Artificial Life
Summer 2015

Overview
Questions & Answers

Master Computer Science [MA-INF 4201]
Mon 8:30 – 10:00, LBH, Lecture Hall III.03a

Dr. Nils Goerke, Autonomous Intelligent Systems,
Department of Computer Science, University of Bonn

Some important details for the exam

Written exam:

Thursday 30. July 2015, Room III.03, LBH, 10:00 – 11:40

It would be nice, if you arrive earlier

Last possibility to retreat from the exam without getting negative credits is one week before exam date; which is:

Wednesday 22nd, July.

Re-Sit examination, will be:
Tuesday, **8. Sept 2015** from **10:00** to 11:40,
LBH Building

Some important details for the exam

Thursday 30. July 2014, Room III.03, LBH, 10:00 – 11:40

- only pen, ball pen, felt-tip pen are allowed, NO pencil.
- only blue or black, NO red or green colors
- all answers need an explanation.
- please indicate clearly what you consider to be the solution.
- when you use formulas, all variables must be explained explicitly.
- short sentences and keywords are preferable to long text passages.
- no extra tools or utilities or electrical devices are allowed.

Some important details for the exam

For the exam:

- Please take your students id card (Studentenausweis) with you.
- Documents with a photo, to check your an identity with you (identity card, or passport, or drivers license, …).
- Bring a pen, ball pen, felt-tip pen with you.
- You will not need a calculator for the exam.
- Paper will be provided.

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Topics of the 2015 Artificial Life Lecture

1. Natural Life – Artificial Life, Langton's Ant
2. Cellular Automata (1dim)
3. Cellular Automata 2D, Conway's Game of Life
4. Self Replication, Langton's Loop, Lindenmeyer Systems
5. Pattern Formation in Biological Systems
6. Self Organizing Criticality (SOC), Ant Algorithms
7. Evolutionary Algorithms, part 1
8. Evolutionary Algorithms, part 2
9. Evolutionary Algorithms, part 3
10. Complex Behavior, Braitenberg Vehicles
11. Swarm Behavior, Boids, Particle Swarm Optimization (PSO)
12. Subsumption Architecture
13. Overview, Questions & Answers

Natural Life – Artificial Life

- Definitions of Life or Living
- Sets of common criteria
- What is Artificial Life?
- Weak Artificial Life – Strong Artificial Life

Langton's Ant

- CA like agent, on a 2-dim rectangular grid
- 2-dimensional Turing Machine
- Computational universality
- Micro behavior: scan – turn – flip – move
- 3 phases of macroscopic behavior:
  “symmetry”, “chaos”, “highways”

Cellular Automata (1dim)

- CA: discrete model of information processing (space, time, value)
- Ingredients: lattice, neighborhood, alphabet, rule, initial state
- Boundary of the grid / lattice
- No of rules, incl. formula
- Properties: symmetric, silent state, legal , peripheral, totalistic
- Rule table
- Wolfram number
- 4 Classes of behavior: homogeneous, periodic, chaotic, patterns

Cellular Automata 2-dim

- Grid in higher dimensions 2-dim ,3-dim, ...
- Neighborhood in 2 dim:
- Neighborhood for a 2 dim rectangular grid: von Neuman, Moore
- Probabilistic extensions to CAs
- Example: majority voting CA,
- Example: forest fire CA
- Example: Conway's Game of Life

Conway's Game of Life

- Game of Life, Conway's Game of Life
- 23/3 rule, survival, birth, death, loneliness, overcrowding
- 4 classes of behavior and special prototypic patterns
- Special Game of Life Patterns:
  - block
  - blinker
  - glider
  - glidergun
  - r-pentomino
- Computational universality

Self Replication, Langton's Loop

- Self replication as a fundamental principle for living
- Von Neumanns universal constructor
- Von Neumanns self replicating constructor
- Self replicating loops
- Chris Langton's self replicating loop
- CA, d=2, r=1, k=8, with 219 interesting entries
- Initial pattern (loop) with 86 cells replicates in 151 steps
- Loop, arm, channel, sheath, message string, signals

Lindenmeyer Systems, L-Systems

- Idea, purpose, model plant growth
- D0L-Systems
- Definition: symbols, constants, axiom, rules, (depth)
- Example: {C,A} , C, $C \rightarrow A$, $A \rightarrow CA$
- Visualization in 2 dim or 3 dim
- Applications of L-Systems

Pattern Formation in Biological Systems

- Iterated functions
- Linear and exponential growth
- Fibonacci sequence
- Logistic growth
- Predator-prey system
- Lotka-Volterra equations
- Activator-inhibitor equations
- Reaction-diffusion systems
- Plant morphogenesis, phylotaxis
- Golden section, Golden angle
- Self similarity

Self Organizing Criticality, SOC

- What is Self Organized Criticality?
- Motivation
- Power law, Scaling law
- Examples of SOC systems
  - Sandpile model
  - Land slides
  - Forest fire model
  - Gutenberg-Richter Law, Earthquakes
  - Zipf's Law

Ant Algorithms

- Ant Algorithms are a family of method for discrete optimization.
- Essential ingredients of an Ant System (AS) are:
  - Multiple cooperating agents,
  - which are simple structured;
  - they have a sensory system,
  - a method to deposit pheromones (stigmergy),
  - and a simple mechanism to decide where to go.
  - The pheromones evaporate after a while.
- Ant System (AS),
  Ant Colony System (ACS),
  Ant Colony Optimization (ACO),
  Ant Net

Evolutionary Algorithms

- Evolutionary Computation,Historic Remarks
- Different Approaches
- Optimization, some basics
- Idea of Evolutionary Algorithms (EA)
- EA Steps
  - Individual, Genome, Fitness, Population
  - Parent selection
  - Inheritance
  - Mutation
  - Fitness evaluation
  - External selection
  - Finish
  - Initialization

Evolutionary Algorithms

- Strategy: $(\mu + \lambda)$, $(\mu + \lambda)$
- Performance Graph
- Genome structure
- Examples: Fkt.Maximum, Sorting, 42, TSP,
- Example: 8 queens
- Super-individuals
- External-selection and parent-selection combined
- Probabilistic parent-selection
  - Wheel of fortune
  - Tournament selection
- Genetic programming
- Co-evolution

Roots of Complex Behavior, Braitenberg Vehicles

- Ideas from biology and from engineering
- Control architectures, reactive control, proactive control
- SMPA architecture
- some systems theory
- Braitenberg vehicles
  - Type 1
  - Type 2
  - Type 3
  - Type 3b based obstacle avoidance
  - Type 4
  - Type 5 - 14

Swarms, Swarming, Swarm behavior

- Cooperating Robots
- The Didabot Experiment, Swiss-Robots
  Clustering, building heaps
- Swarm Behavior
- Swarms
- C.Reynolds: Boids

Boids

- Craig Reynolds' Boids are a simple model to build swarm like behavior.
- 3 rules of individual behavior
  - Separation:
    steer to avoid crowding local flockmates
  - Alignment:
    steer towards the average heading of local flockmates
  - Cohesion:
    steer to move toward the average position of local flockmates
- Applications of Boids

Particle Swarm Optimization, PSO

Particle Swarm Optimization is an Artificial Life inspired, multi hypothesis, meta heuristic method for optimization.

The PSO consists of:

- a population of P particles
- a search space ***S***, with positions **X** in ***S***
- an objective function f(**X**)
- a memory for global best: $\mathbf{X}_{gb}$, f($\mathbf{X}_{gb}$)
- (several sub-groups of particles)

Each particle i has:

- a position $\mathbf{X}_i$ in search space **S**
- a velocity $\mathbf{V}_i$, (change in position)
- a memory to store the best result for the individual so far personal best: $\mathbf{X}_{i,pb}$, f($\mathbf{X}_{i,pb}$)
- (group of particles it belongs to, group best $\mathbf{X}_{i,grb}$, f($\mathbf{X}_{i,grb}$))

Subsumption Architecture

The subsumption architecture proposed by Rodney Brooks is:

- A hierarchical control architecture
- Organized in layers of competence
- Simple control modules (finite state machines)
- Each layer is working autonomously (unless)
- Controlled by higher layers
- Inhibition and suppression control the lower layers
- The layers consist of simple structured modules
- Rather robust against damage or module failure
- Implementation can be very complex

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Questions that could be part of the exam

Compare Wolframs class III and class IV behavior.
Explain differences and similarities between these two classes of behavior.

Name and explain in detail the two ways how the higher levels in the Subsumption Architecture can influence the lower levels.

Describe the overall structure of the so called Glidergun (Gospers Glidergun) in Conway's Game of Life.

Explain how a hypercube and a binary genome of an Evolutionary Algorithm are related to each other.
Draw a sketch, visualizing this for a binary genome that has more than two bits.

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MA-INF 4204 Technical Neural Nets WS15/16

Mo 10-12, Lecture Hall III.03a, LBH

The lecture gives an overview over the most important technical neural networks and neural paradigms.

The following topics will be explained in detail:
Perceptron, Multi-Layer Perceptron (MLP), Radial-Basis Function nets (RBF), Hopfield nets, Self Organizing feature Maps (SOMS, Kohonen), Adaptive Resonance Theory (ART), Learning Vector Quantization (LVQ), recurrent networks, back-propagation of error, reinforcement learning, Q-learning, Support Vector Machines (SVM), pulse processing neural networks, Neocognitron.

In addition exemplary applications of neural nets will be presented and discussed: function approximation, prediction, quality control, image processing, speech processing, action planning, control of technical processes and robots.

Implementation of neural networks in hardware and software: tools, simulators, analog and digital neural hardware.

http://www.ais.uni-bonn.de/WS1516/4204_L_NN.html

MA-INF 4310 Lab Mobile Robots WS15/16

1st preparation meeting, **Tuesday 28.7.2015, 11:00, LBH / I.42a**
2nd preparation meeting and start: Wed 21.10.2015, 15:15, LBH / I.42a

The lab course will introduce some basic state-of-the-art building blocks of mobile robotics using simulations and and our teaching and research platform **RoomRider**.

The lab course is organized in two parts:

Part 1 Experiments: a series of experiments to learn and practice basic building blocks of mobile robotics with a state of the art robot control environment and our teaching and research platform RoomRider.

Part 2 Mini Projects: chose a state-of-the task for a mobile robot, pick or develop an algorithm to solve that task and implement it using the RoomRider mobile robot platform.

You will work in 2 person groups doing the experiments and implementing the mini-project.
The programming language is C++; Java and Python access is possible if desired.

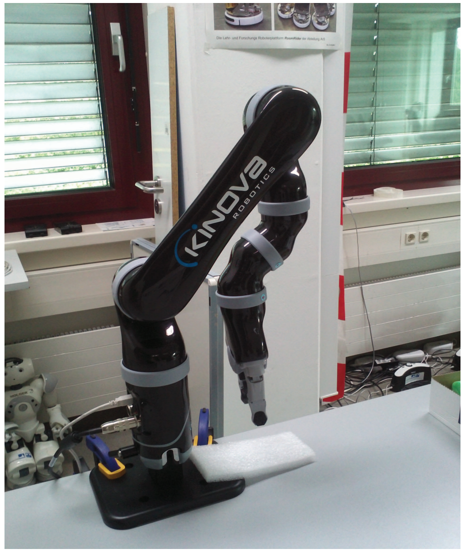
The lab course will cover in parts:
robotic sensors, robotic actuators, robot control schemes, robot control software, simulators, middle-ware, reactive control, localization, navigation, path planning, map making, some computer vision, cooperative robots, swarming behavior, multi robotics.

http://www.ais.uni-bonn.de/WS1516/4310_Lab_Mobile_Robots.html

MA-INF 4310 Lab Mobile Robots, WS15/16

Our RoomRider robots:

MA-INF 4310 Lab Mobile Robots, WS15/16



MA-INF 4310 Lab Mobile Robots, WS15/16

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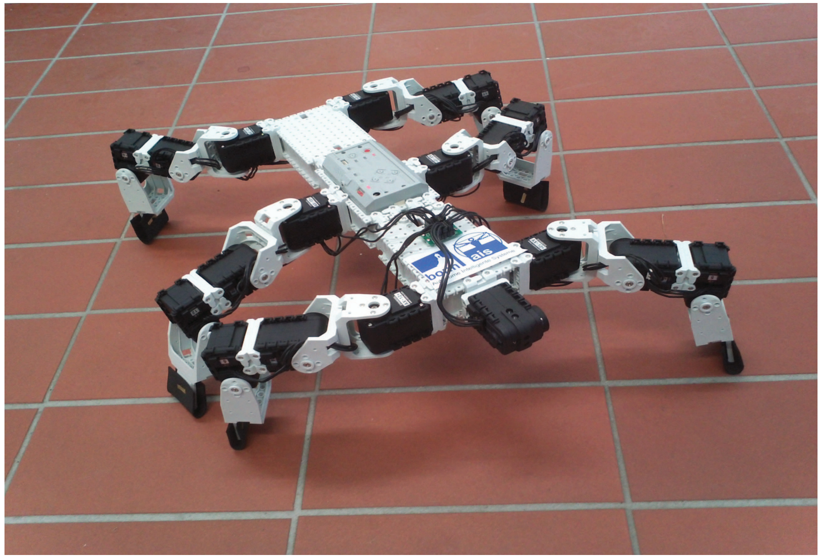
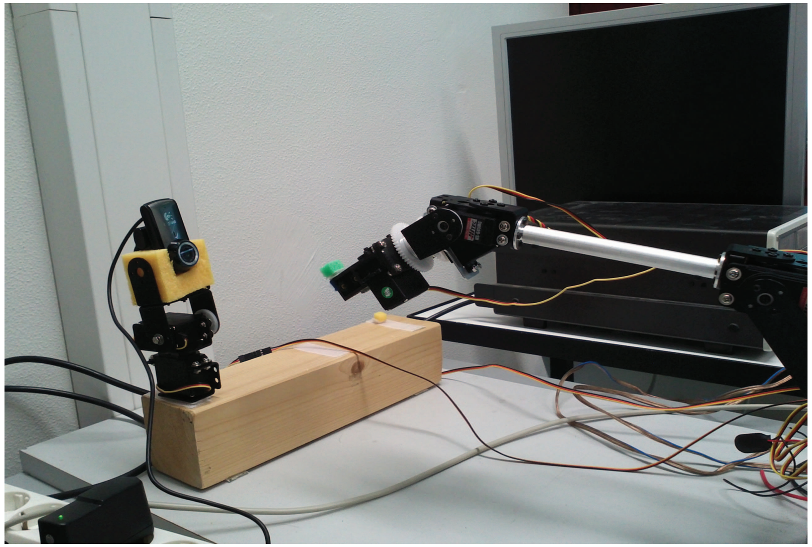


MA-INF 4310 Lab Mobile Robots, WS15/16



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Thank you for your patience
and
all the best for your exams

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