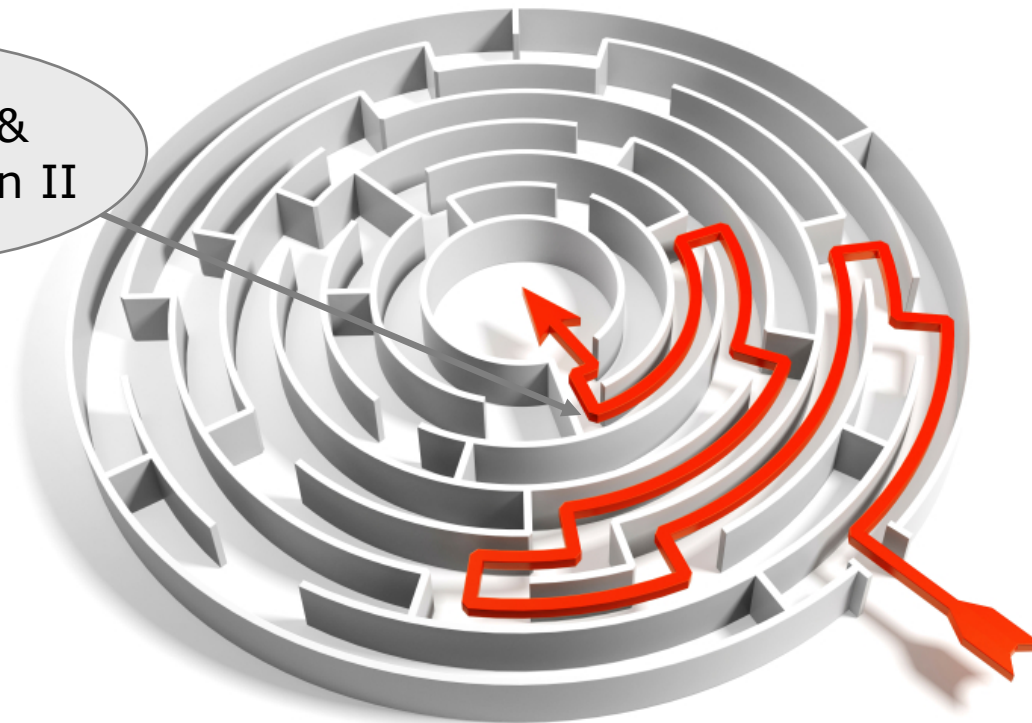


Artificial Cognitive Systems

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Knowledge &
Representation II



Topic Overview

- The duality of memory and knowledge
- Representation and anti-representation
- The symbol grounding problem
- **Joint perceptuo-motor representations**
- Acquiring and sharing knowledge

Joint Perceptuo-motor Representations

- **Mental imagery – internal simulation** – comprises both **visual imagery** (or, better still, perceptual imagery) and **motor imagery**
- These two forms of imagery are tightly entwined
 - the **simulation of perception and covert action** both involve elements of visual and motor imagery
 - Neuro-scientific evidence for the interdependence of perception & action

Joint Perceptuo-motor Representations

Sensory-motor Theory and **Ideo-motor Theory** [Stock & Stock 2004]

- **Sensory-motor action planning**

- Treats actions as reactive responses to sensory stimuli
- **Assumes that perception and action use distinct and separate representational frameworks**
- Builds on the classic uni-directional approach to perception, proceeding stage by stage from stimulus to percept and then to response
- **Doesn't allow the resultant (or intended) action to impact on the related sensory perception**

Joint Perceptuo-motor Representations

Sensory-motor Theory and **Ideo-motor Theory** [Stock & Stock 2004]

- **Ideo-motor action planning**

- Treats action as the result of **internally-generated goals**
- **The selection and control of a particular goal-directed movement depends on the anticipation of the sensory consequence of accomplishing the intended action**
- The agent images (e.g. through **internal simulation**) the desired outcome and selects the appropriate actions in order to achieve it

Joint Perceptuo-motor Representations

Sensory-motor Theory and **Ideo-motor Theory** [Stock & Stock 2004]

- **Ideo-motor action planning**

- There is an important difference between the concrete movements comprising an action and the higher-order goals of an action
- Actors do not voluntarily pre-select the exact movements required to achieve a desired goal
- **Instead, they select prospectively-guided intention-directed goal-focussed action**

with the specific movements being adaptively controlled as the action is executed

Joint Perceptuo-motor Representations

Sensory-motor Theory and **Ideo-motor Theory** [Stock & Stock 2004]

- **Ideo-motor action planning**

- How can the goal, achieved through action, cause the action in the first place?
- How can the later outcome affect the earlier action?
- **Prospection!** It is the anticipated goal state, not the achieved goal state, that impacts on the associated planned action
- **Goal-directed action is a centre-piece of ideo-motor theory**
- Also referred to as the **goal trigger hypothesis** [Hommel et al. 2001]

Joint Perceptuo-motor Representations

Sensory-motor Theory and **Ideo-motor Theory** [Stock & Stock 2004]

- **Ideo-motor action planning**
 - **Perception and action share a common representational framework**

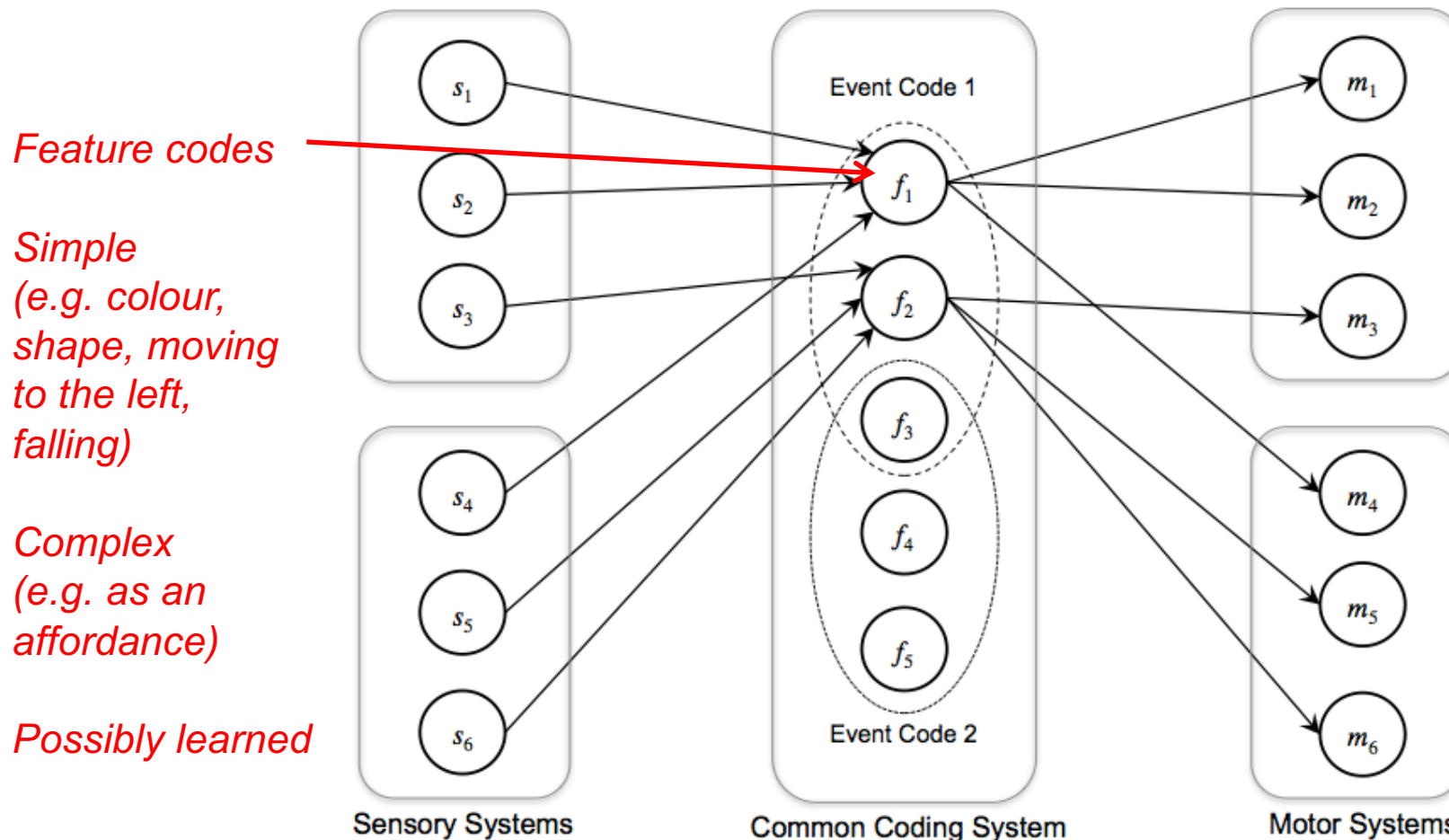
Joint Perceptuo-motor Representations

The Theory of Event Coding (TEC) [Hommel et al. 2001]

- Concerned with perceptual features but not with how those features are extracted or computed
- Concerned with preparing actions — action planning — but not with the final execution of those actions and the adaptive control of various parts of the agent's body
- Perception, attention, intention, and action all work with a common representation
- Action depends on both external and internal causes

Joint Perceptuo-motor Representations

The Theory of Event Coding (TEC) [Hommel et al. 2001]

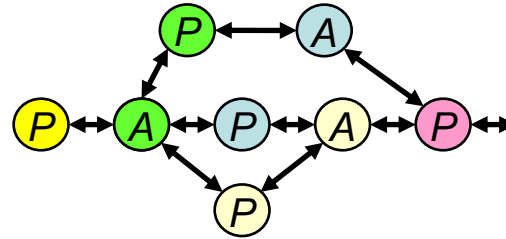


Joint Perceptuo-motor Representations

The Theory of Event Coding (TEC) [Hommel et al. 2001]

- Feature codes associated with an event are activated both when the **event is perceived** and **when it is planned**
- Features can be elements of many event codes
 - the activation of a given feature effectively primes, i.e. predisposes, all the other events of which this feature is a component
- The features that make up an event are bound together: integrated into some event code
- The nature of the binding isn't specified in TEC
 - the effect of binding is a form of event code suppression
 - one event inhibits other events that share some of the event codes features

**Transferrable
Structural/Syntactic
Model**



**INTERNAL
SIMULATION:
Planning,
Prediction,
Action Selection**

**GENERATIVE
MODELLING
(Linguistic/Syntactic)**

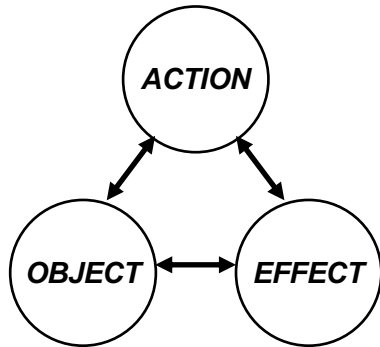
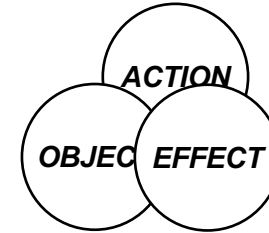
XPERIENCE
Integrated Project



*“Robots Bootstrapped through
Learning from Experience”*

www.Xperience.org

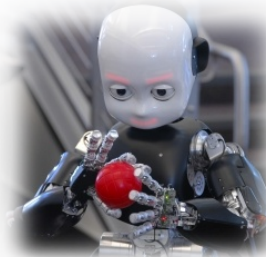
Expected:



**Object-Action Complex
OAC**

**ENACTED
GROUNDING**

**CATEGORIZATION
(affordances,
sensorimotor
contingencies)**



Joint Perceptuo-motor Representations

Object-Action Complex, or OAC [Kruger 2011]

- An OAC is a triple, i.e. a unit with three components: (E, T, M)
 - E is an “execution specification”; think of it as an **action**
 - T is a function that predicts how the attributes that characterize the current state of the agent’s world will change if the execution specification is executed
 - Think of T as a **prediction** of how the agent’s perceptions will change as a result of carrying out the actions given by E. S is just the space of all possible perceptions of the agent
 - M is a statistical measure of the **success** of the OAC’s **past predictions**

Joint Perceptuo-motor Representations

Object-Action Complex, or OAC [Kruger 2011]

- An OAC: a **predictor** that links current perceived states and future predicted perceived states that would result from carrying out that action
- An OAC **models an agent's interaction with the world as it executes some motor program** (low-level control program CP in the OAC literature)
- For example, an OAC might encode how to grasp a object or push an object into a given position and orientation (usually referred to as the object pose)
- OACs can be **learned** and **executed**, and they can be **combined** into more complex representations of actions and their perceptual consequences.

Recommended Reading

Vernon, D. *Artificial Cognitive Systems – A Primer*, MIT Press, 2014;
Chapter 8.