Developmental Learning: from Infants to machines

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Working in the areas:

- Biologically and psychologically inspired robot learning and control, sensory-motor coordination.
- Learning from imitation and adaptive behaviour
- Computer vision, and image processing
- Human-robot interaction
- Multi-robot system, and networked robots
- Human facial expression recognition, human motion and behaviour analysis
- Intelligent robotics and assistive robotics
- Unmanned aerial vehicle

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Developmental Learning: from Infants to machines

Parents → inheritance →  → Infant cognition →  → Adult

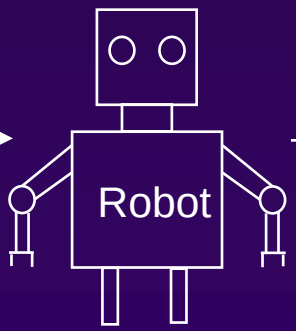
development

Parents, environments

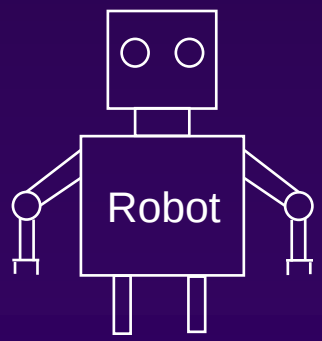
physical development: taller and stronger

Cognitive development: through internal changes(e.g. neural growth), and external environmental changes(e.g. The effect of an action).

Developers → control code → learning mechanism → Reflexes



developmental learning



Humans, environments

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Developmental learning

- Sensory-motor interaction (eye/head/hand coordination learning)
- Incremental and self-organizing learning
- Intra-modality and inter-modality mapping
- Staged learning, scaffolding by constraints
- Motivation, novelty and habituation, self-exploration and active learning
- Neural plasticity: Growing & shrinking of neurons
- Adaptation to the environment and bodily changes : tool use

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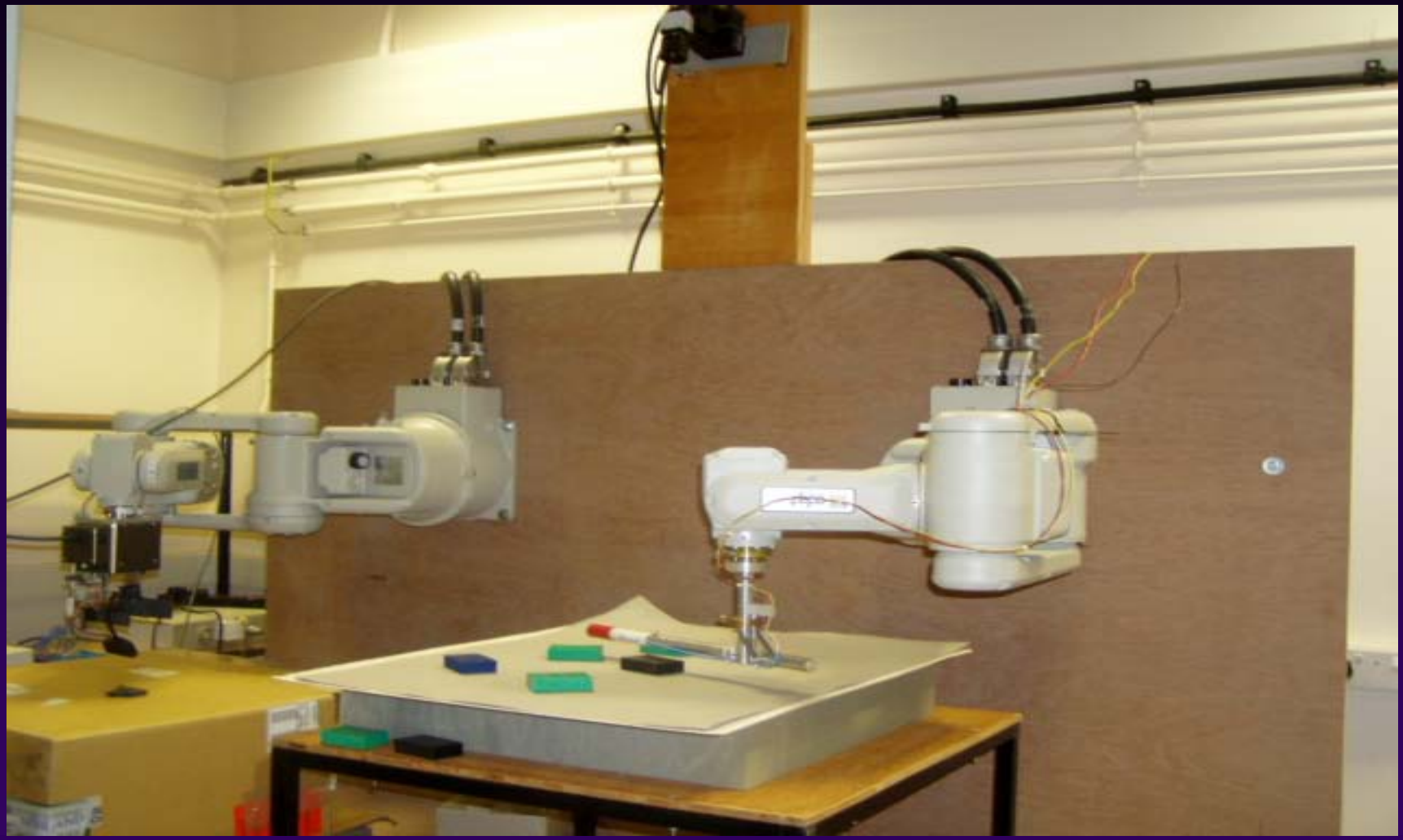
Our Experimental Developmental Learning System



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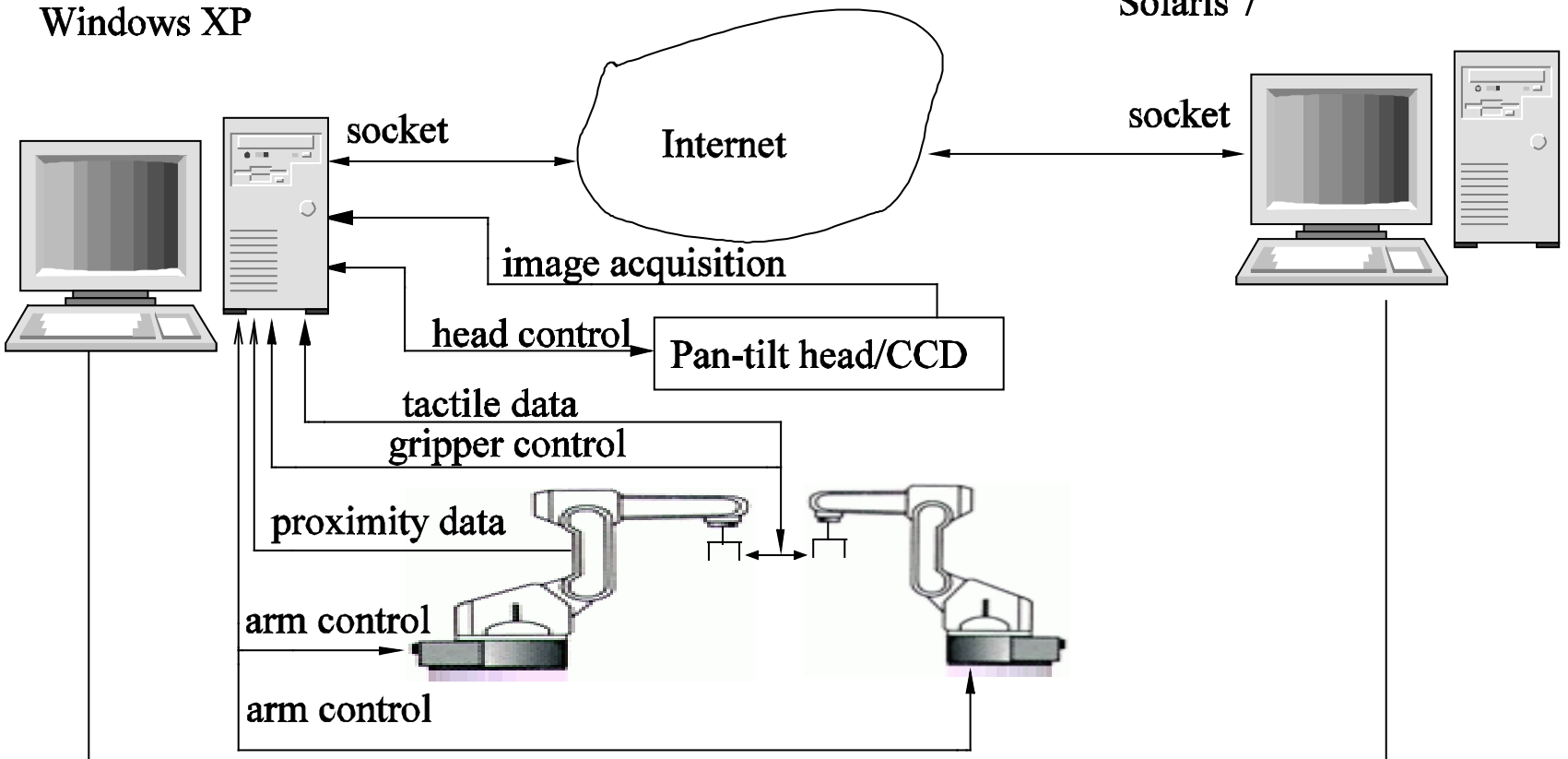


Two arms control, two grippers control
Pan-tilt head control
Image processing
force sensor information processing
proximity sensor information processing

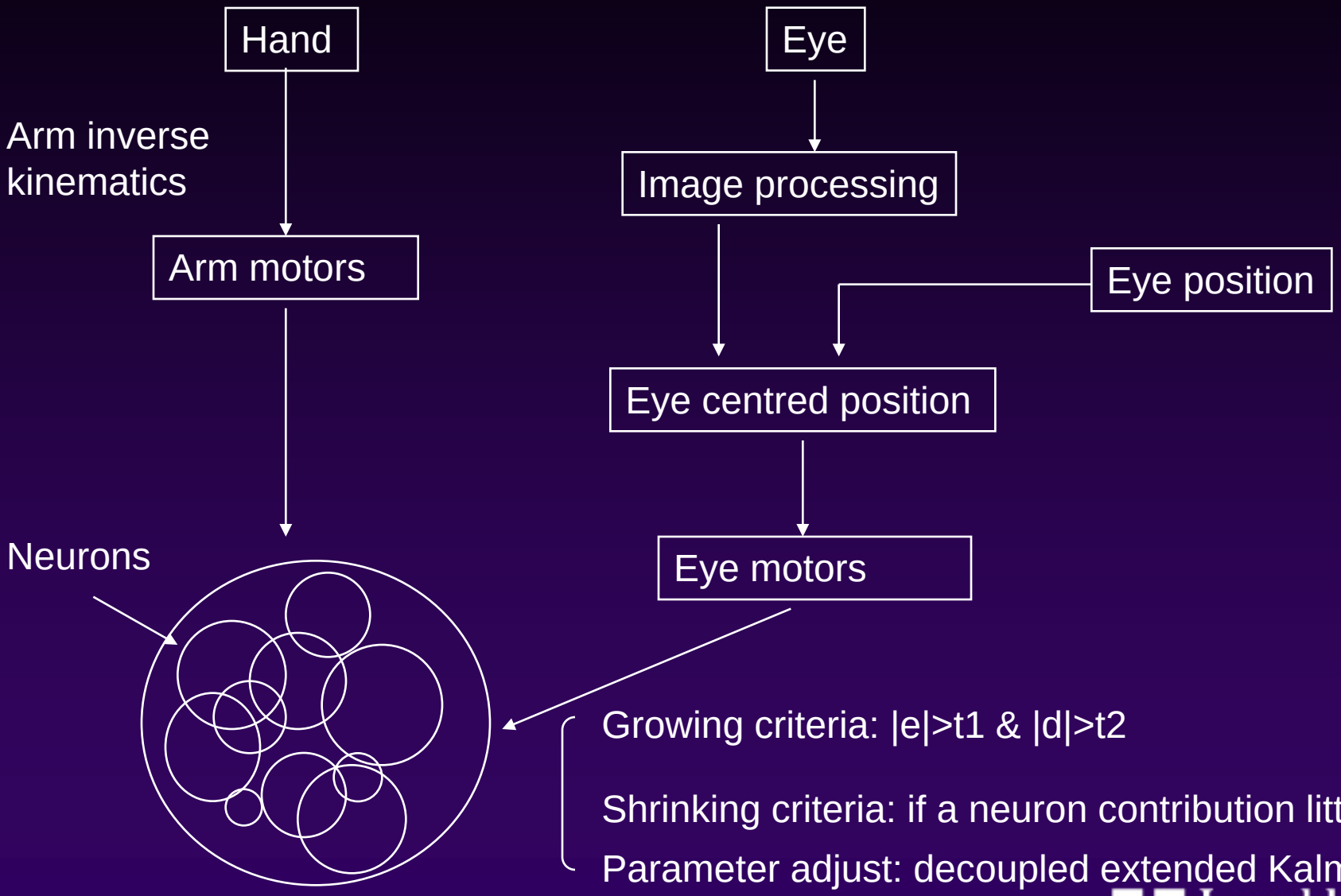
Visual C++.Net

Socket Socket

Developmental Learning Algorithm
Cognitive map building/updating
Cognitive maps display
User's Interface
Imitation

Java 1.4

Example: eye/hand coordination



Growing sensory-motor mapping network

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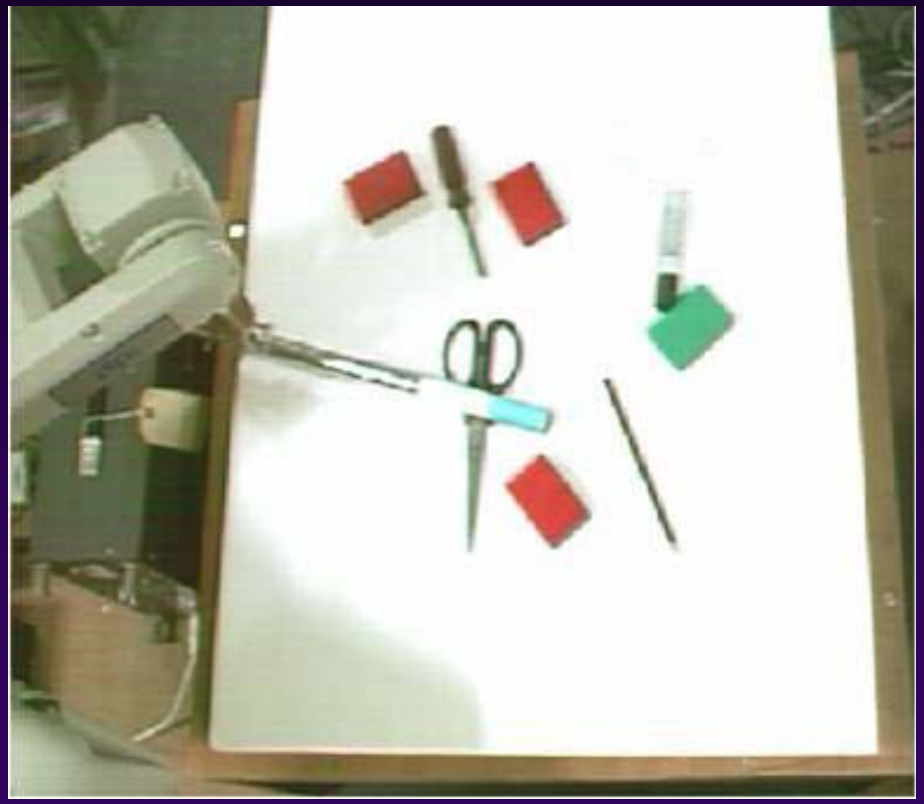
Example: Eye/hand mapping learning



- Eye locates the green object
- Calculate the centre of the object
- Move head to focus the object
- Hand finger points to the object

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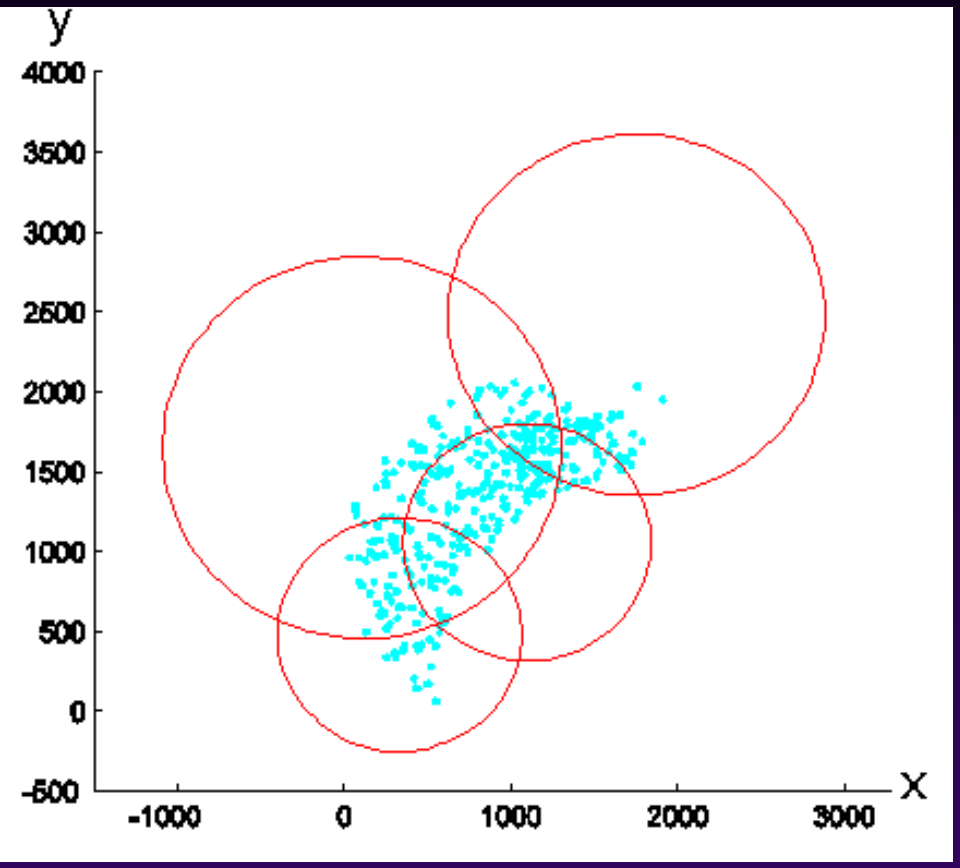
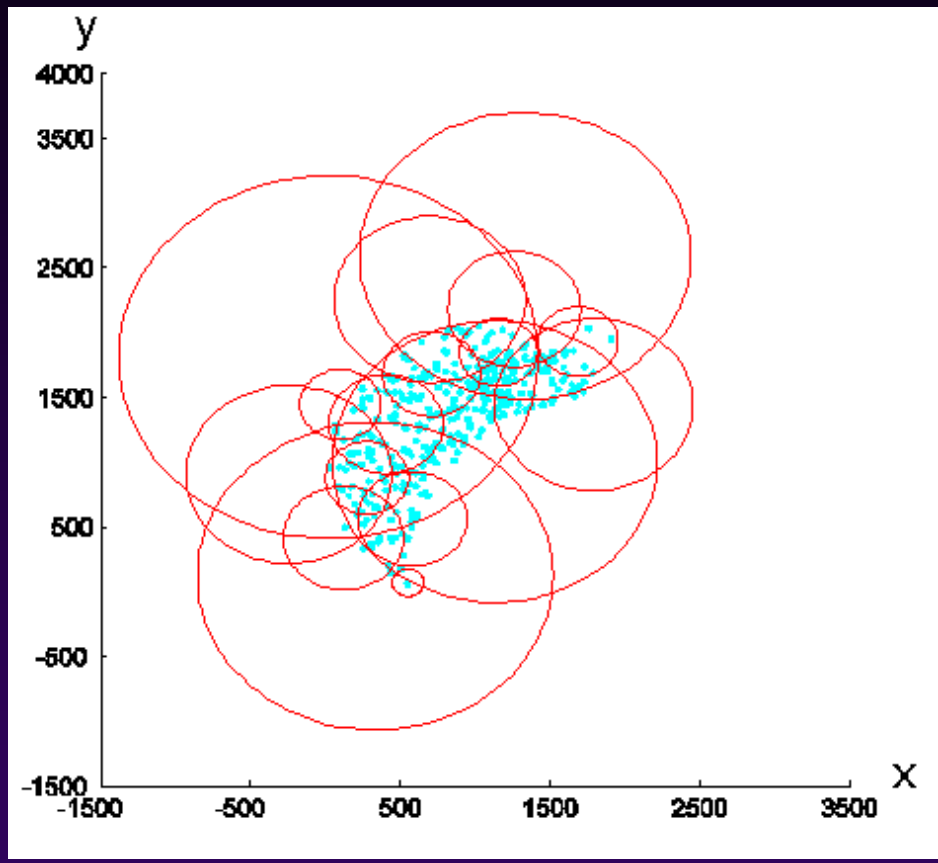
Neuron growing and distribution in learning



After 100 learning steps



After 1600 learning steps

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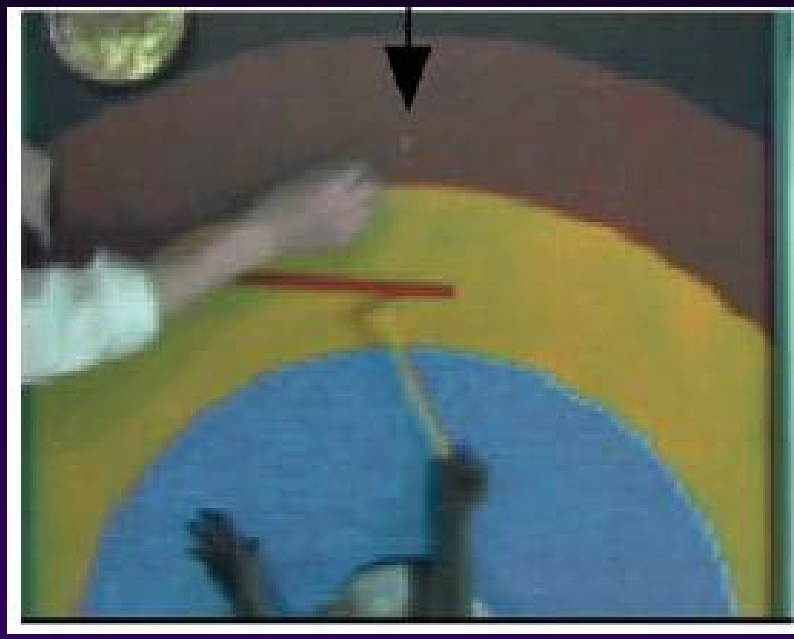
Adapt to structure changes

- reuse and refine learned knowledge

- Most traditional calibration methods: recalibration
- Humans and animals can quickly adapt to the structure changes such as tool-use

- Full adjustment of the learned network after a structural change.
  - adding new hidden nodes or remove existing
  - adjusting the centres and widths of the existing nodes
  - updating the weights
- Adjusting the weights, removing the insignificant hidden units, keeping the rest of the hidden units unchanged.
- Only adjusting the weights, keeping structure of the network unchanged.



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- Neuron growing and shrinking in brain
  - Many biological evidence
  - Basis functions exist in human brain (Pouget & Snyder, Nature, 2000)
- Biological support from humans and animals during tool-use
  - Japanese macaque monkey studies in tool-use:

    Bimodal neurons in anterior intraparietal sulcus dynamic alter their visual receptive field properties (Maravita & Iriki, Trends in Cog. Sci, 2004)
  - Humans: Updating plastic neural networks in the brain for tool-use (Johnson-Frey, Trends in Cog. Sci. 2004)
- Kalman filters in human brain?
  - In the entorhinal-hippocampus loop(Szirtes Neurocomputing, 2005)
  - Visual information processing (Rao, Ballard, Nature Neuroscience, 1999)
  - Motor coordination control (Todorov & Jordan, Nature Neuroscience, 2002)
  - Spatial learning (Bousquet, PSB'98; Szirtes Neurocomputing, 2005)

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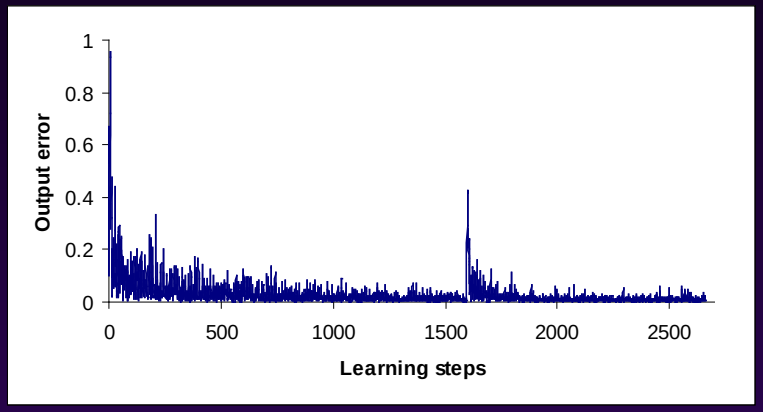
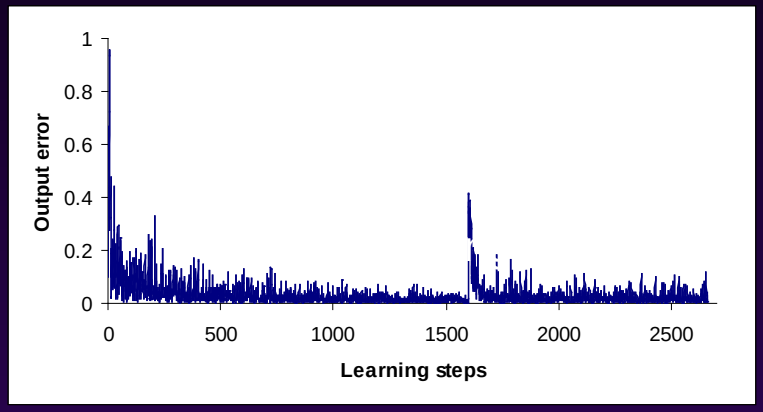
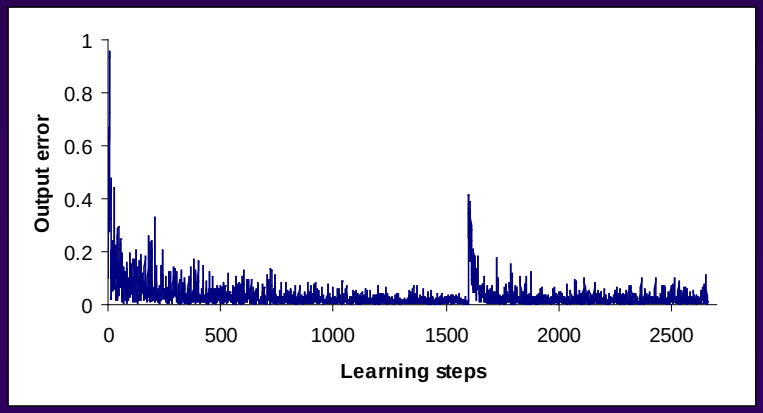
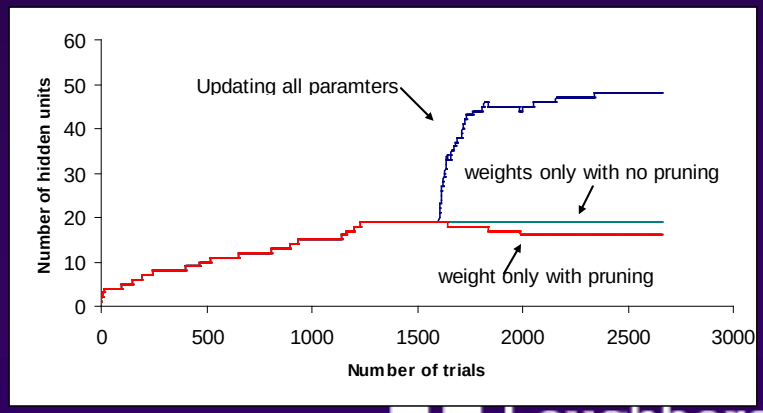
Adaptation of the mapping network to structure changes









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Pan/tilt vision system (robosoft)

Schunk 7DOF arm with 3-fingered gripper

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Other research areas can be found from my current PhD students' projects:

1. Ibrahim Tholley
   - Robot learning to dance with music (Sony AIBO dogs)

2. Syah Razali
   - Immune system inspired multi-robot cooperation

3. Afizan Azman
   - Driver's cognitive distraction detection

4. Santoshi Joshi
   - Rail track inspection

5. Mohammed Saada
   - Intelligent aids for elderly people at home

6. Kai Cao
   - Human behaviour pattern detection

7. Simon Hunt
   - UAVs (Unmanned Aerial Vehicles)

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