Notes on cognitive robotics

# 1 Machine psychology (2002)

Jeff Krichmar is currently a professor in the departments of Cognitive Sciences and of Computer Science at the University College Irvine. This lecture is based on the paper by Krichmar and Edelman 2002[1]

- NOMAD=Neurally Organised Mobile Adaptive Device
- Darwin VII is a mobile robot that was used to simulate 14 experimental subjects.

Darwin was a series of robots developed at the Neurosciences Institute in CA, and has now progressed to the CARL series of robots at UCI[2]. The software to run CARL's brain has been made available online as Carlsim 3 [3]

see `http://www.socsci.uci.edu/~jkrichma/CARLsim/`

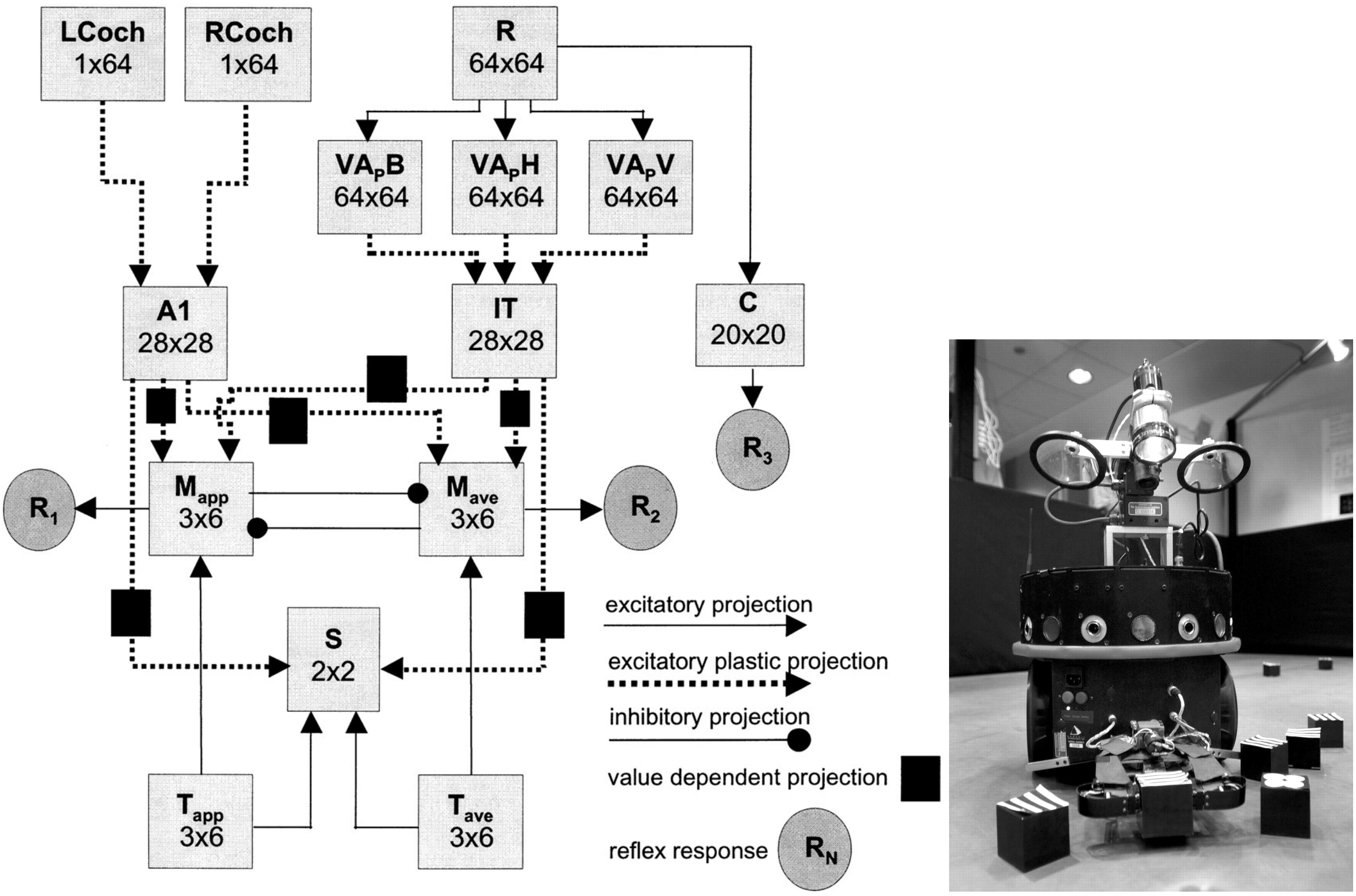


Figure 1: Darwin's brain (left) and Darwin (right) From[1]fig 2

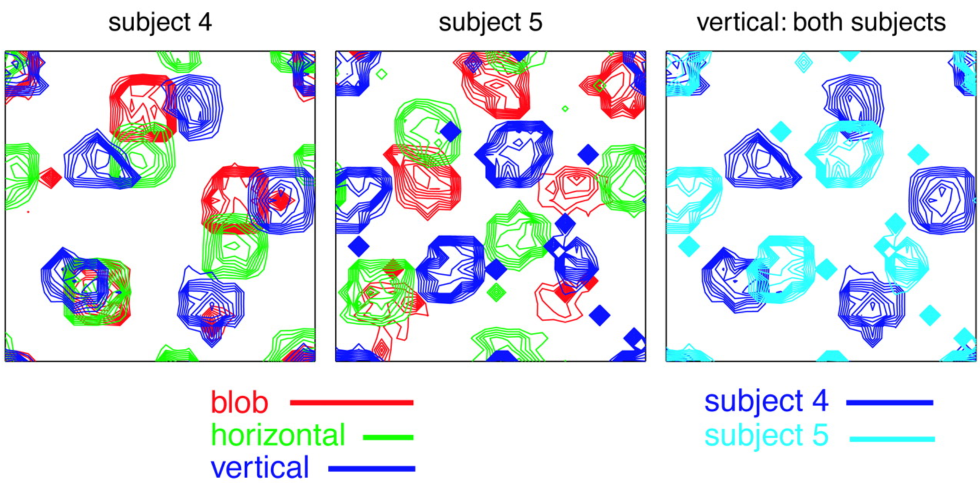


Figure 2: How the IT area classified objects. 'Subject 4' (left), 'subject 5' (middle). Response of IT to vertical lines - subject 4 and 5 overlayed (right) From[1]fig 5

| | | |
|---|---|---|
| R | Retinal area | |
| VAP | Primary visual area | |
| VAPB | Visual area for Blobs | |
| VAPH | Visual area for Horizontal lines | |
| VAPV | Visual area for Vertical lines | |
| LCoch/ RCoch | Left and right Cochlear | |
| A1 | Primary audio area | |
| IT | Inferotemporal cortex (secondary visual area) | Object recognition |
| S | Value system | |
| Mapp | Appetitive motor area | |
| Mave | Aversive motor area | |
| TappA | Appetitive taste (strongly conductive blocks) | |
| Tave | Aversive taste (weakly conductive blocks) | |
| C | Colliculus | Allows visual tracking |
| R1 R2 R3 | Reflex response | |

#### 1.0.1 Brain areas

| | |
|---|---|
| Retina R | Cluster centres in IT |
| Auditory (A1)<br>Top area is high f<br>mid area is low f | Response of motor areas<br>Left=Mave, right=Mapp |

- Appetitive=satisfying bodily needs
- Aversive=something to avoid
- Blocks with blobs impart a bad taste and hence cause an aversive response
- Blocks with stripes impart a good taste and hence cause an appetitive response

### 1.1 Unconditioned

`Unlearned_combined.mpg`

IT does not form a strong opinion on the objects.
tastes the reward/aversion for confirmation

### 1.2 Conditioned visual

`Learned_combined.mpg`

Stripes are considered appetitive and the behaviour rewarded accordingly
Blobs are aversive and at this stage the robot can avoid the stimulus.

### 1.3 Conditioned autitory

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Blocks are neither blobs or stripes so are not recognised by the visual sytem, but give a tone when the robot is near by.
The high frequency tone was associated with appetitive responses (rewards)
The low tone was associated with the aversive response

## 2 Resilient machines (2006)

Key paper is Bongard, Zykov and Lipson 2006[4]
Robot is the starfish. Fixed morphology

- 8 joint sensors,
- 2 tilt sensors and
- 8 joint actuators.
- Most robotic systems get the humans to construct a mathematical model of the robot kinematics and/or dynamics and then plan movement against that model.
- Approach is expensive (time to construct a valid model), and requires calibration
- Robot does not have an explicit model of itself
  - Methods like SLAM model and adapt to change the environment
  - Very few robots allow adapt to changes to their own morphology
- Premise, create multiple internal models and use a system identification like approach to select the best
- Don't freeze the system identification process during use
  - Rather look for disagreements between model and sensors (recall Kalman filters?)

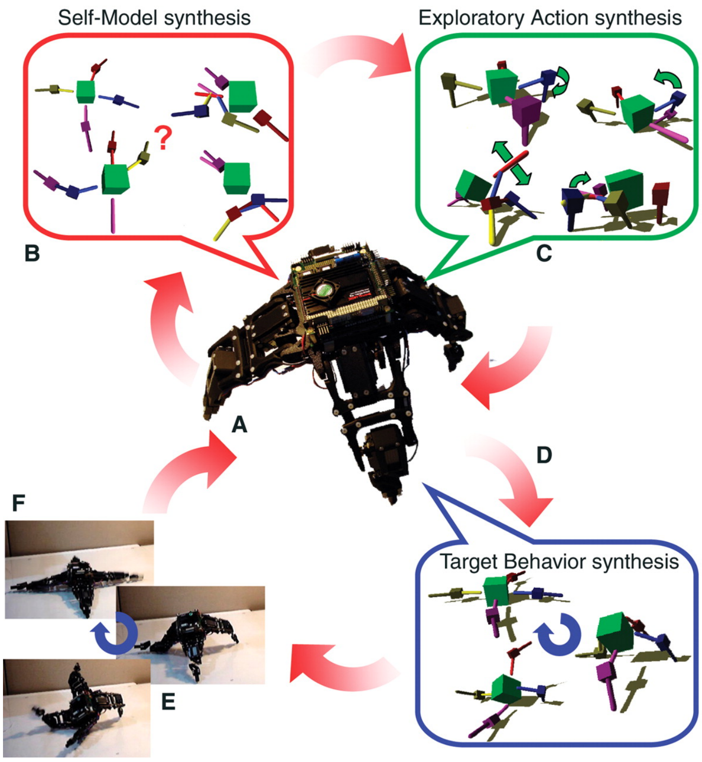


Figure 3: Start at A, cycle A-C around 16 times to build the model. Evaluate walking in simulation, Best simulation is implimented on the robot. From[4]fig 1

- When disagreement is high, reinitiate the 'model generation and evaluation' cycles.

Some info on the neural network based learning of movements is covered in[5]
Internal model done with the Open Dynamics Engine (www.ode.org)

## 2.1 SUPPLEMENTAL MATERIAL

### 2.1.1 Video

Part I three cycles of model synthesis and action synthesis (Fig. 1A-C).
Part II locomotion synthesis using the best self-model (Fig. 1D).
Part III the physical robot executing the best behavior (Fig. 1E).
Part IV a sample experiment after the robot suffers damage. The robot is shown alternating self-modeling with exploratory action (Fig. 1A-C); then, the best compensatory gait is shown running on the self- model (Fig. 1D), after which it is executed by the physical robot (Fig. 1E).
Part V some other compensatory gaits,
(https://youtu.be/x579QKA6fkY)
(https://youtu.be/ehno85yI-sA?t=69)

## REFERENCES

[1] J.L. Krichmar and G.M. Edelman. "Machine psychology: autonomous behavior, perceptual categorization and conditioning in a brain-based device". In: *Cerebral Cortex* 12.8 (2002), p. 818. DOI: 10.1093/cercor/12.8.818 (cit. on pp. 1, 2).

[2] B.R. Cox and J.L. Krichmar. "Neuromodulation as a Robot Controller". In: *IEEE Robotics and Automation Magazine* 16.3 (2009), pp. 72–80. DOI: 10.1109/MRA.2009.933628 (cit. on p. 1).

[3] Michael Beyeler et al. "CARLsim 3: A user-friendly and highly optimized library for the creation of neurobiologically detailed spiking neural networks". In: *Neural Networks (IJCNN), 2015 International Joint Conference on*. IEEE. 2015, pp. 1–8 (cit. on p. 1).

[4] Josh Bongard, Victor Zykov, and Hod Lipson. "Resilient machines through continuous self-modeling". In: *Science* 314.5802 (2006), pp. 1118–1121. URL: http://sclab.yonsei.ac.kr/courses/11cognitive/11cognitive.files/referred/10.pdf (cit. on pp. 2–5).

[5] Josh Bongard and Hod Lipson. "Automatic Synthesis of Multiple Internal Models Through Active Exploration". In: *American Association for Artificial Intelligence, Fall Symposiumon Reactive to Anticipatory Cognitive Embodied Systems*. 2005. URL: http://www.aaai.org/Papers/Symposia/Fall/2005/FS-05-05/FS05-05-004.pdf (cit. on p. 3).

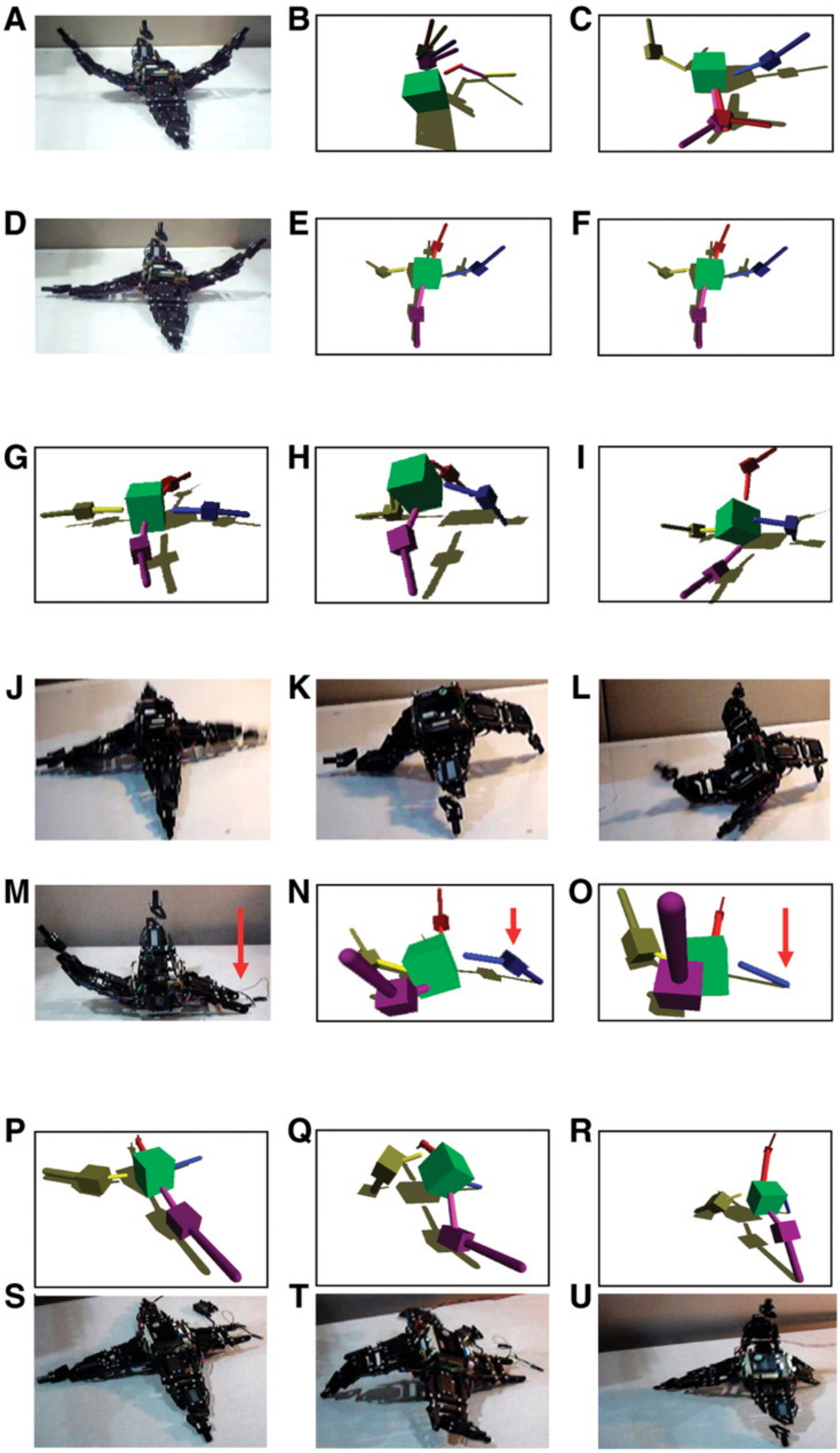


Figure 4: A and D try random actions, B,C,E,F try to fit a model. G,H,I try to walk in simulation. J,K,L try the walk on the robot. M Inflict damage, N,O, large errors therefore reinitiate modelling (this time only the limb lengths get changed), P,Q,R evaluate a new gait on model, S,T,U evaluate new gait on robot. From[4]fig 2

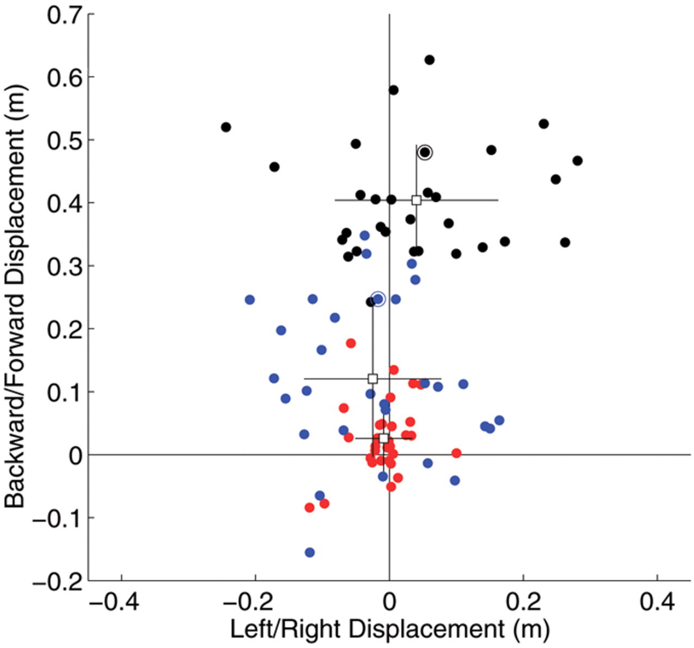


Figure 5: Evaluation of the ability the robot has to use its internal represent to survive in the real world. Red dots=random behaviour, Black dots=evaluation of movement from internal model, Blue dots=actual movement. From[4]fig 3