Neural Architectures for Lifelong Learning on Humanoid Robots

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Outline

- Motivation
- Background
- Approaches
- Results
- Discussion
- Conclusion

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What is Lifelong Learning?

- Continual acquisition of knowledge
- Fine-tuning of knowledge
- Learning from experiences
- Retaining of previously learnt experiences

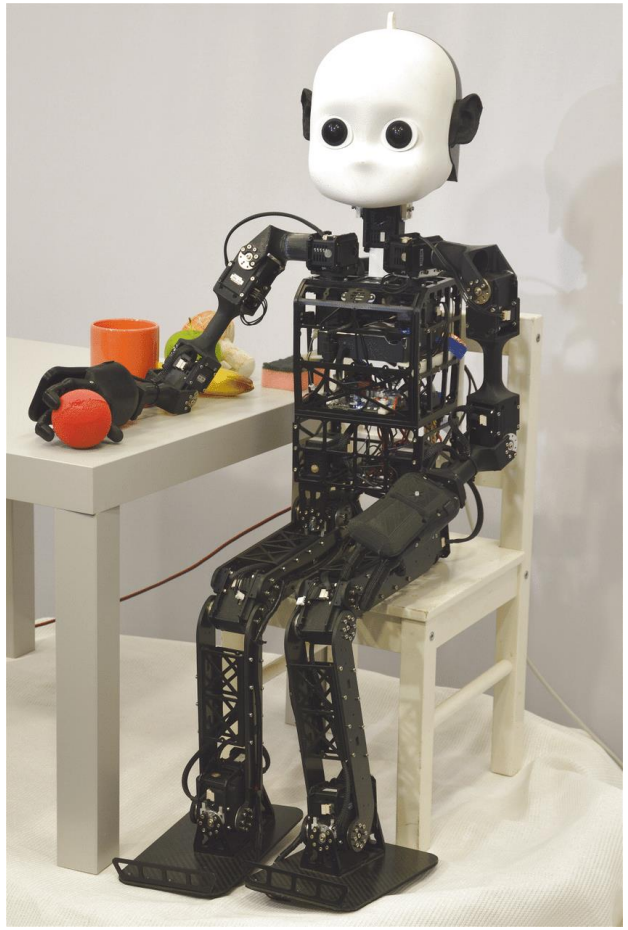
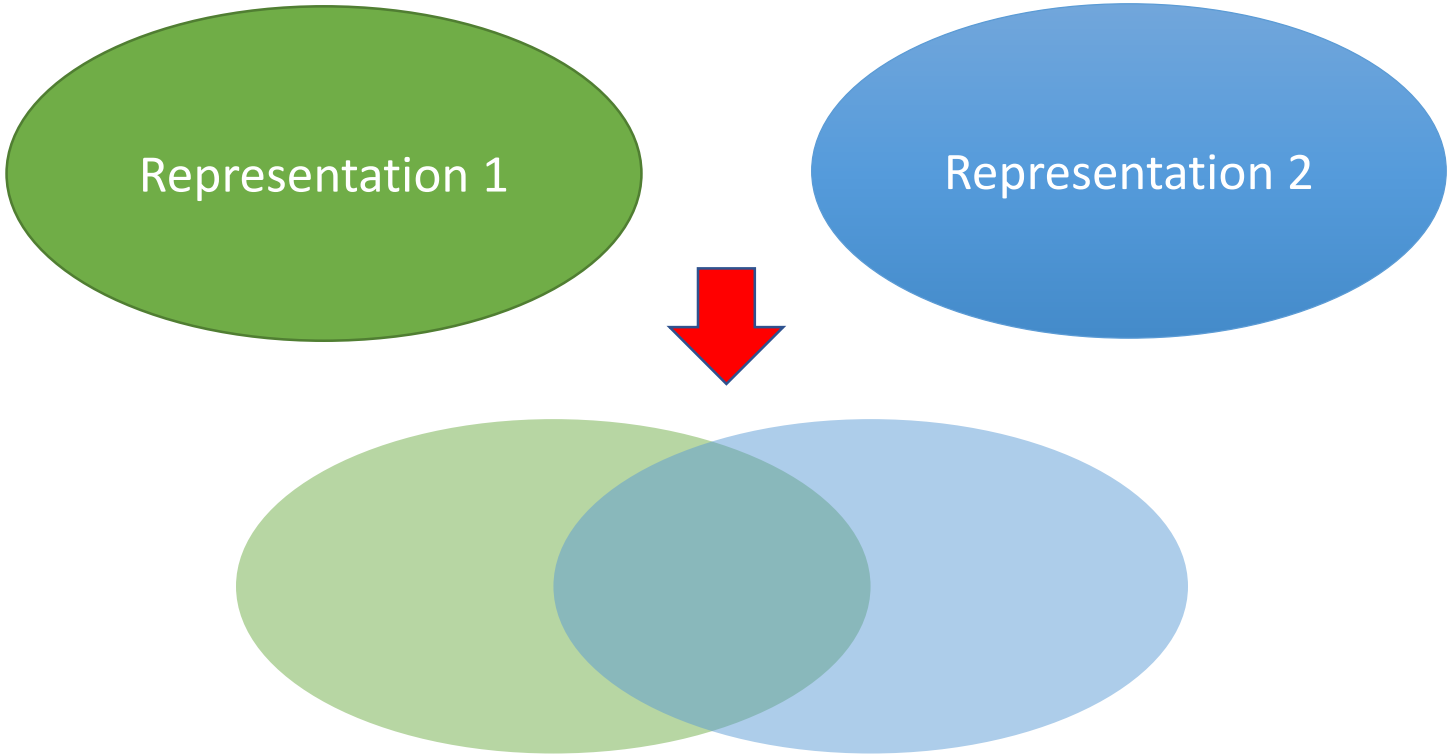


Figure 1.1: NICO – Neuro-Inspired COmpanion (Source: Kerzel et al. [2]).

Catastrophic Forgetting

- Interference of learnt representations with new information



Inspiration from Biological Systems

- Neurosynaptic plasticity
- Hippocampus and cerebral cortex
- Transfer learning
- Intrinsic motivation
- Crossmodal learning
- Incremental learning

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Neural Networks

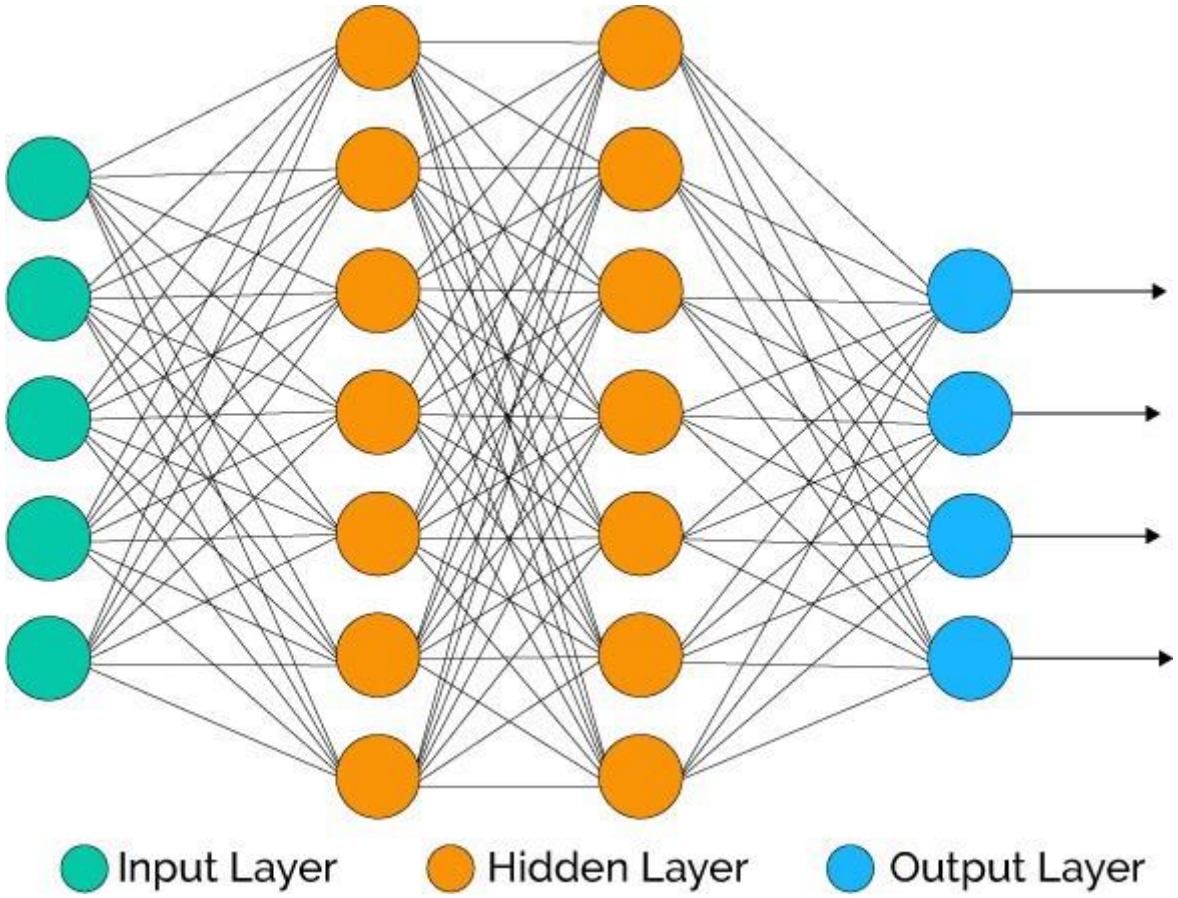


Figure 2.1: Neural network representation (Source: McDonald [3]).

Convolutional Neural Networks (CNNs)

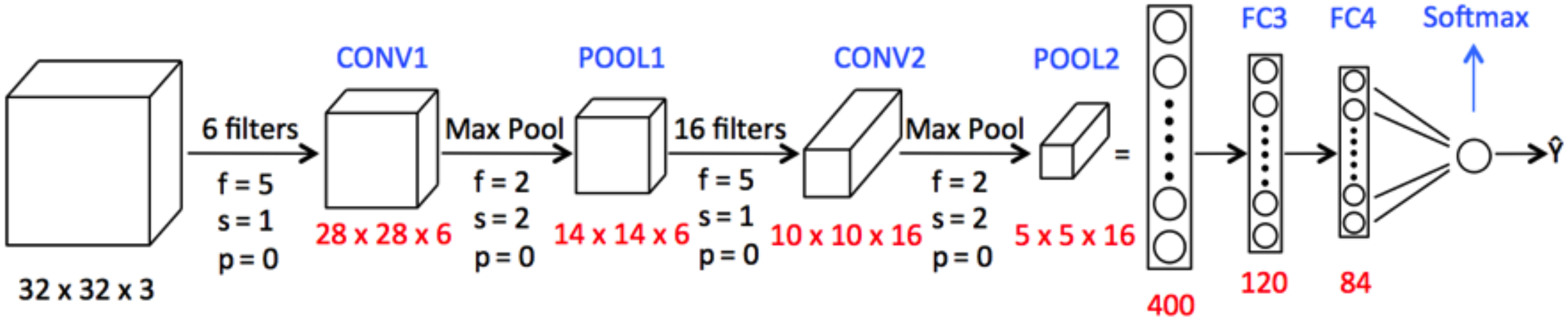
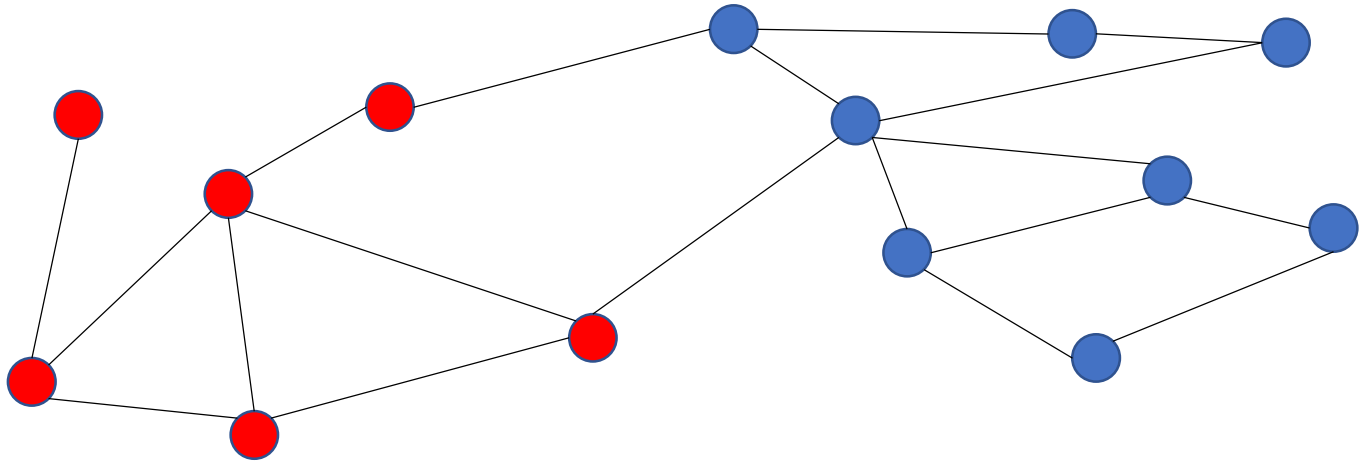


Figure 2.2: Convolutional neural network (Source: Cavaioni [1])

Self-Organizing Networks



- Self-Organizing Map (SOM)
- Grow When Required Network (GWR Network)
- Recurrent GWR

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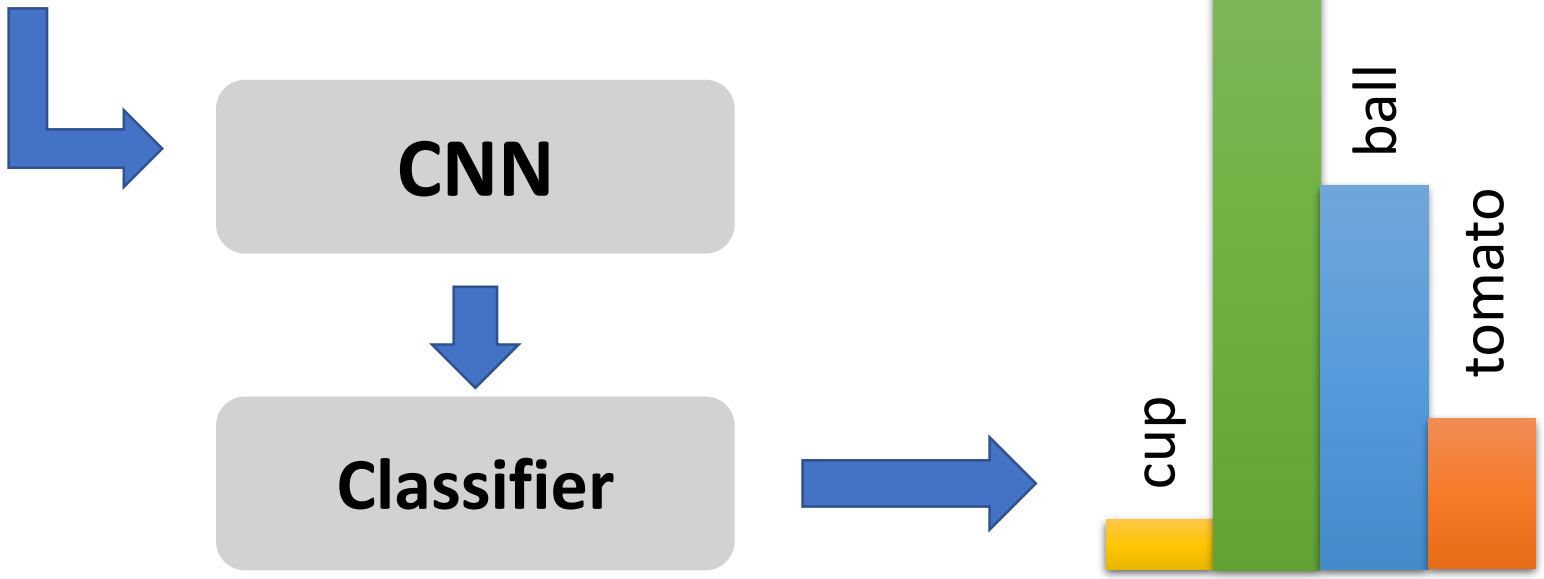
Object Recognition: CNN + Classifier

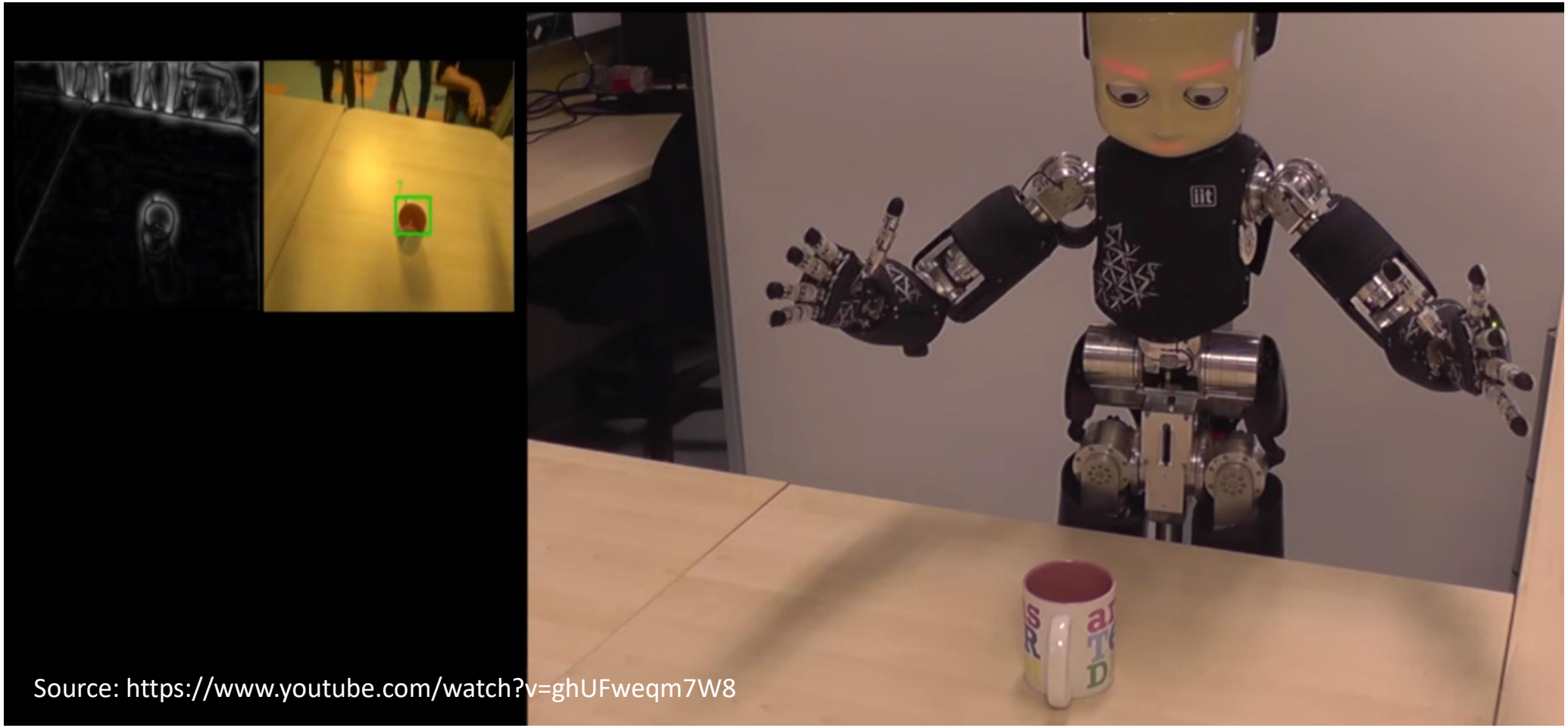
- Learning from video sequences
- Visual transformations of objects
- Changing environment

Figure 3.1: iCub (Source: Pasquale et al. [6]).

Object Recognition: CNN + Classifier



iCub: Object Learning



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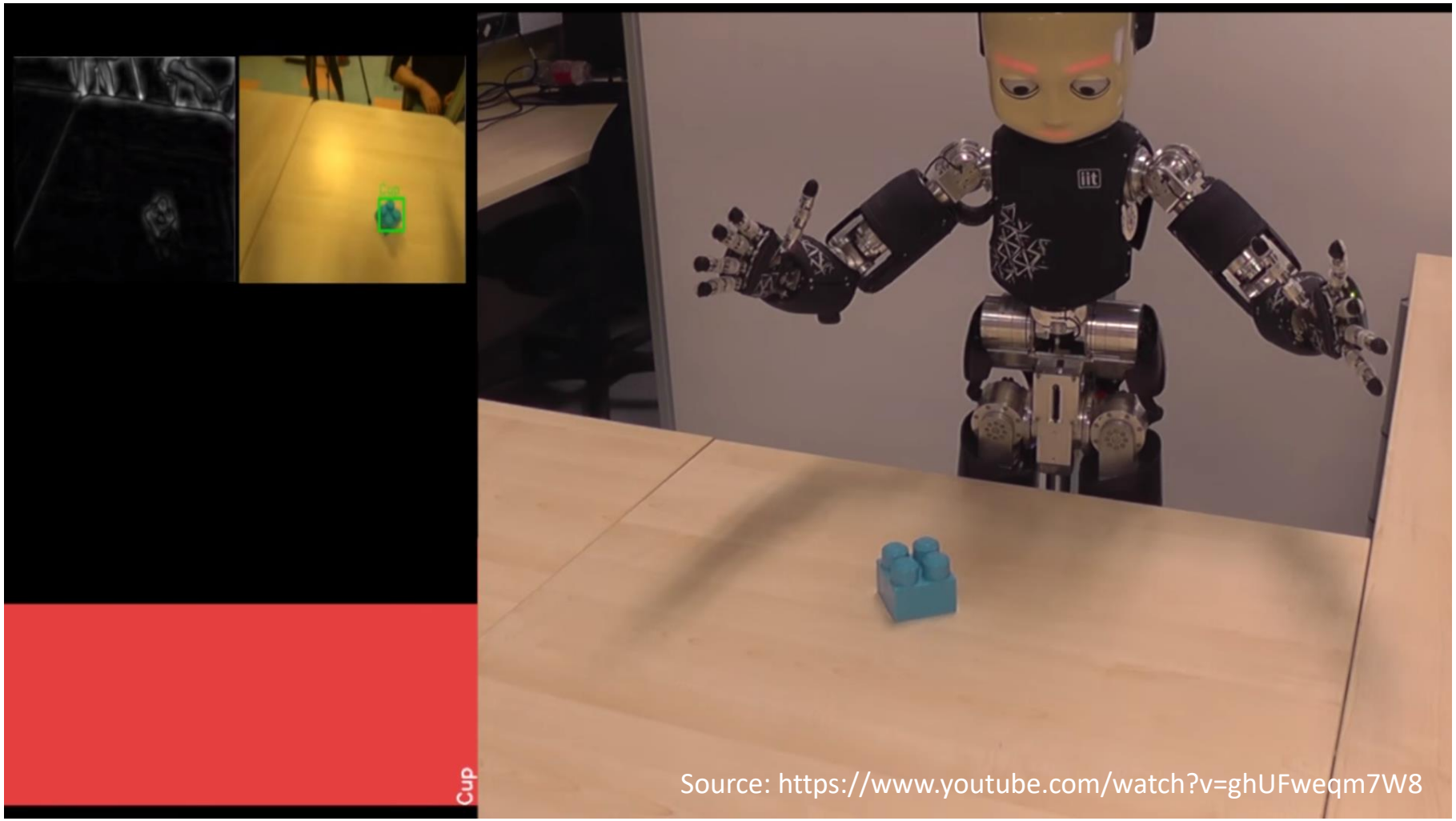

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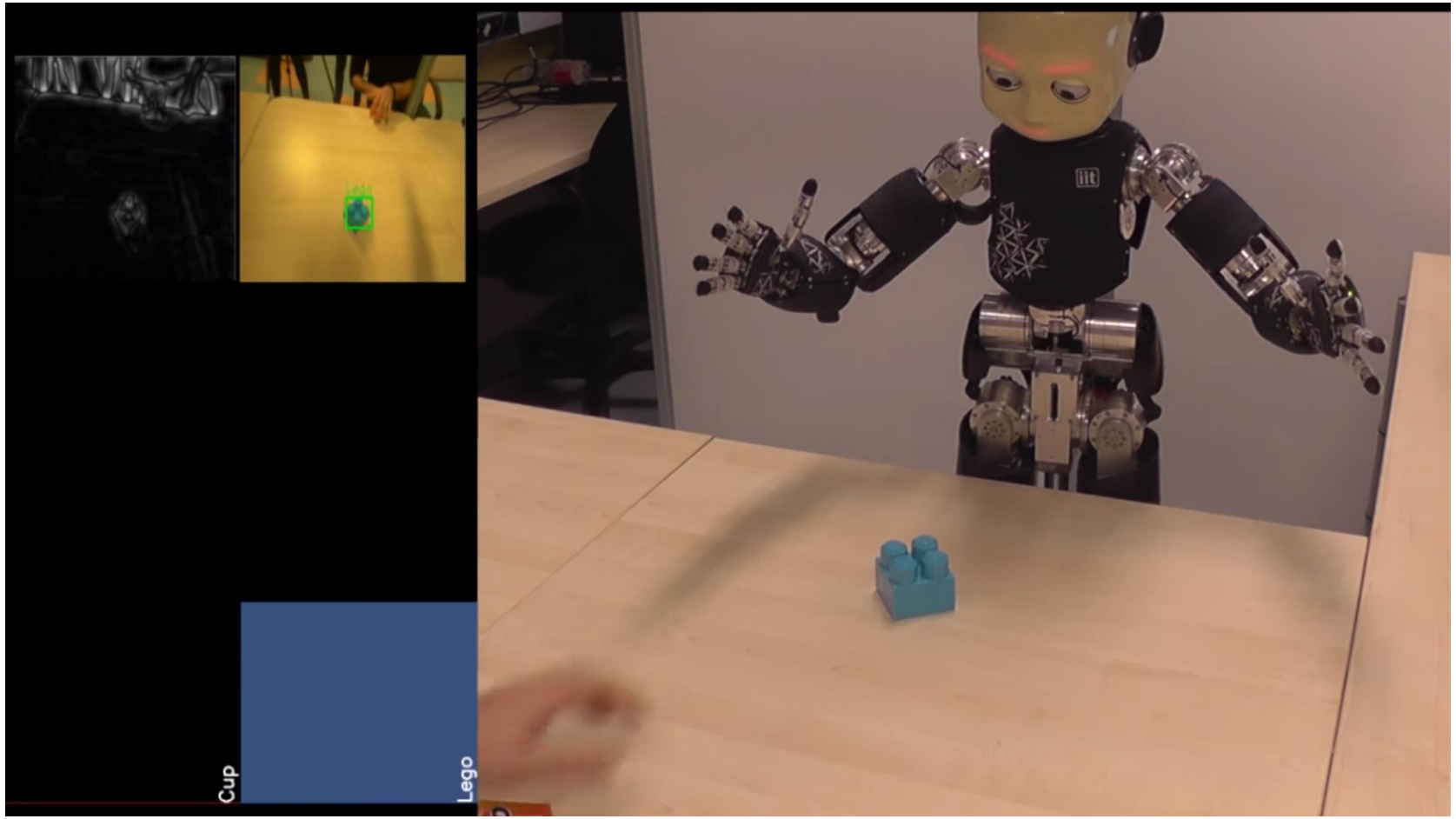

Source: https://www.youtube.com/watch?v=ghUFweqm7W8

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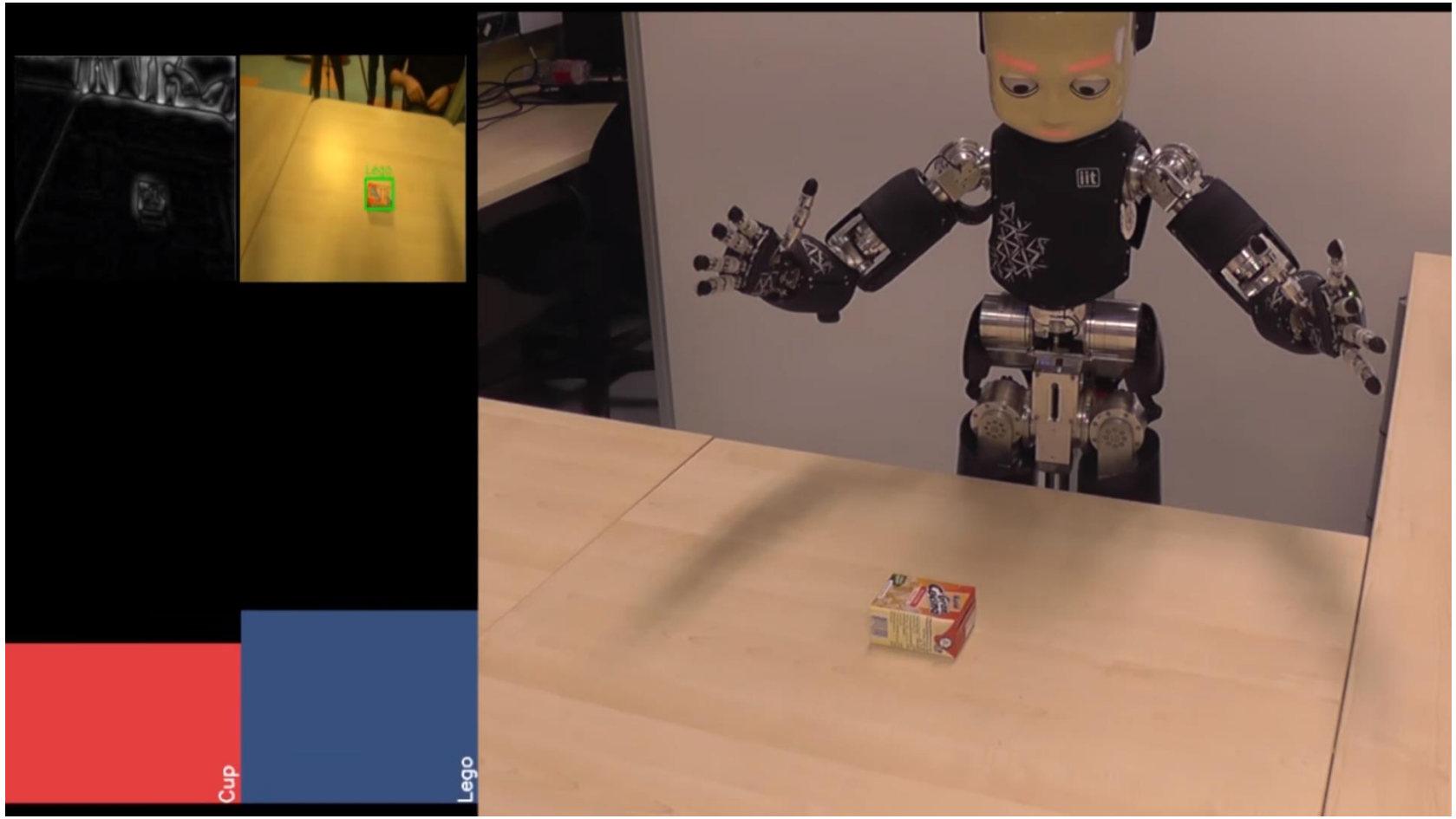

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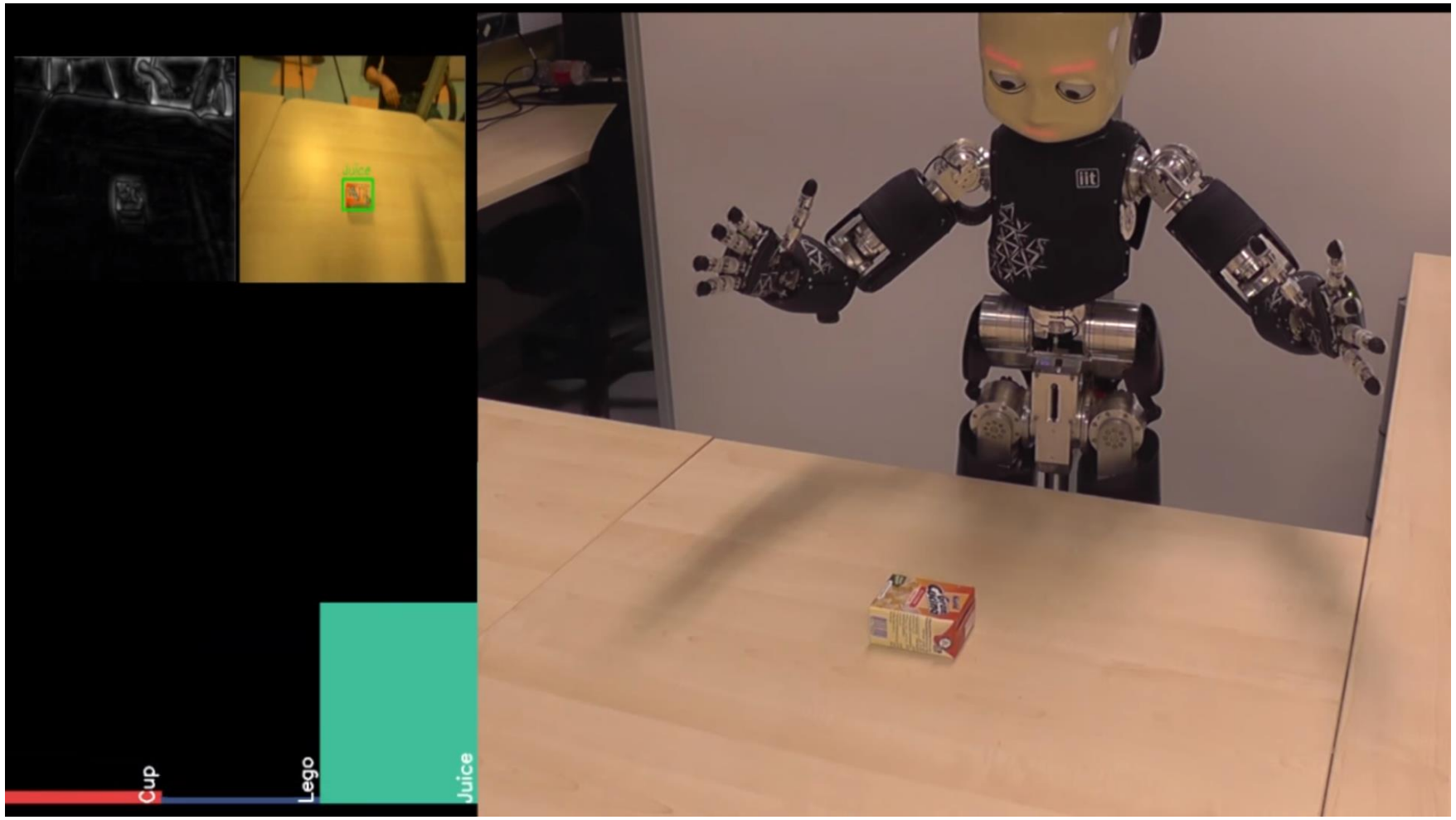

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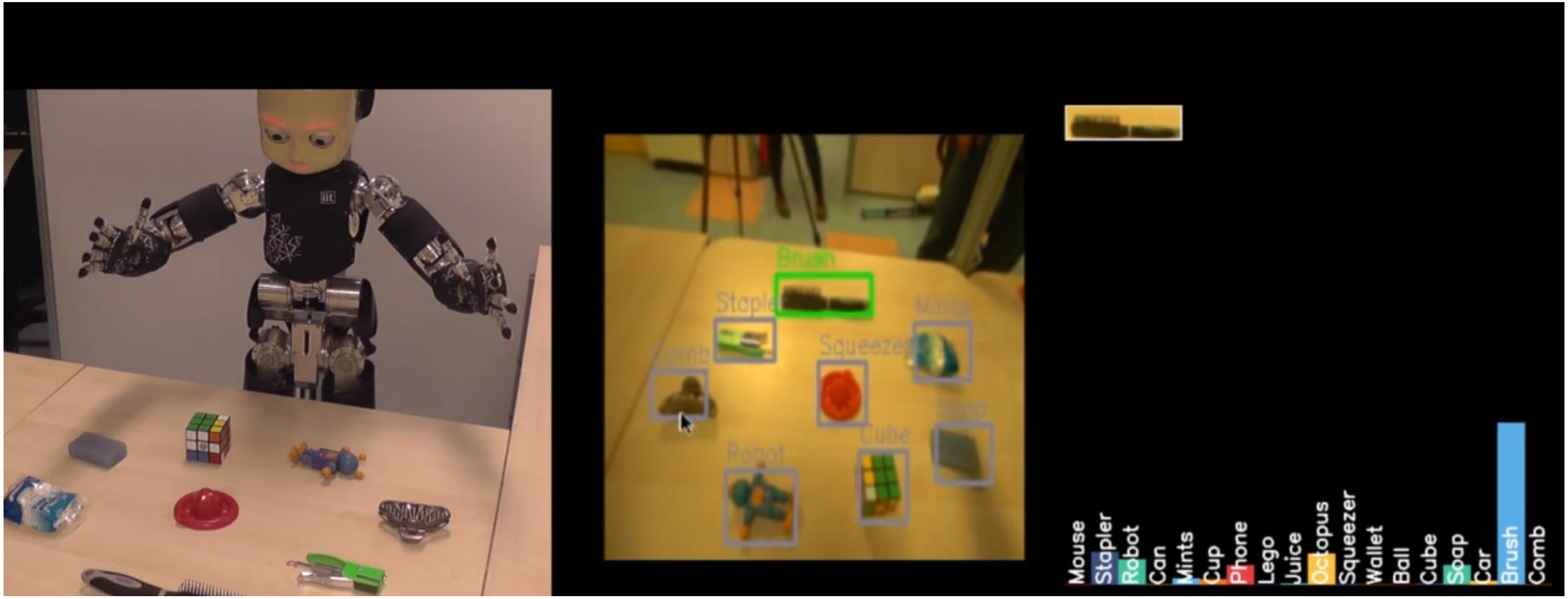

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Sensorimotor Learning: Self-Organization

- Latency in sensorimotor systems
- Predictive mechanisms for future motor states
- Online learning

Sensorimotor Learning: Self-Organization

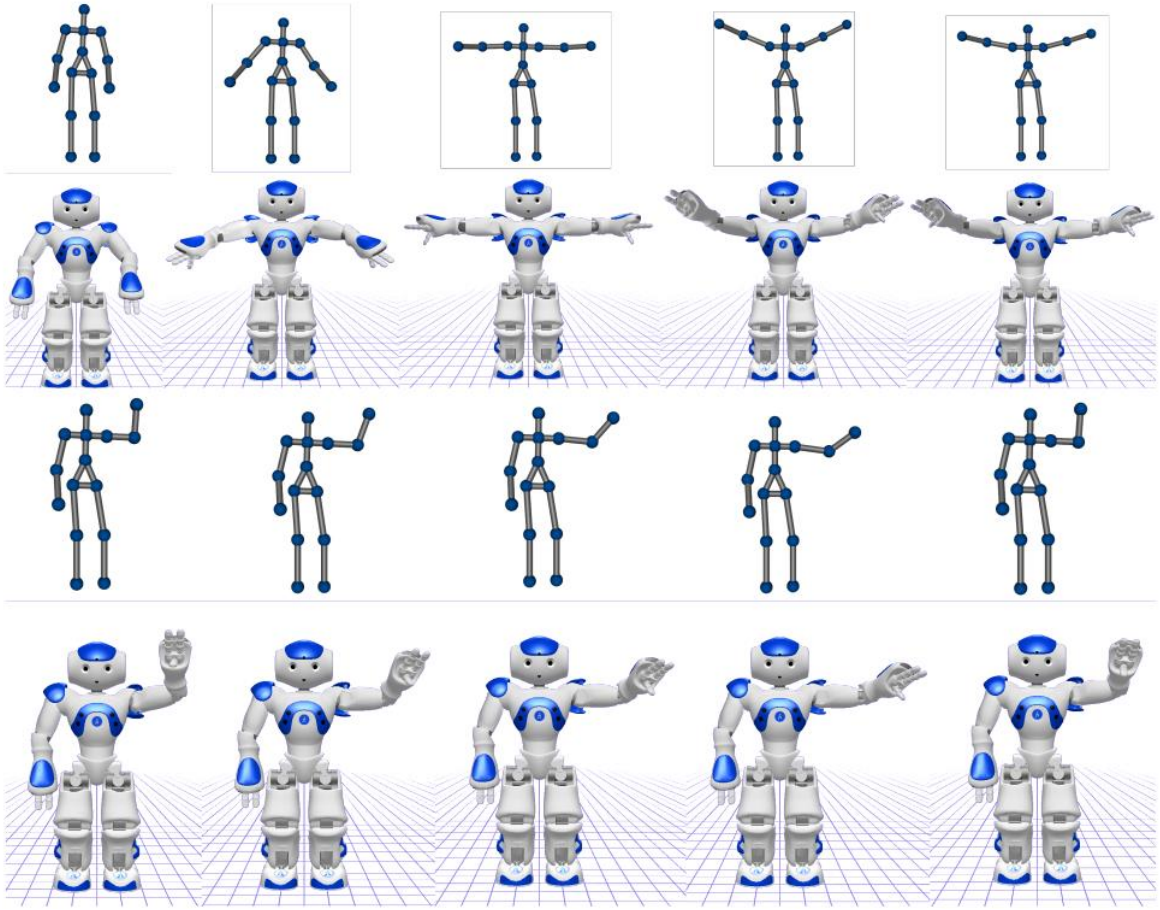

Figure 3.2: The imitation scenario (Source: Mici et al. [4]).

Sensorimotor Learning: Self-Organization

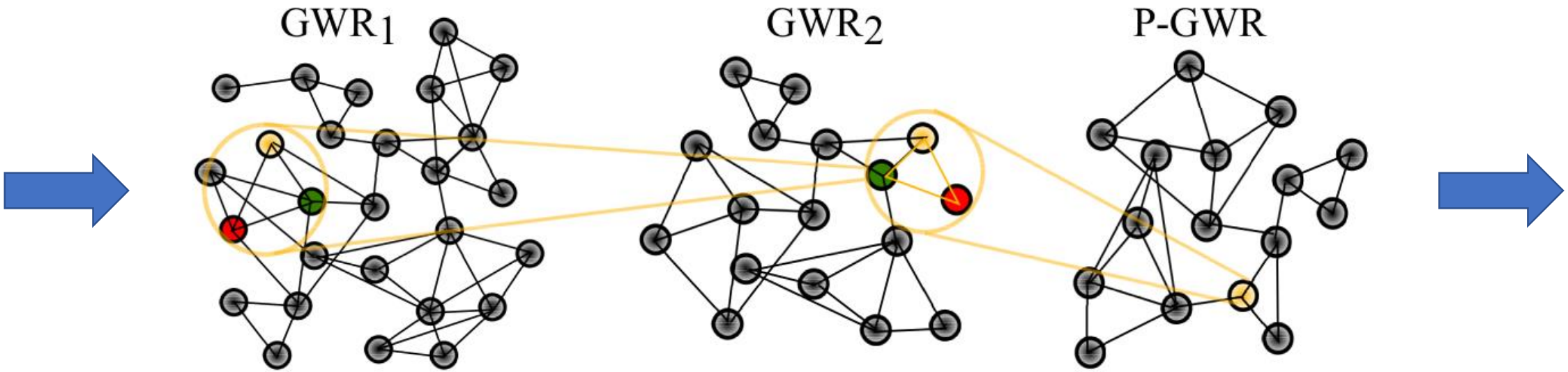

Figure 3.3: Visuomotor learning (Source: Mici et al. [4]).

Object Recognition: CNN + Self-Organization

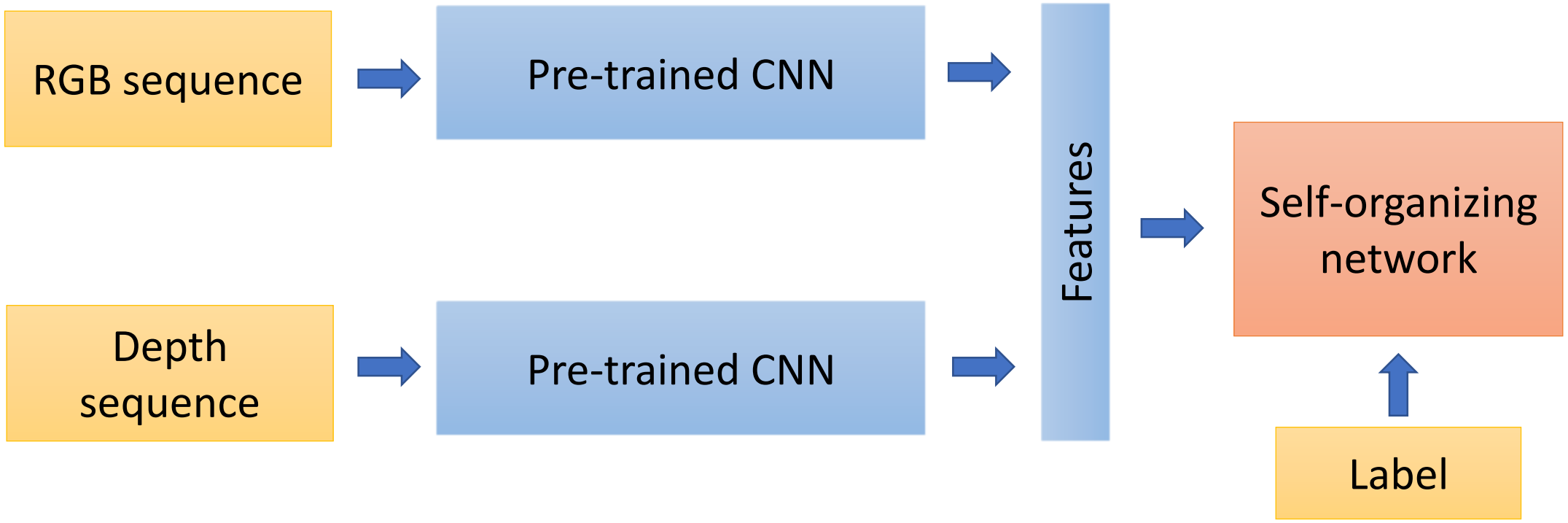

Figure 3.4: Recognition pipeline (Adapted from Part et al. [5]).

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Object Recognition: CNN + Classifier

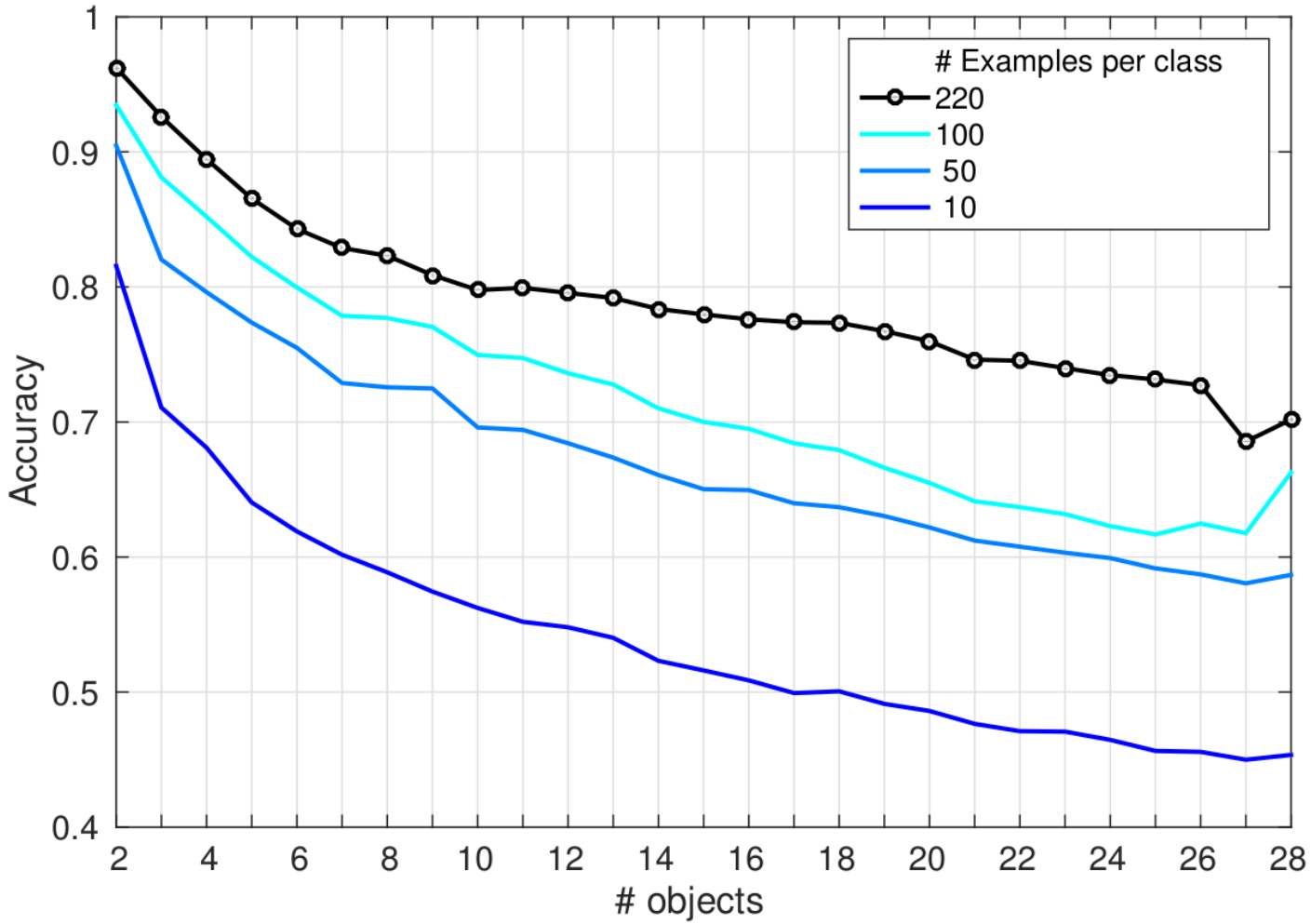

Figure 4.1: Classification accuracy of the model, which was trained on an incremental number of objects (Source: Pasquale et al. [6]).

Object Recognition: CNN + Classifier

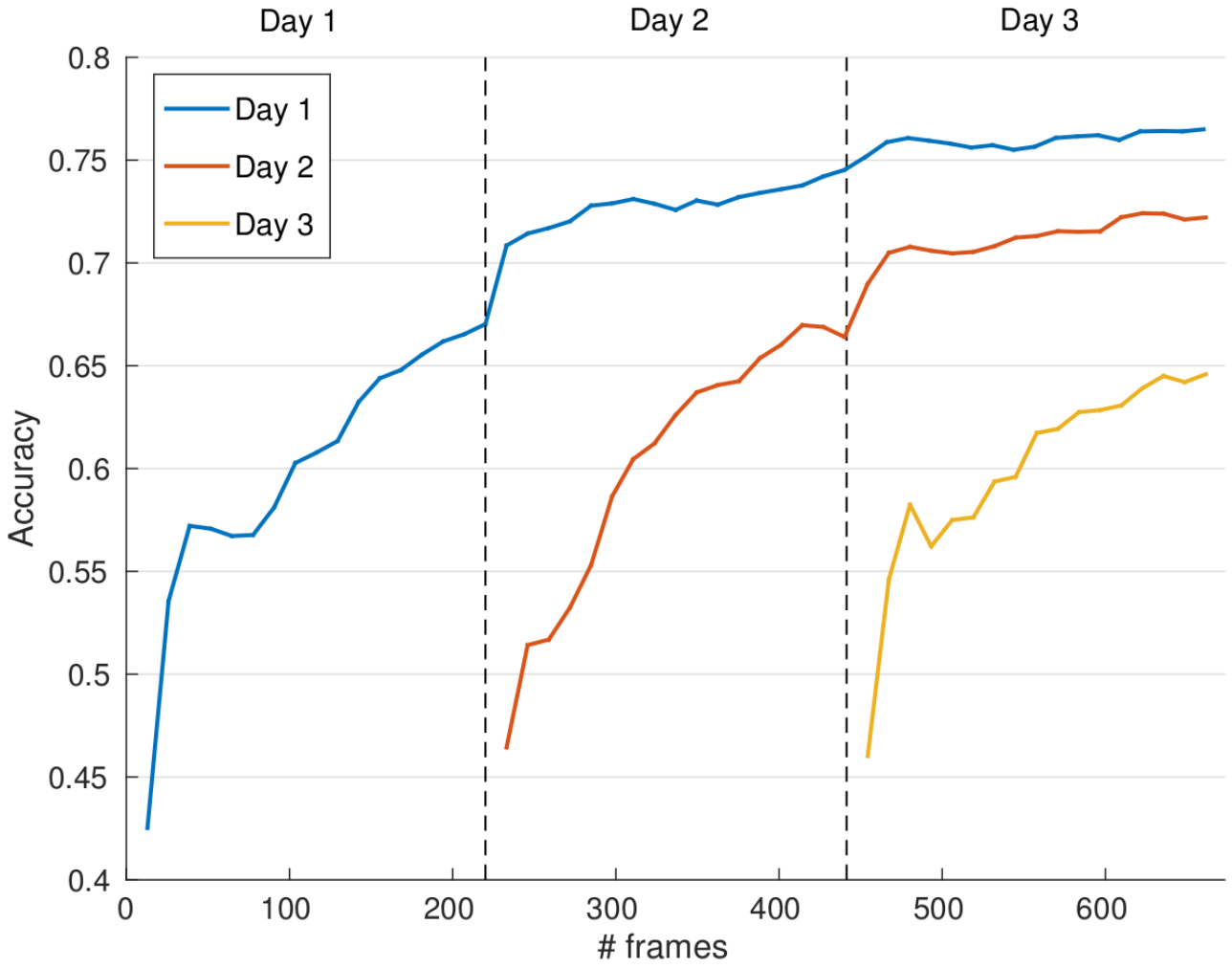

Figure 4.2: Classification accuracy of the model trained incrementally on different days (Source: Pasquale et al. [6]).

Sensorimotor Learning: Self-Organizing Architecture

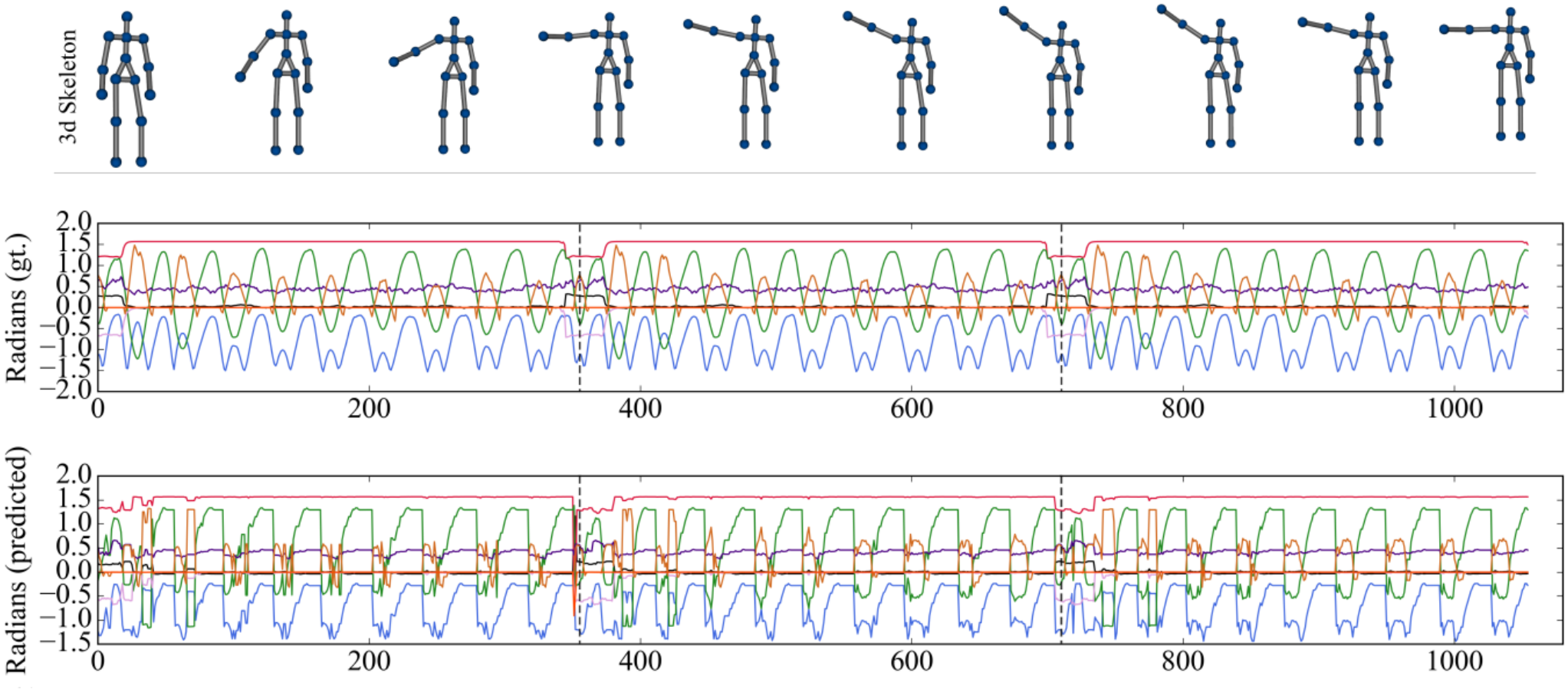

Figure 4.3: Behaviour of the architecture (Source: Mici et al. [4]).

Object Recognition: CNN + Self-Organization

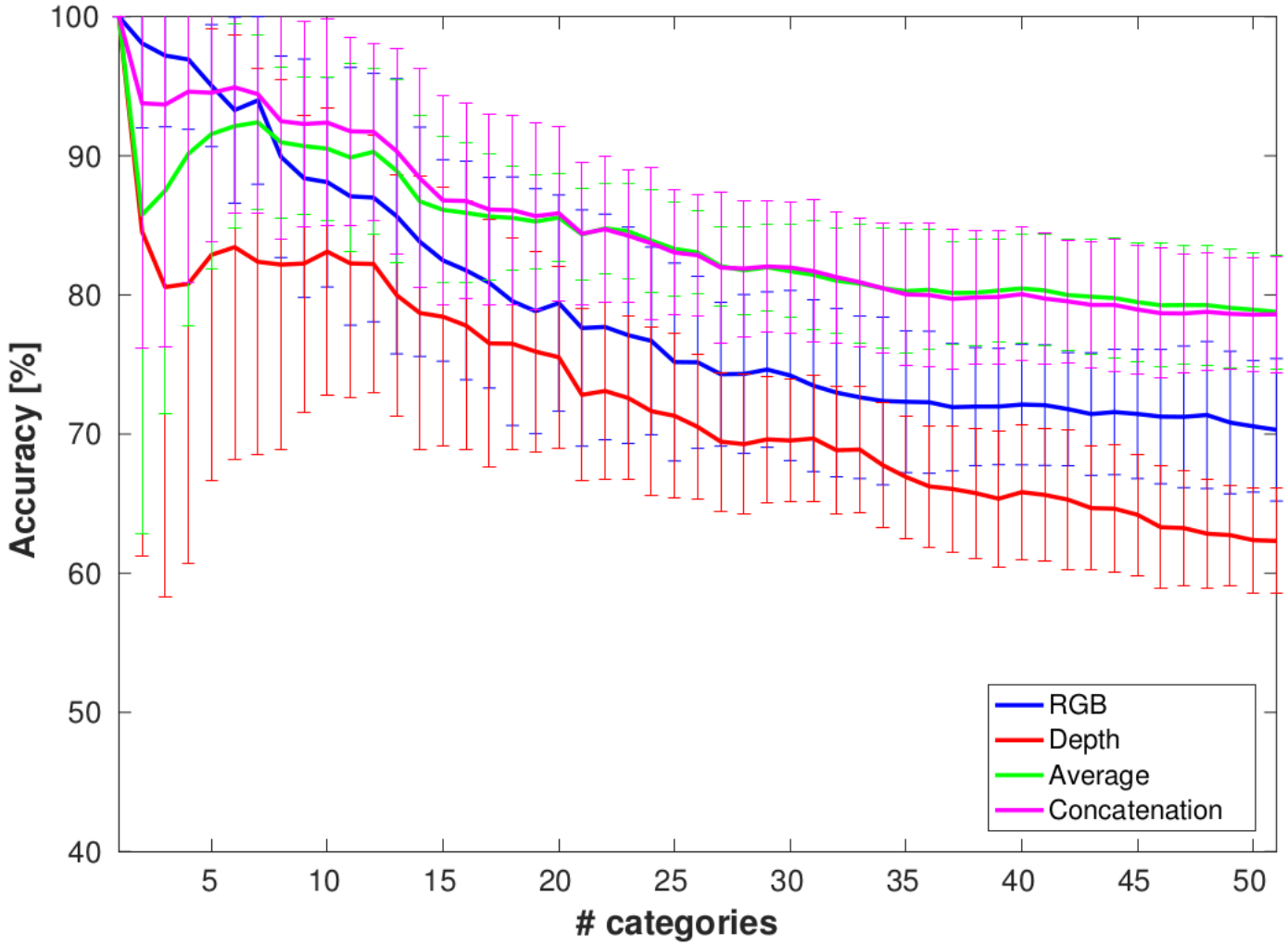

Figure 4.4: Recognition pipeline (Source: Part et al. [5]).

Discussion

- CNN + Classifier architecture for object recognition:
  - Features extracted from a CNN are dependent on a dataset the model was trained on
  - Old representations are overwritten by the new information
- Self-organizing architecture for sensorimotor learning:
  - Incremental online learning and prediction
  - Unreliability of visual body tracking framework in complex body positions
- CNN + self-organization for object recognition:
  - Self-organizing network grows when required
  - Temporal context is not considered

Conclusion

- Lifelong learning is crucial for intelligent robots
- Biological systems provide a basis for the incremental learning
- Self-organizing networks preserve the topology
- CNNs learn efficient feature descriptors
- Catastrophic forgetting increases during incremental tasks

Thank You!
Questions?

References

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- [4] Mici, L., Parisi, I. G., Wermter, S. An Incremental Self-Organizing Architecture for Sensorimotor Learning and Prediction. CoRR, abs/1712.08521, 2017.
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- [6] Pasquale, G., Ciliberto, C., Odone, F., Rosasco, L., Natale, L. Real-world object recognition with off-the-shelf deep conv nets: How many objects can iCub learn? CoRR, abs/1504.03154, 2015.