Acting outside the box

Lessons learned when embodiment is the only option.

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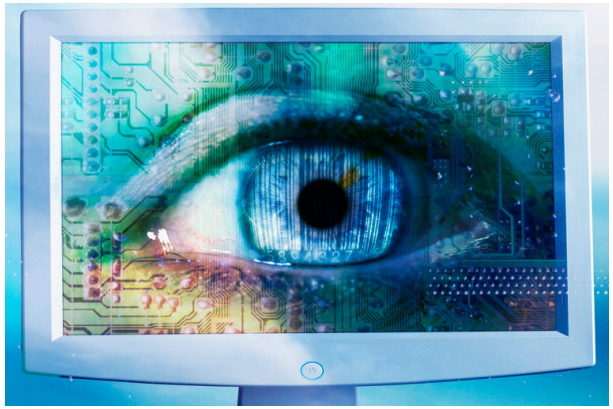
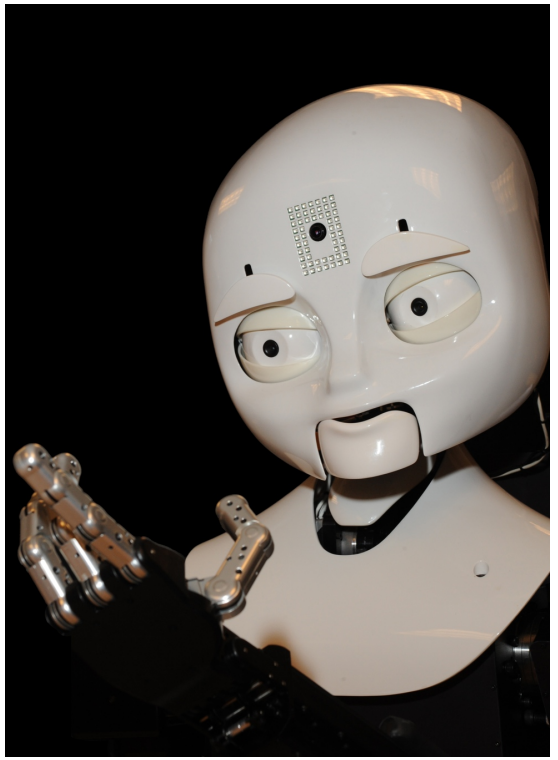
Modeling Embodiment





http://www.nrl.navy.mil/aic/iss/aas/CognitiveRobotsVideos.php

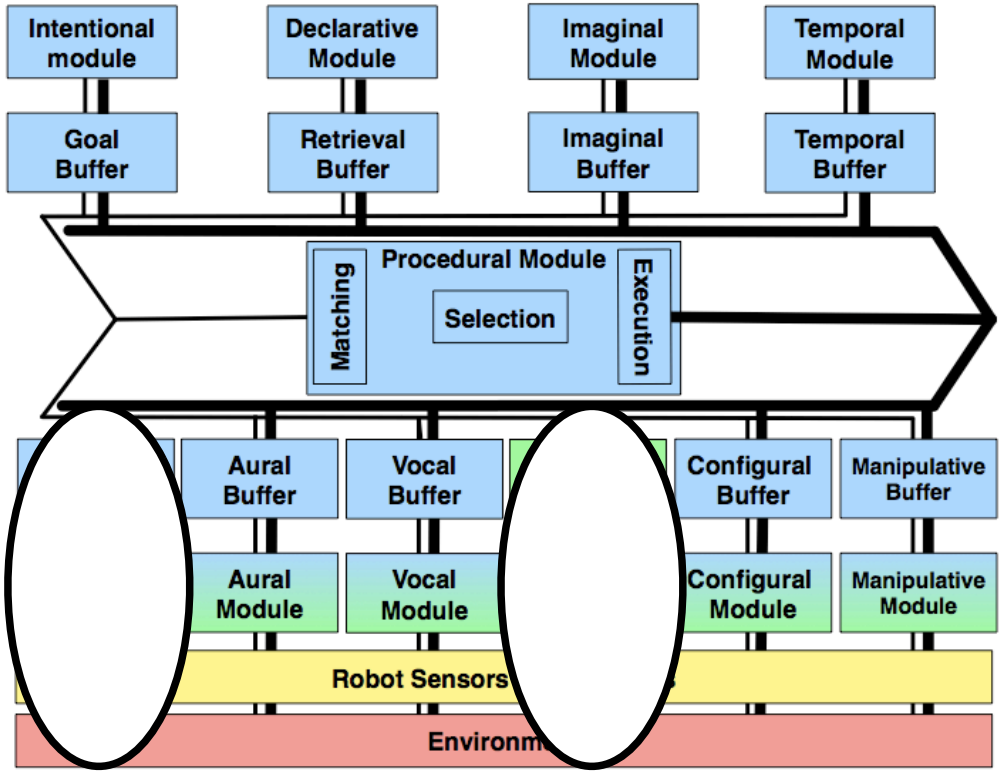
ACT-R/Embodied

Modified ACT-R *implementation*

- Mostly at /PM level

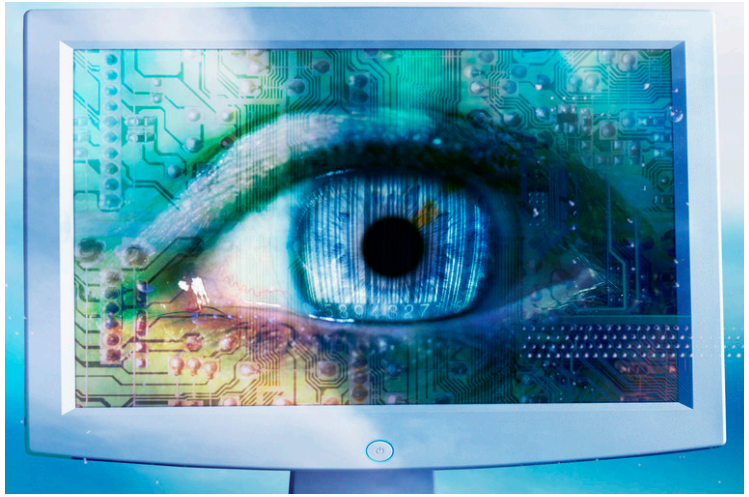
Uses jACT-R

- Older version using Lisp



Visual : What does ACT-R have?

- Full FOV foveal vision / no peripheral
  - Saccades merely direct attention
  - Doesn't change visual field
- Screen-based vision
  - *screen-x, screen-pos*
- Tuned to static displays
  - +visual> isa track-object
- Limited error checking/handling



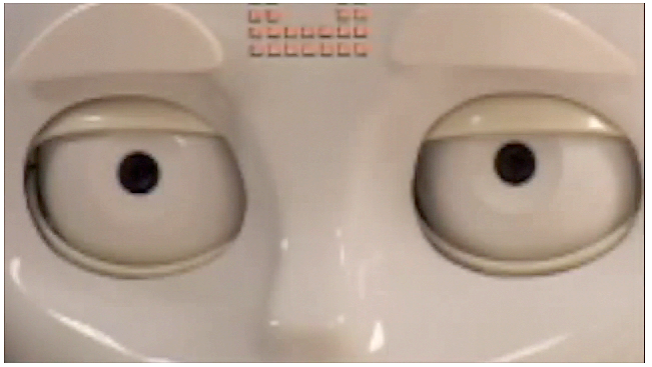
Visual : What do we need?

Foveal & peripheral vision

More *natural* visual-locations

Dynamic vision needs to be automatic

Richer error information



Visual : What we've done

- Everything is moving
  - Motion tolerances dramatically increased (x10)
  - Tracking is automatic
- Moving eyes & visual-locations
  - retinotopic visual angles (feeds directly to motor)
  - Transient (and recycled)
- FINSTs
  - Object, not location, based
- Fine-grained errors/states
  - *nothing-matches, nothing-to-match*, *out-of-fovea*, *object-disappeared, object-changed*

Visual : What do we still need?

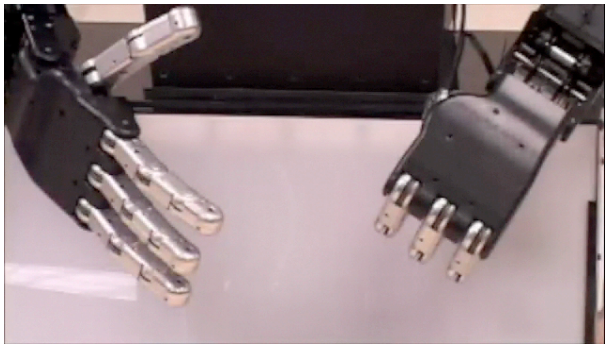
- Peripheral vision
- Change-blindness
  - Smoothing of sensor noise
- Capacity buffer
  - Subsumes FINSTs
  - Temporal ejection (decay)

Manual : What does ACT-R have?

Keyboard & mouse focus

Limited, style-based movements

Serial preparation* & execution (at the style level)



* Thank you Kieras for exorcising preparation

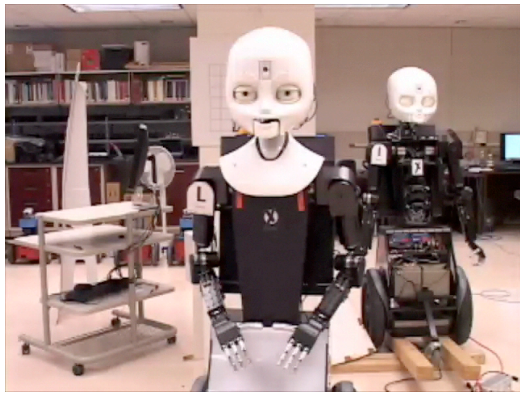
Manual : What do we need?

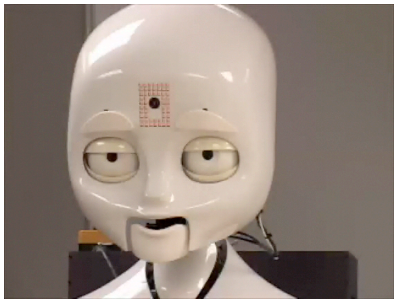
Parallel movements

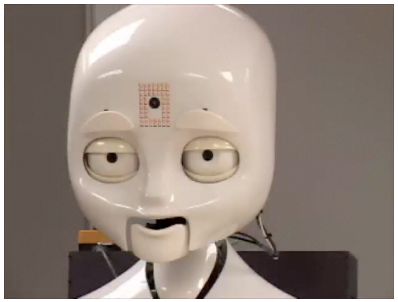
Proprioception

Complex, coordinated, multi-joint movements

Not *manual* but ***motor***







Motor : What we've done

Muscle-level parallelism

- execution & preparation

Scope queries & requests with *muscle* slot

- Provides state & proprioception
- w/o *muscle*, queries operate globally

```
(p clap-hands
   ?motor>
      muscle left-hand
      state free
   ?motor>
      muscle right-hand
      state free
   ==>
   +motor>
   isa hand-to-center
      muscle left-hand
   +motor>
   isa hand-to-center
      muscle right-hand)
```

Motor : What we've done

Motor buffer is an interface **and** a container

Perceptual integration

Permits production-level composition of movements

```
(p start-tracking
   ?motor>
      buffer empty
   =visual>
   isa face
   ==>
   +motor>
   isa track-object
      target =visual
   =visual>)
```

```
(p target-outside-fixation
   =visual>
   isa visual-object
      screen-pos =loc
   =motor>
   isa track-object
      target =visual
   ?motor>
      muscle eyes
      state free
      x =x
      y =y
   !eval! (....)
   ==>
   +motor
   isa move-eyes
      rel-x =dx
      rel-y =dy)
```

Motor : What we still need

Motor learning & refinement

Internal body model

Much more detailed error states

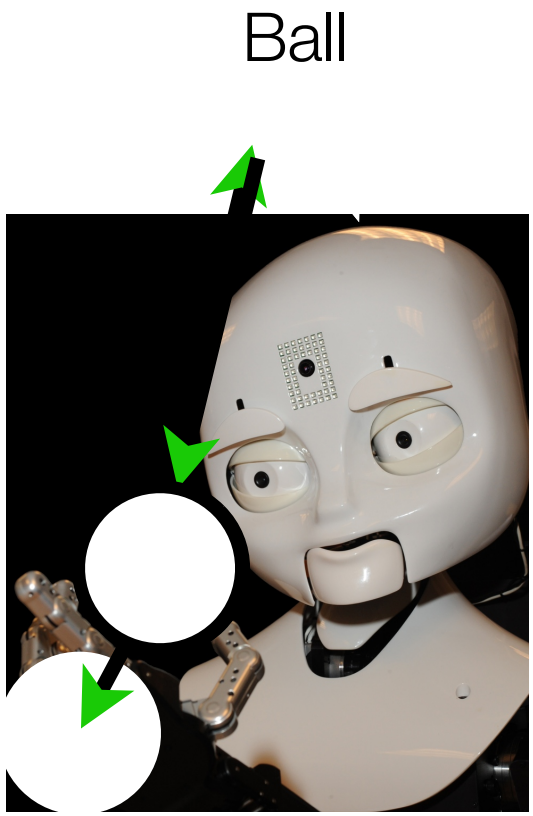
collision? self-collision? broken/aching limb?

Things to come...

More integrated perception than embodied cognition

Perceptual priming

- Percept → Chunk
  - generalized ACT-R 4 associative-learning mechanism
- Chunk → Percept
  - Contextual feedback for sensors
    - activation & task



Aside..

Scale & Reuse

Scale

- Long term robot engagement
- 100k chunks + productions in an hour

Reuse

- Beyond the Roomba

Collaborators & Funders

Revolutionary Research . . . Relevant Results

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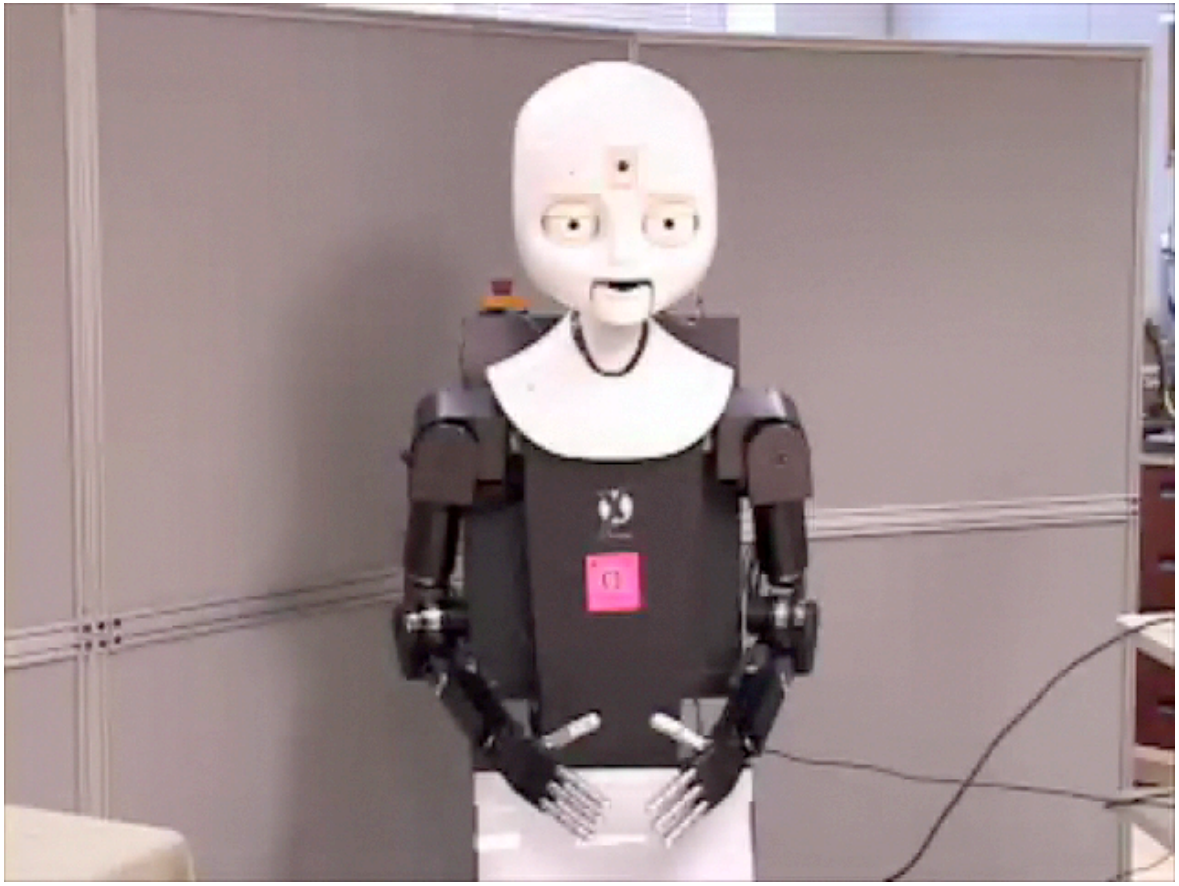

Thanks for the WiFi