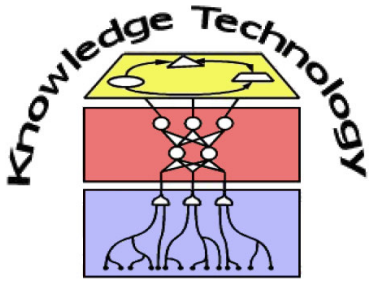
Bio-Inspired Artificial Intelligence

Lecture 13: Revision



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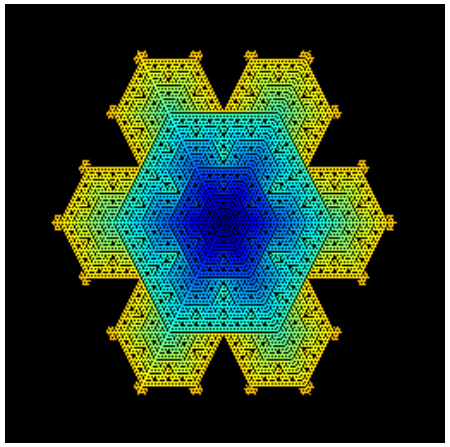
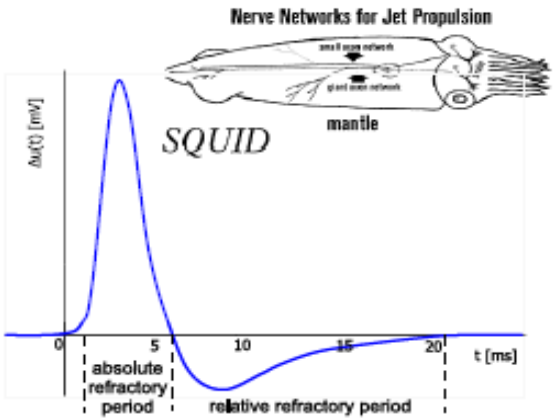
Cellular Systems

- Basic unit of all organisms: a simple cell
- Differentiation of cell types for specific functionality
- Cells communicate with each other locally
  - Interaction leads to specific behaviour of an organism
- Cellular automaton: grid cells with states (e.g. on/off)
- Evolution of grid cells follow specific (transition) rules
  - Rely on topology of grid and are applied to neighbourhood accordingly
  - Wolfram rules
  - Conways ‘Game of Life’

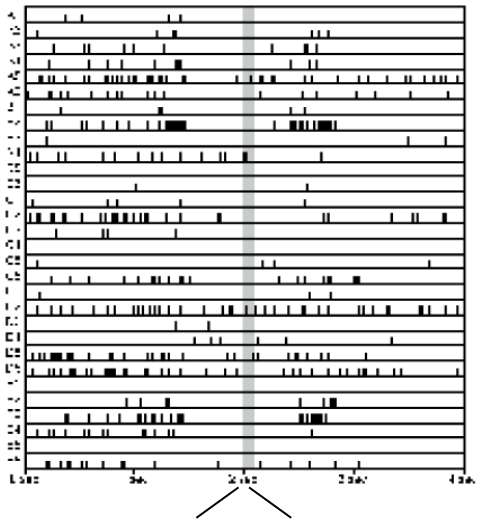


Spiking Neural Networks

- Inspired by electro-chemical neural processing in the brain
- Stimuli arriving at dendrites are transferred via axon to synapses → activity measured as spikes or pulses
- Integrate-and-Fire models, Spike-Response Model,…
  - Spikes represented as Dirac-Impulses (time-dependency)
  - Negative feedback models refraction period

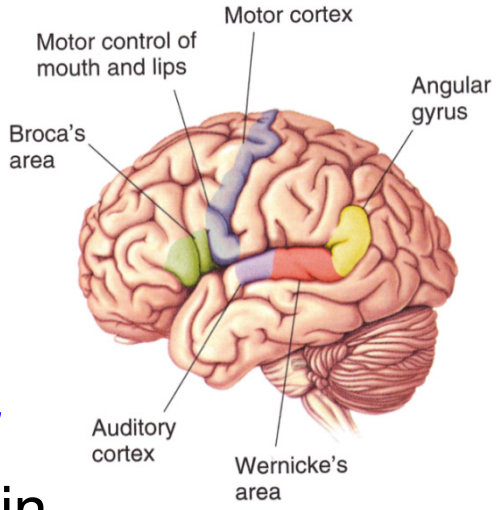


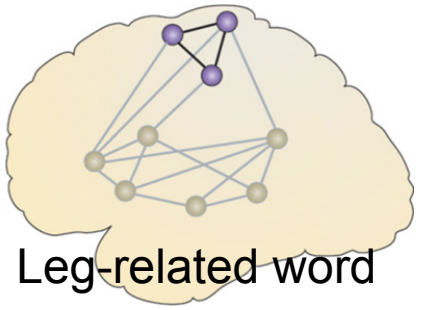
Dynamics of spike emission

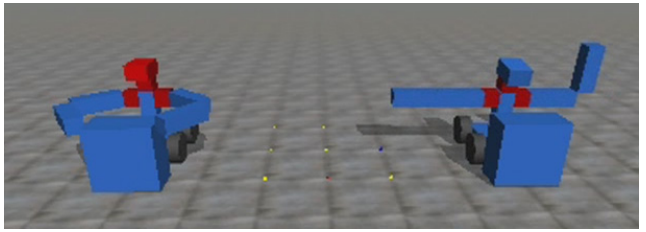


Bio-inspired Language Processing

- Cognitive ability unique to humans
- Processing in various brain regions:
  - Wernicke & auditory areas: ***Comprehension***
  - Broca & motor areas: ***Production***
- Recent assumptions: Language is ***embodied*** and ***distributed*** over several areas of the brain
  - Example: understanding the verb ‘kick’ also stimulates according leg-region in the motor cortex (frontal)
- Grounding experiments help to understand language acquisition
  - Sensor to actuator mapping
  - Semantic association

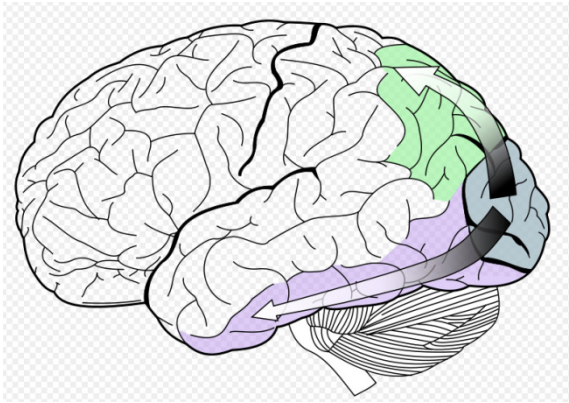



Leg-related word



Bio-inspired Vision

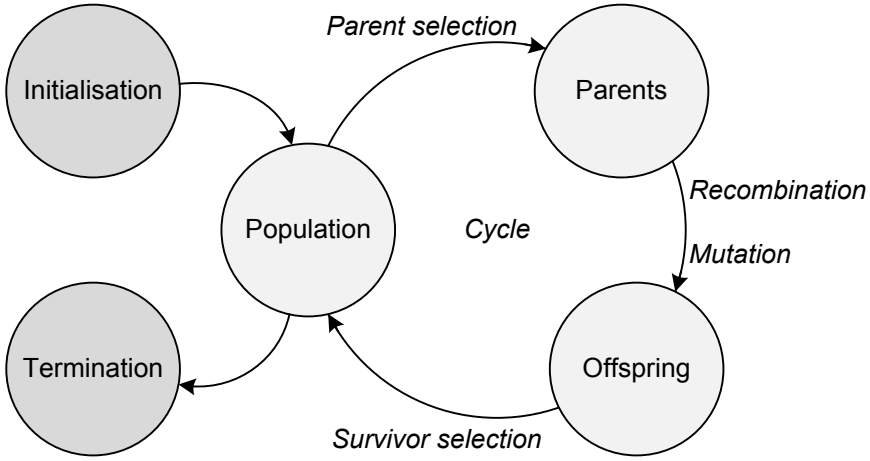
- Complex pathway of visual stimulus from retina to brain areas in visual cortex (V1-V5)
- Two pathways in object recognition
  - Ventral ‘what’ and dorsal ‘where’
  - Ventral codes for object properties, dorsal for spatial position



- Computational models reflect visual processing in feedforward fashion
  - Distinction between *simple* and *complex* cells
  - Inspiration for convolutional networks (LeCun) or Neocognitron (Fukushima)
- Feedback connections important in perception-to-action tasks e.g. reaching for an object → location update

Evolutionary Computing

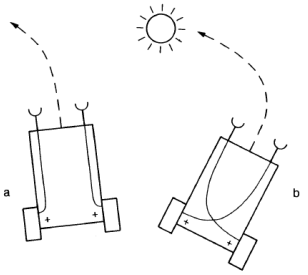
- Evolutionary mechanisms like mutation, recombination and survival-of-the-fittest applied to problems e.g. optimization
- Genotype determines phenotype
- Fitness function measures quality of genotype
- Three main concepts:
  - Population of genes
  - Recombination of selected parents
  - Mutation of created offspring



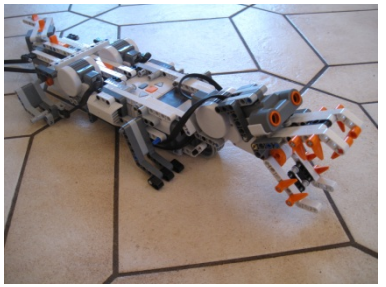
- Tool to explore and exploit problem space without (much) prior knowledge

Behaviour Based Robotics

- Architecture for autonomous robotics
- Braitenberg vehicle (1984)
  - Simple agent with sensors and actuators
  - Motion guided by light sensors, stops when dark
  - But does not model cognitive process



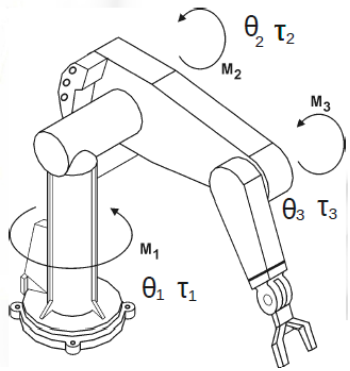
- Important terms:
  - Situatedness: robot operates directly with and in the world
  - Embodiment: physical interaction through body



- More biologically motivated: motor schemas
  - Produce output vectors that can be visualized as potential field
- Application: Obstacle-avoidance, Trajectory planning

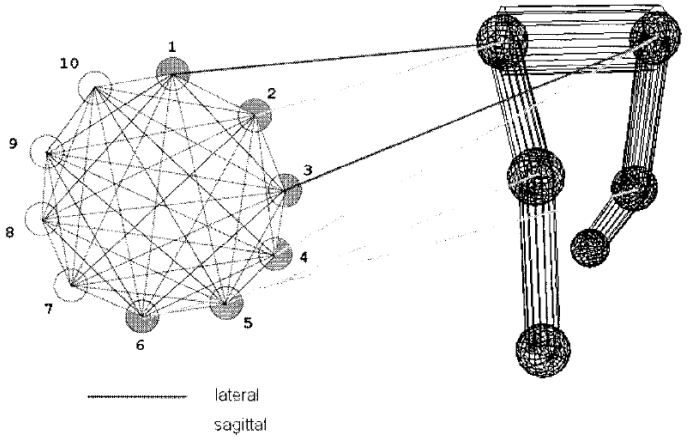
Dimensionality Reduction and Coordinated Movement Control

- Invited talk by Naveen Kuppuswamy
  - Post-Doc at University of Zürich, Pfeifer Lab
- Dimensionality in movement control is hard
  - Real-time control and optimisation in robotic
  - Development of motor skills in humans
- Nature offers reduced dimensionality principles
  - Ex.: Bell-shaped velocity profiles in reaching
  - Muscle synergies
- Use principles to reduce dimensionality
  - Mathematically: Orthogonal decomposition
  - Design and control of embodied systems: Motor primitives with model order reduction



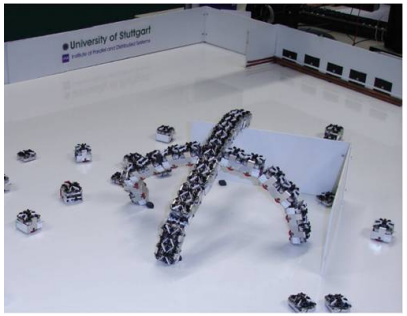
Evolutionary Robotics

- Neural Networks applied to robotics provide learning strategies for autonomous behaviour
  - But: for net training (backprop) topology needs to be fixed
  - Solution: Evolving Neural Networks
  - Mutation of node connections in NN in terms of addition and removal
- Combination of evolutionary and neural learning algorithms
  - Learning can improve individuals' fitness
- Evolution of body parts
- Application: Navigation, Bipedal walking



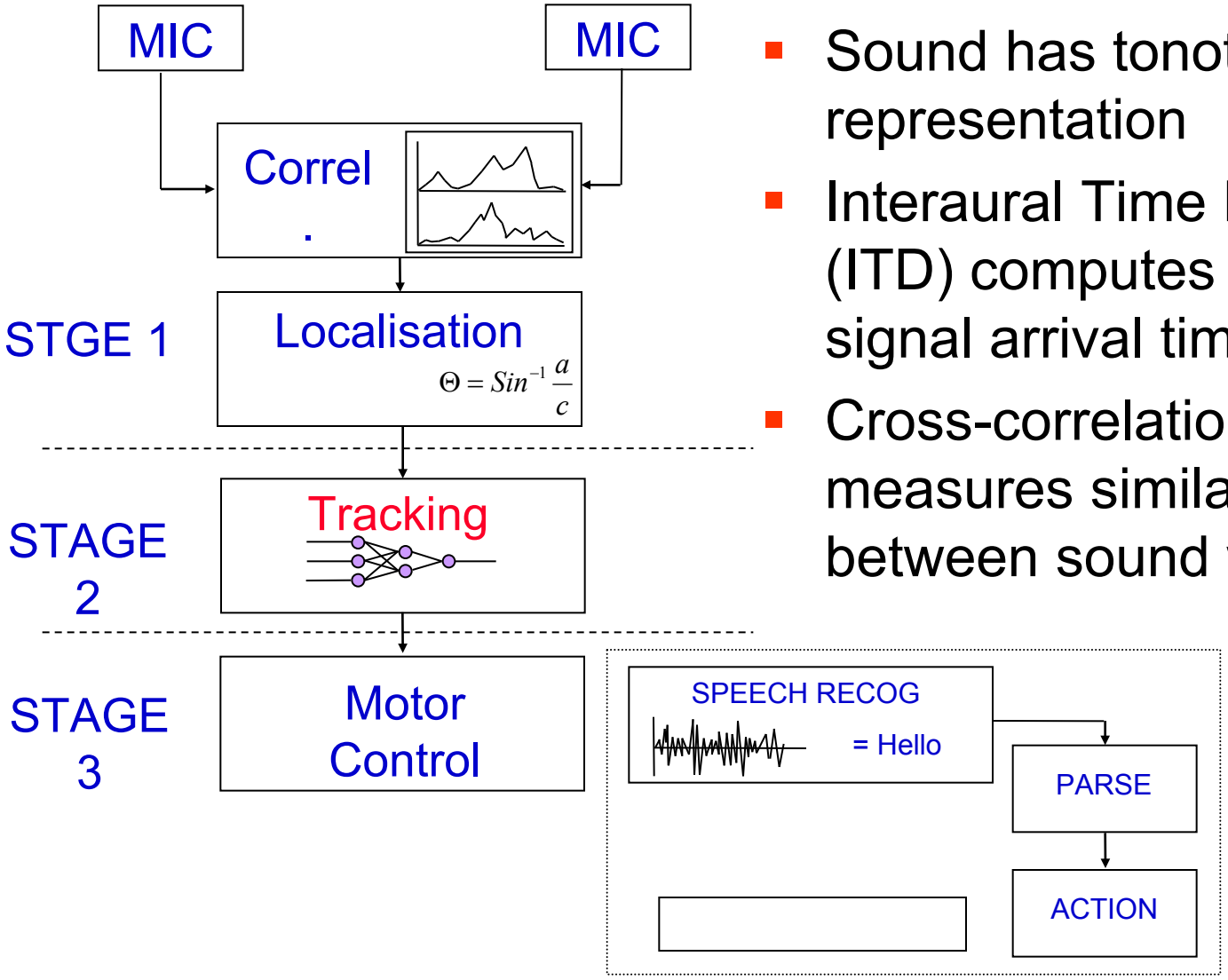
Swarm Intelligence & Swarm Robotics

- Swarm systems have desirable properties
  - Robustness, Scalability, Flexibility
- Self-Organisation through local interactions
  - Stigmergy, positive/negative reinforcement, flocking
- Algorithms that exploit mechanisms for optimisation:
  - Ant Colony Optimisation,
  - Particle Swarm Optimisation



- Definition of individual behaviour to "construct" global behaviour far from trivial
- Swarm robotics still hot topic in research
- Many areas: Collective construction, mapping, exploration, sensor fields, collection, especially with small robots

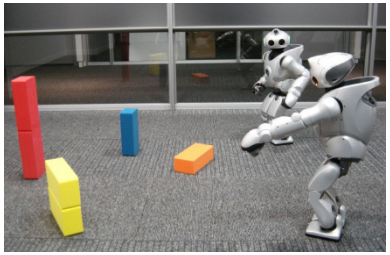
Bio-Inspired Sound Localisation



- Sound has tonotopic representation
- Interaural Time Difference (ITD) computes different signal arrival times
- Cross-correlation measures similarity between sound waves

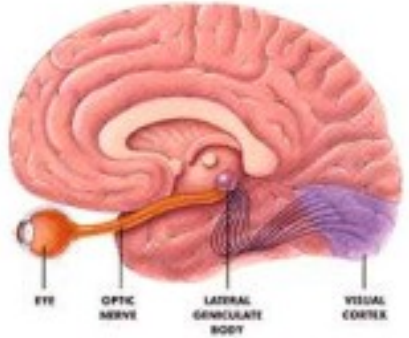
Communication-based Cooperation

- Investigate how communication emerges and evolves in ***Embodied***, ***Situated*** and ***Adaptive*** systems
  - communication can alter the behaviour of another individual
  - involves effort for transmitting and receiving,
  - offers means to cooperate or to defect
- Open Research: Whether and how communication can emerge in light of
  - Conflict of interests
  - The need for co-evolution of behaviour
- Experiments:
  - Evolved communicating foraging agents with neural controller
  - Evolved communication modalities and forms
  - Evolution and Formation of Language

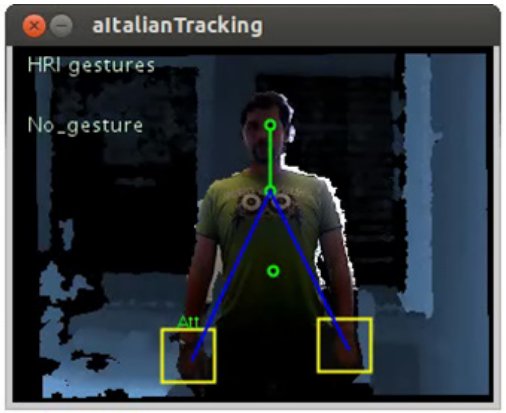


Gesture- & Action Recognition

- Gestures: visual form of communication
- Different forms
  - Hand-, arm,-head-,whole-body actions
  - Different sensors: static vs. dynamic



- Complex neural interaction of different brain areas
  - Visual cortex for shape, temporal lobe for motion
- Neural architectures compute features and implement processing stages based on these findings
  - Deep Learning, EGM, SOM
- Systems extendable for action recognition
  - Fall detection in a domestic environment



Examinations

- Examination dates: Thu 13.02.2014 & Thu 27.03.2014
  - Double-check with the Studienbüro for your time slot
- Examination place: F-230 (Prof. Wermter)
- Final pieces of advice
  - Grasp the ***idea*** and the biological foundation of the discussed methods – books and papers are in the CommSy
  - Repeat the ***formalisations*** of models and methods to a ***reasonable*** depth
  - Take care for ***transferring*** the idea of a method from one problem to another

Upcoming courses

- L+S Knowledge Processing with Neural Networks
  - Discover ***neural computing***: architectures, learning, hybrid systems & models for ***cognitive capabilities***
  - … and learned to apply these capabilities to ***artificial intelligent systems***
- Next Winter: Project Human-Robot Interaction
  - Challenge: Robotic device capable ***of interacting with people*** as naturally as we interact with each other
  - Approach: solve a ***simple task*** in a ***complex environment***, e.g. “Serve coffee!”
  - Inspiration: RoboCup@home tasks
  - Chance: Follow up on ideas & progress of recent groups
- *Additional*: Oberseminar Knowledge Technology

  http://www.informatik.uni-hamburg.de/WTM/teaching/