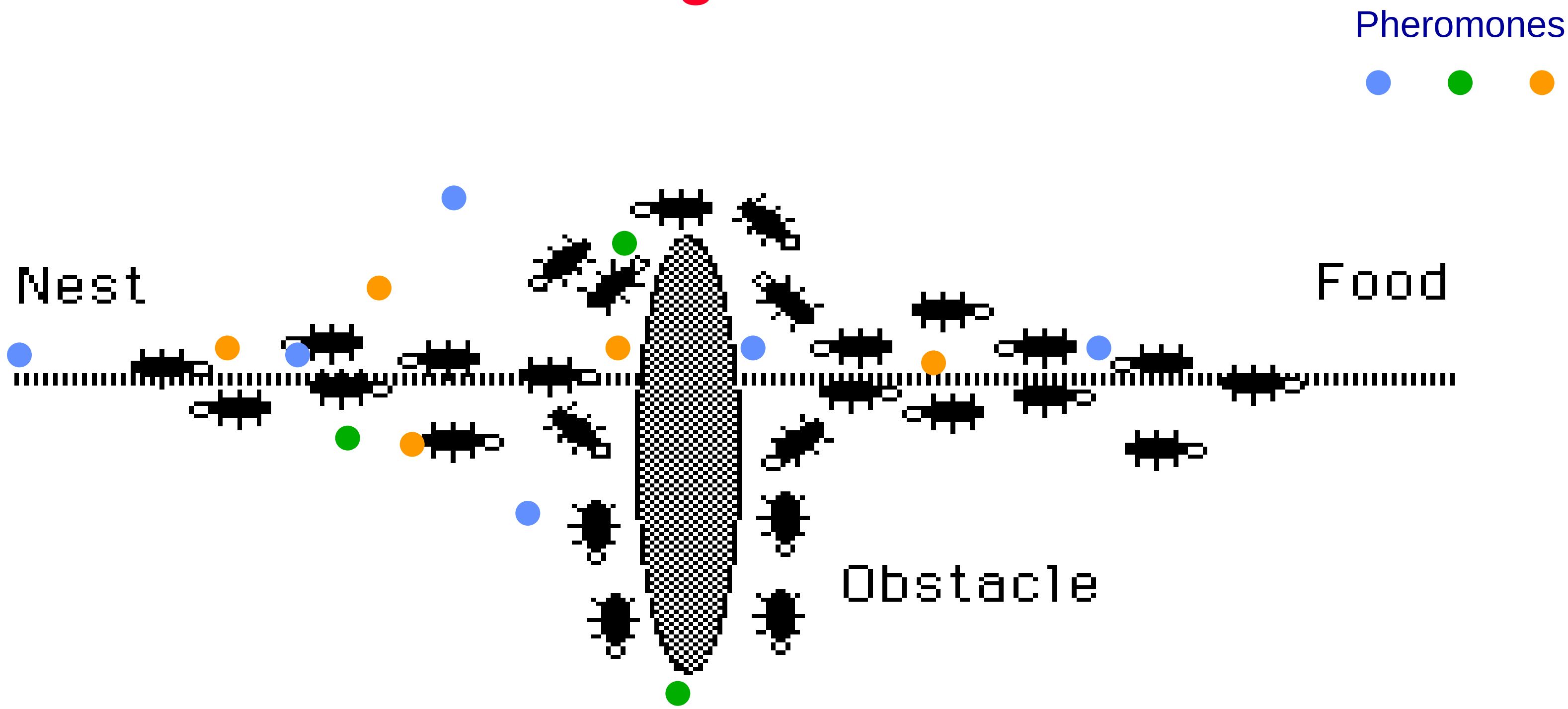
Differences to be considered for adaptation to road networks:

- **Road network is much denser.**
- **no time-tables or opening hours**
- **Traveling time depends very much on traffic density.**
- **Traffic devices are not controlled centrally.**

Application: Road Navigation

Swarm Intelligence: Pheromone-Based Approach

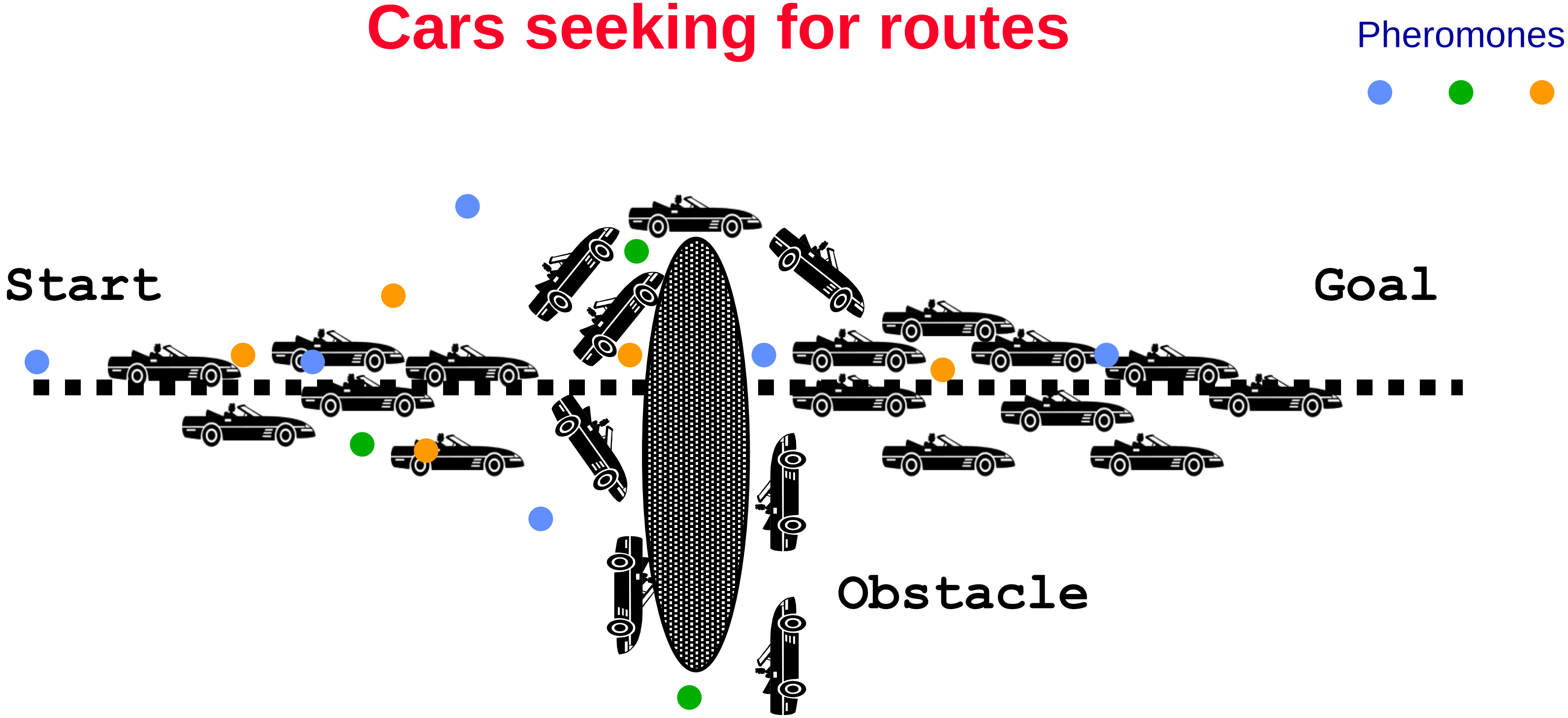
Ants seeking for food



Application: Road Navigation

Swarm Intelligence: Pheromone-Based Approach

Analogue:
Cars seeking for routes



Base Technology: Swarm Intelligence

- a lot of small autonomous units, each with limited ability
- total organism has a higher ability than the sum of the units ("emergent behaviour")
- determined rule system for total organism
- anytime ability

Research focus at FH Wedel by iw:

Several projects, graduation theses and publications since 2006

Application: Game AI

Chess computer (Ex. for a turn-based game)

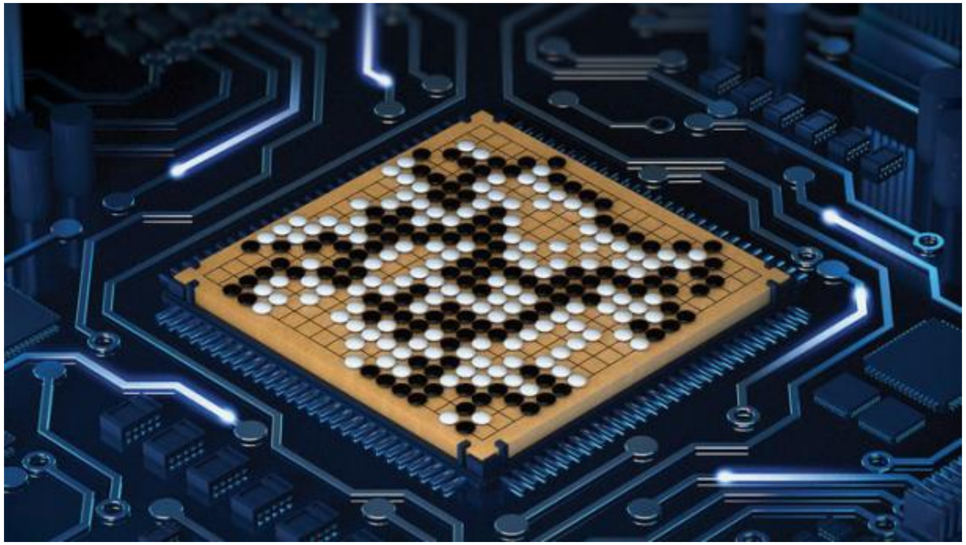
First Milestone 1997:

Kasparov 2.5 – Deep Blue 3.5

Further infos: http://www.research.ibm.com/deepblue

Application: Game AI

Go computer (a much harder turn-based game)

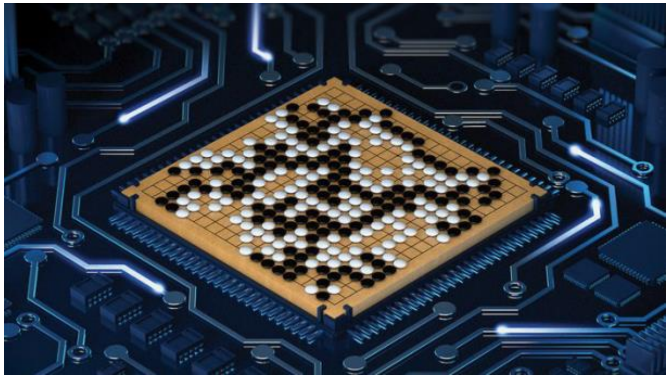


Second Milestone 2015:

- Google's Deep Mind developed Alpha Go.
- Alpha Go used Machine Learning and was trained by experienced Go players.
- In 2015 Alpha Go beat several world famous Go players.

Application: Game AI

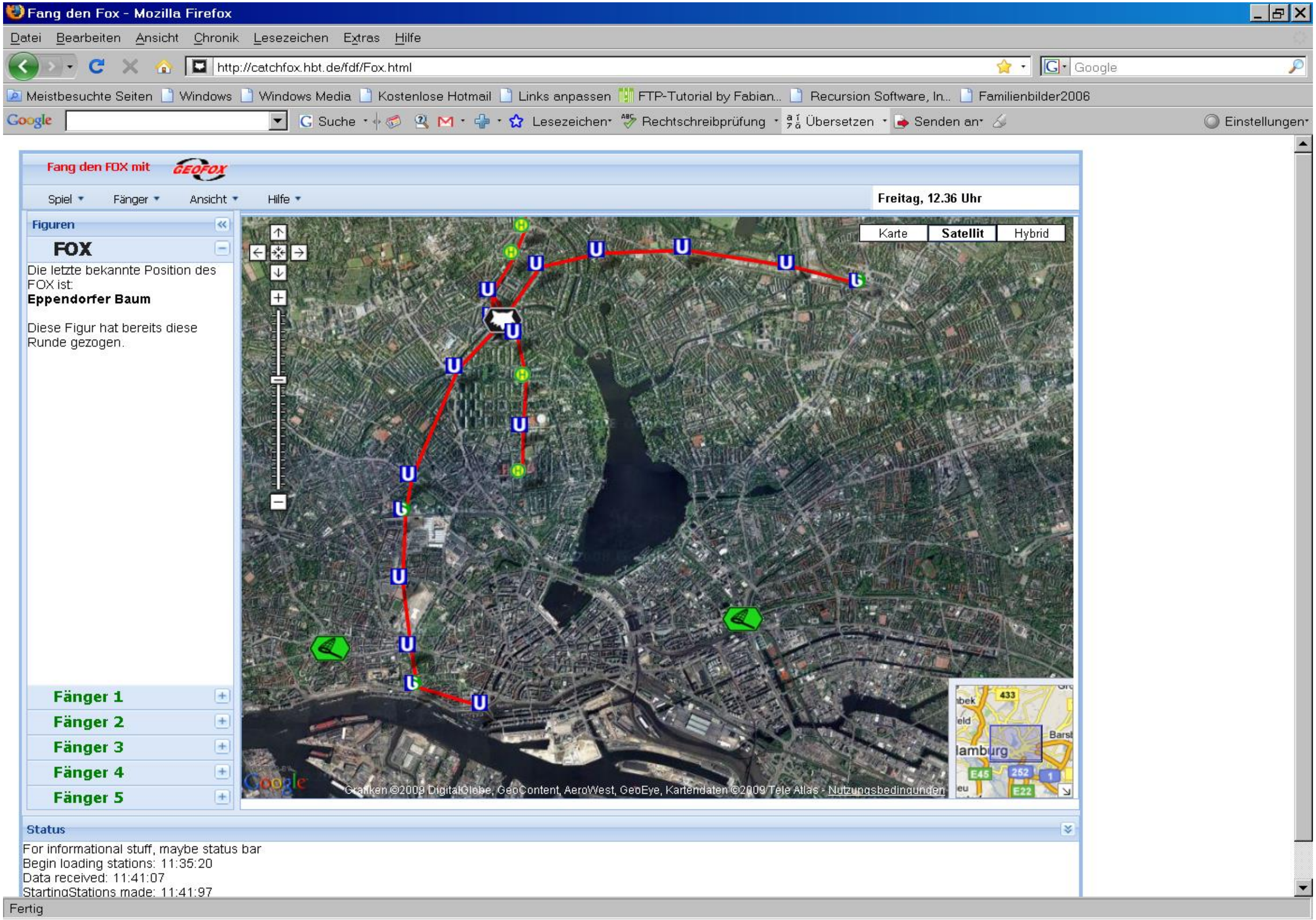
Go computer (a much harder turn-based game)



Third Milestone 2017:

- In 2017, Deep Mind developed the update version Alpha Go Zero.
- Alpha Go Zero started by playing against itself and was not trained by humans at all.
- Within 3 days of continuous training, Alpha Go Zero reached a stage, experienced Go players need years for.
- Alpha Go Zero played 100 matches against Alpha Go and won them all.
- By now, DeepMind developed improved versions, e.g. AlphaZero which can also play other games like chess.

Application: Game AI



Application: Game AI

Turn-based game „Catch the fox“

- Diploma thesis 2009 at HBT (operator of Geofox)
- 3. prize of Hochbahn award
- Computer controls the fox
  which should be caught by human-controlled avatars
- Game uses real time information of HVV
- Originally programmed on GoogleMaps, then transferred to licensed map
- License reasons forced to switch off the online game.
- A new implementation is only possible with OpenStreetMap.

➡ **Project work possible at HBT**

Application: Game AI

Real-time strategy games

Source Age of Empires 2, screenshot of Nils van Kan

Application: Game AI

Real-time strategy games

Typical AI requirements:

- Path finding and location analysis
- Resource planning
- Policies and strategies

Base Technology: Search Strategies

- **Construction of search spaces**
- **Uninformed search strategies**
  - **breadth-first search**
  - **depth-first search**
  - **combined search** → **Special case: Dijkstra‘s algorithm**
- **Informed search strategies**
  → **Special case: A* algorithm**

is used in navigation products as well

Application: Game AI

Realtime strategy games

Requirements in modern games:

- Pathfinding and terrain analysis in environments changing dynamically

Algorithmic techniques:

- Construction of way graph for navigation
- Learning from suboptimal paths
- Working with unsafe information

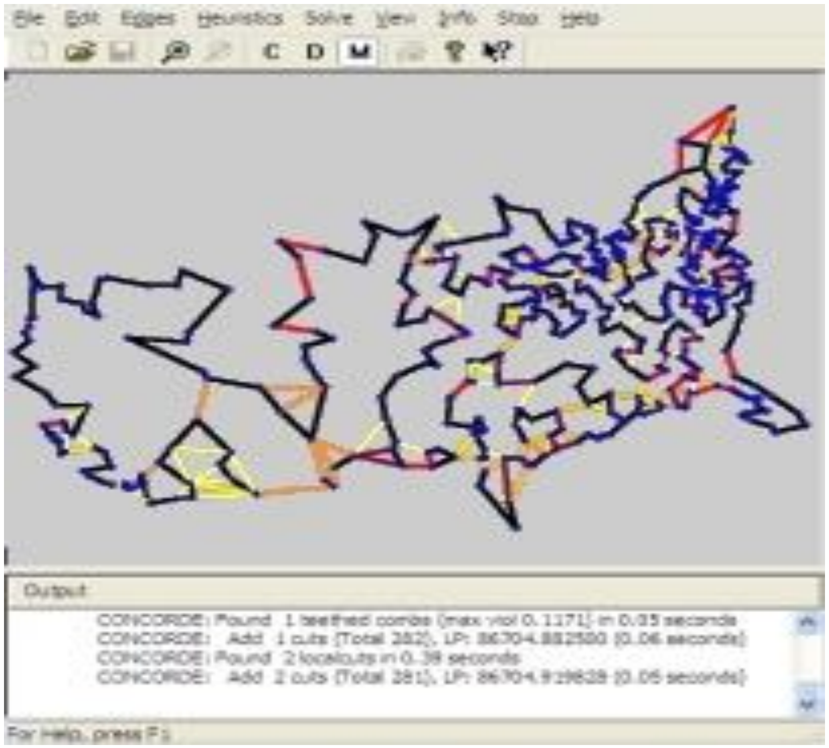
does not always include classical AI

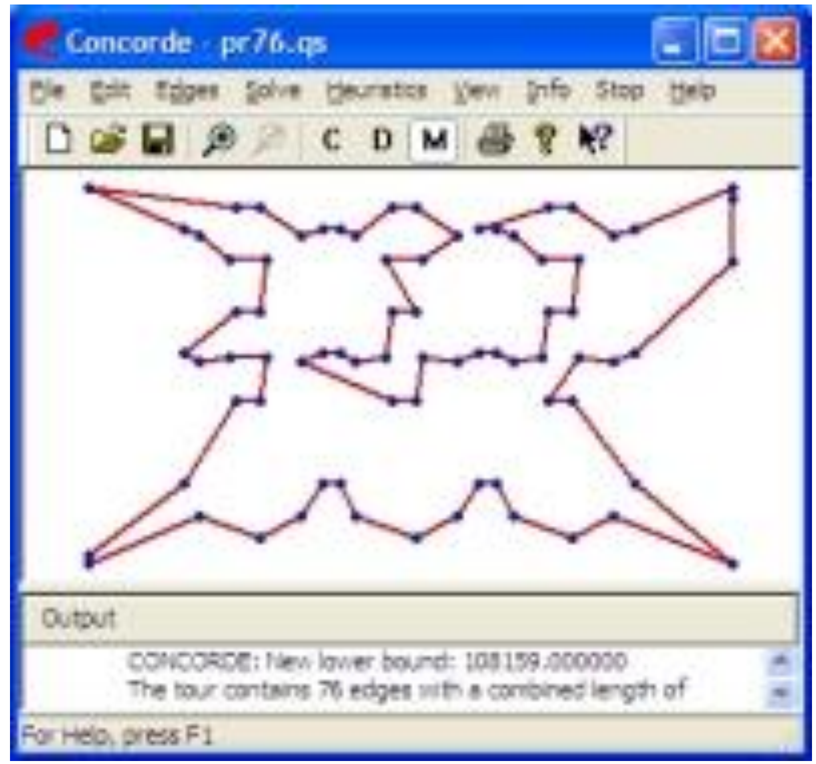
but is always considered Game AI!

Application: Traveling Salesman Problem (TSP)

Master example for an NP-hard problem:

For a given set of cities with known mutual distances, find the shortest round trip passing each city at least once.





Source: http://www.tsp.gatech.edu//index.html

Application: Traveling Salesman Problem (TSP)

Generalisations in logistic applications:

- **considering time restrictions (time windows)**
- **considering load capacities for delivery problems**
- **further system-specific requirements**

Examples for graduation theses in companies:

implico: Tour planning for oil and gas delivery (SS 2010, SS 2011, SS 2013)

Long-term development project: Tourist Information System

Christoph Forster / Thomas Kresalek / Felix Döppers:
Master project Hamburg Tourist Information (since 2009)

http://vsrv-studprojekt2.fh-wedel.de:8080/touristinformationsystem/home

Solution of dynamic problems via ant systems

Example for a graduation thesis in a company:

Christopher Blöcker: Dynamic optimisation of tour delivery using an ant system (SS 2011)

Application: Class Scheduling

Given finite sets Courses**, R**ooms**, T**ime slots

Task: Generate an injective (one-to-one) function C → RxT

Strict Constraints (must be fulfilled in any case):

- **Certain courses must not take place at the same time**
- **For some courses, certain time slots are not admitted**
- **For some courses, certain rooms are not admitted**

Soft constraints (may be violated):

- **Certain courses should not take place at some times**
- **Certain courses should take place successively**
- **Certain courses should not take place on the same day**

Optimisation function:

- **fewest violations of soft criteria**
- **fewest free periods for certain study programmes**
- **most uniform distribution on different days for ...**

Base Technology: Constraint Satisfaction Problem (CSP)

Specification of a CSP:

- **set of variables**
- **domains of definition**
- **constraints: relations between variables (strict or soft)**
  (nomally, equations and inequalities)
- **optimisation criterion**
  (normally, a real-valued function on the variables which has to be minimised or maximised)

valid solution:

assignment of all variables with values such that all strict constraints are satisfied

optimal solution:

valid solution optimising the optimisation criterion

Manifold application scenarios in various problems of logistics

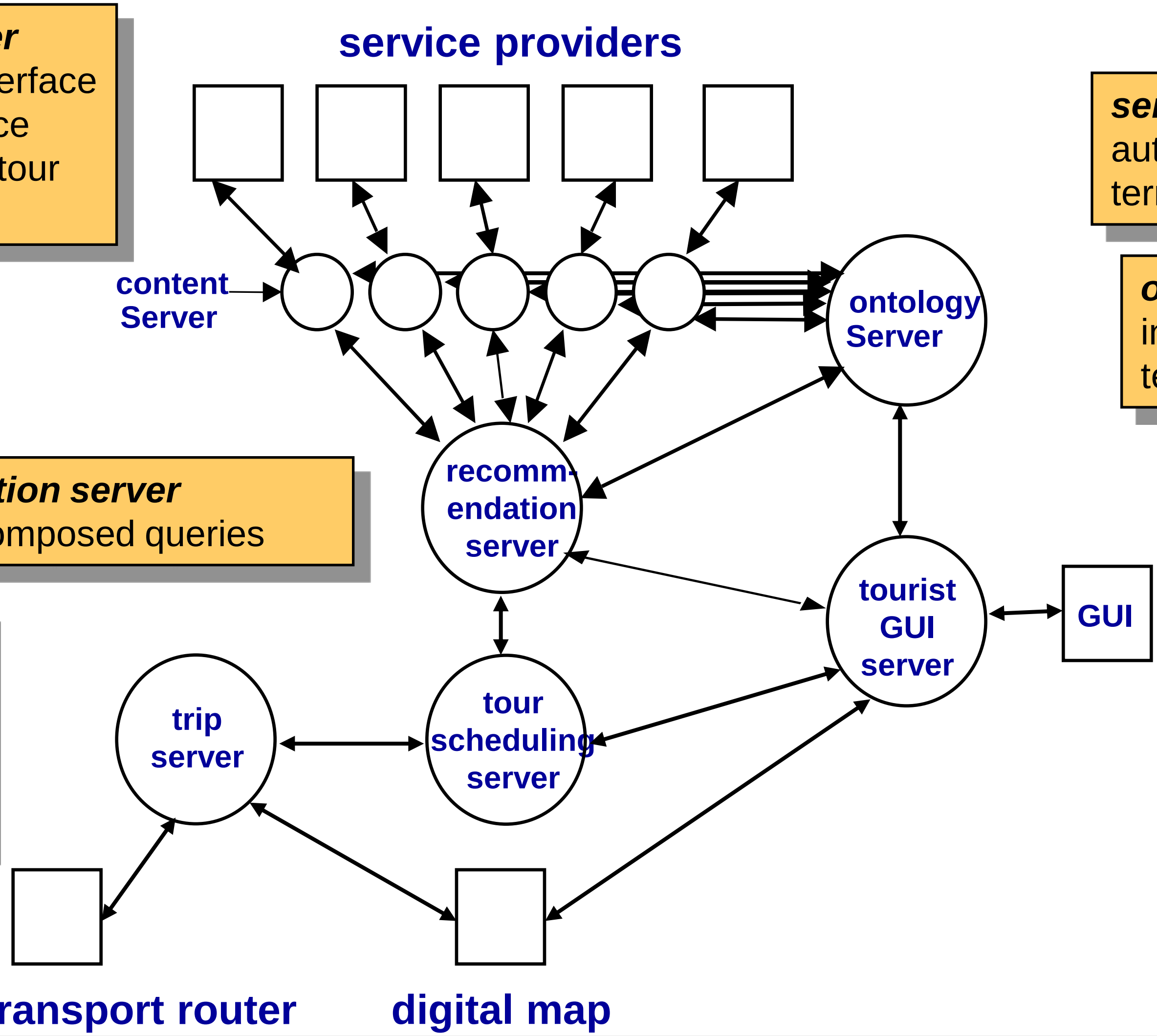
Application: Tourist Information System

Requirements:

- Tourist gets the final control.
- Service provider is autonomous and takes responsibility for all information
- Independent broking between several providers
- Flexible response to requirement changes even during the tour
- Fault tolerance for single provider failure
- ***Arbitrary*** service providers should be subject to be added or withdrawn automatically during system operation.

Application: Tourist Information System

Architecture of tour planning system: prototype of a SOA



content server provide the interface between service providers and tour planner

service providers are autonomous and have own terminologies and concepts

ontology server provide the interface between different terminologies and concepts

recommendation server responds to composed queries

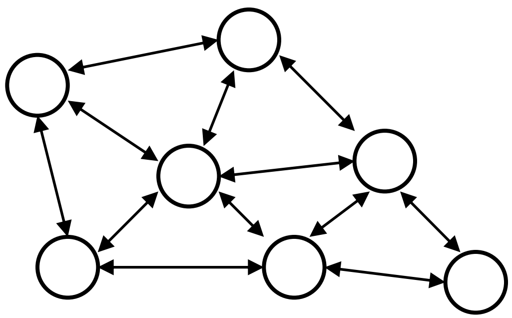
Tourist GUI Server administrates individual preferences and tours

trip server computes paths between two places

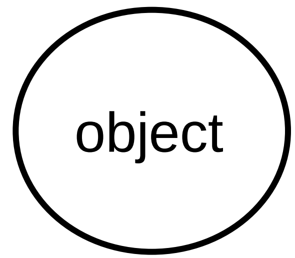
Tour Scheduling Server composes the tours

Base Technology: Agent-Oriented Software

Multi-agent system:



Software agent:



autonomous

social competence

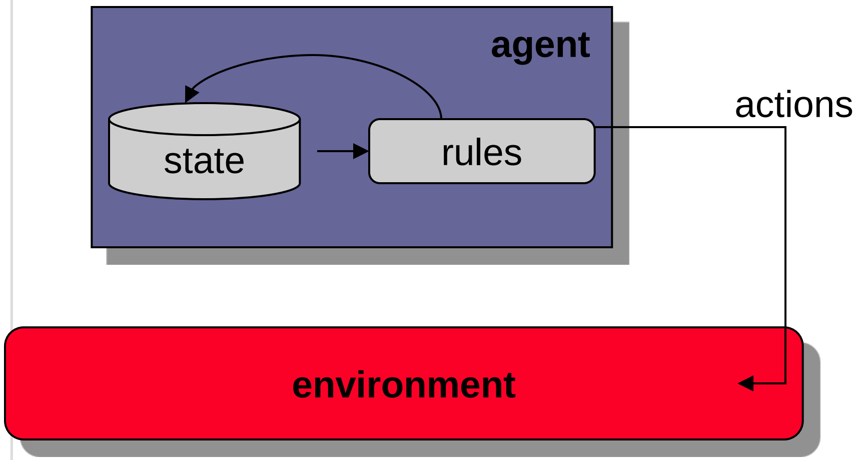
reactive

proactive

Weitere Infos: Seminarvortrag und Ausarbeitung von Matthias Rohr, SS 2004, Nr. 4,
http://www.fh-wedel.de/*~si/seminare/ss04/Termine/Themen.html, erreichbar über* ***archiv/iw***

Base Technology: Agent-Oriented Software

Agent property: Proactivity (goal oriented)



Agents do not only react to stimuli of the environment, but also depend on an internal state and have the capibility to pursue own plans and actions.

=> They are taking **initiatives**

„The difference between an automation and an agent is a somewhat like the difference between a dog and a butler. If you send your dog to buy a copy of the New York Times every morning, it will come back with its mouth empty if the news stand happens to have run out one day. In contrast, the butler will probably take the ***initiative*** *to buy you a copy of the Washington Post, since he knows, that sometimes you read it instead."*

Le Du

Quelle: Seminarvortrag und Ausarbeitung von Matthias Rohr, SS 2004, Nr. 4

Base Technology: Semantic Network

- **ontology management**
- **description language**
- **description logics**

} developed in the 1990s based on AI syntax standards of the 1980s

Modern adaptation (2001): *Semantic Web standards*

Initiator: Tim Berners-Lee

Ontology management, description language and description logics in XML or comparable standards

Common feature:
Universally valid definitions in a syntax readable by engines and browsers

Defining AI

Thinking Humanly	Thinking Rationally
"The exciting new effort to make computers think . . . *machines with minds*, in the full and literal sense." (Haugeland, 1985) "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . ." (Bellman, 1978)	"The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985) "The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)
Acting Humanly	**Acting Rationally**
"The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990) "The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)	"Computational Intelligence is the study of the design of intelligent agents." (Poole *et al.*, 1998) "AI . . . is concerned with intelligent behavior in artifacts." (Nilsson, 1998)

Figure 1.1 Some definitions of artificial intelligence, organized into four categories.

Definitions from Russell / Norvig

Defining AI

AI deals with problems which

- **are relevant in practical applications.**
- **may no be specifiable in a mathematical way.**
- **are NP-hard if they can be specified in a mathematical way.**

Definition iw

Features of classical AI solutions

The classical controversy between different research communities in computer science:

AI vs. Algorithmics

- **flexible solutions**
- **human customer oriented solutions**

- **exact solutions**
- **efficient solutions**

This need not be contradictory!

Features of classical AI solutions

Intelligent creatures are able to process very general knowledge: The more general, the more intelligent.

The ability to process general knowledge needs general description languages for data and processes.

The most general description language is the language of mathematical logics.

This is why traditional AI implementations work with logic description languages.

Problems:

- **The tasks are usually formulated in a different way.**
- **There is a trade-off between generality and efficiency.**

Base Technology: Logic Programming Language

- **Input:**
  Specification of the problem with a logical description language

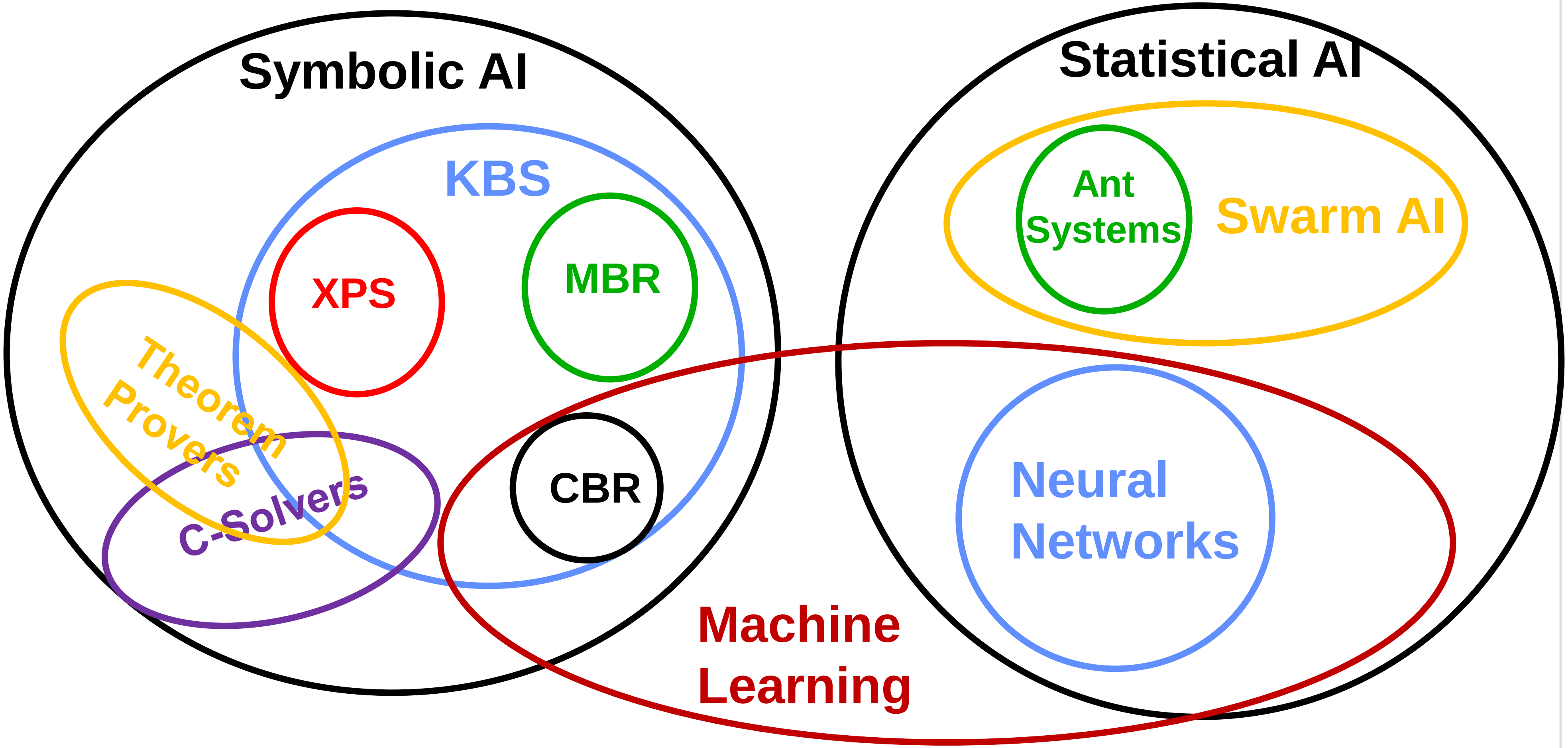
- **Output:**
  Response in a logical description language

- **Automatically (without specifying algorithms!):**
  Generation of output from input

- **For improvement of efficiency:**
  Different specifications of the problem are possible and may influence the output if the automatic generation procedure is well-understood

Summary Chapter 1

The set of AI techniques



Good applications share several techniques

Summary Chapter 1

AI goals for software solutions

- generality
- flexibility, extensibility
- justification of answers (only for „classical“ AI)

Tools and methods classically applied in AI

- Logic programming languages (PROLOG)
- Object-oriented programming languages (Smalltalk)
- Functional programming languages (Lisp)
- Distributed technology (neural networks, multi-agent-systems, swarm intelligence)
- Concept descriptions (ontologies)

Summary Chapter 1

Applications of AI:

- **Diagnosis**
  - Medical diagnosis
  - Technical diagnosis
- **Optimisation problems with dynamic parameters**
  - Passenger information systems
  - Road navigation
  - Logistics (TSP, Scheduling)
- **Resource allocation**
  - Allocation problems with manifold constraints (e.g. class schedule, tourist information system)
- **Flexible management of distributed knowledge**
  - Tourist information system
- **Games where a machine simulates a human player**
  - turn-based
  - real-time

Summary Chapter 1

Base Technologies of AI:

- Knowledge-based systems (generalisation of expert systems)
  - Separation of knowledge and inference engine
  - Intelligent knowledge acquition and representation
  - Main focus: Reusability
- Neural networks
  - Special case of knowledge-based systems, but without explanation component
- Swarm intelligence
  - distributed
  - statistic
  - concurrent updating
- Agent oriented software
  - distributed
  - autonomous
  - proactive

Summary Chapter 1

Base Technologies of AI:

- **Semantic network**
  - **Ontologies: Generation and administration of terminology and concepts**

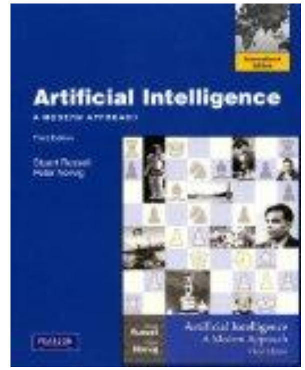
- **Search strategies**
  - **Uninformed vs. informed**

- **Constraint satisfaction problem (CSP)**
  - **Search for valid solutions**
  - **Search for optimal solutions**

- **Logic programming languages**
  - ***What* is specified by man**
  - ***How* is generated automatically**

Literature

Symbolic AI in general:



Stuart Russell / Peter Norvig:
Artificial Intelligence: A Modern Approach,
Pearson 2010 (3. edition),
ISBN 0-13-207148-7

Günter Görz / Josef Schneeberger / Ute Schmid:
Handbuch der Künstlichen Intelligenz
Oldenbourg 2013 (5. Auflage), ISBN 978-3486713077

Wolfgang Ertel / Josef Schneeberger: *Grundkurs Künstliche Intelligenz*
Vieweg 2009 (2. Auflage), ISBN 987-3-8348-0783-0

Machine Learning:

Ian Goodfellow, Yoshua Bengio, Aaron Courville: *Deep Learning*, MIT Press 2016,
available via http://www.deeplearningbook.org/ and FH Wedel handout server (via my website)

for special fields of AI:

see my current website and comments