Embodied Biological Neural Networks

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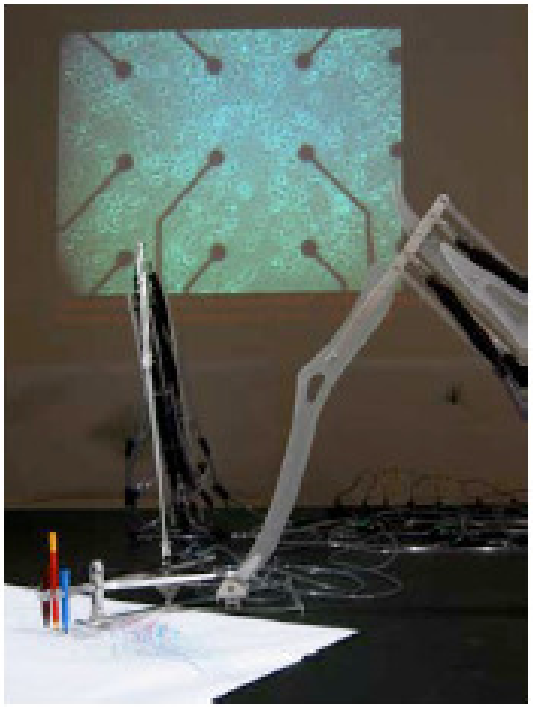
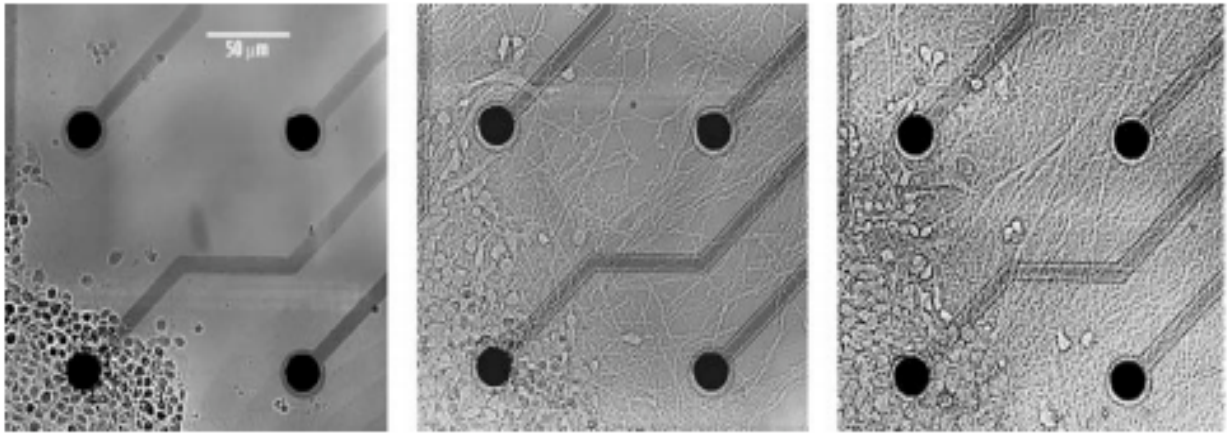
Embodied Cultures



- Networks of biological neurons controlling simulated animals and robots
- Allows for detailed observation of learning, memory, and information processing in real time
- Benefits for both the AI and neuroscience communities
  - Informs AI approaches
  - More detailed observation of working networks than in vivo experiments

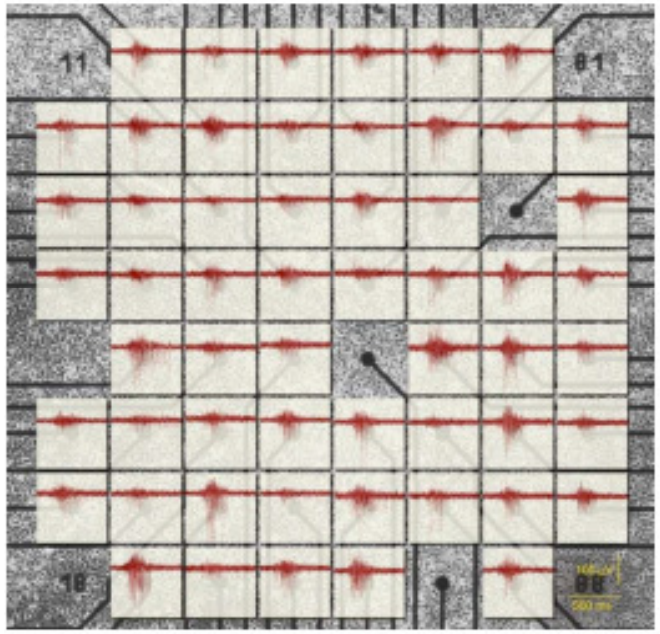
How It's Done

- Brain tissue dissociated from an embryonic-day-18 rat cortex
  - All prior structure lost
  - Number of neurons on the order of tens of thousands
- Suspension deposited onto a multi-electrode array (MEA)
- Neurons allowed to grow for several weeks before experimentation
- Cultures can survive for up to two years



How It's Done cont.

- The MEA consists of 60 electrodes which can both record neural activity and supply stimulation to the culture
- Recorded signals are interpreted as motor commands
- Stimuli represent sensory feedback to the system
- Culture can then be used to control a computer simulated animal ('animat') or robot ('hybrot')



Limitations

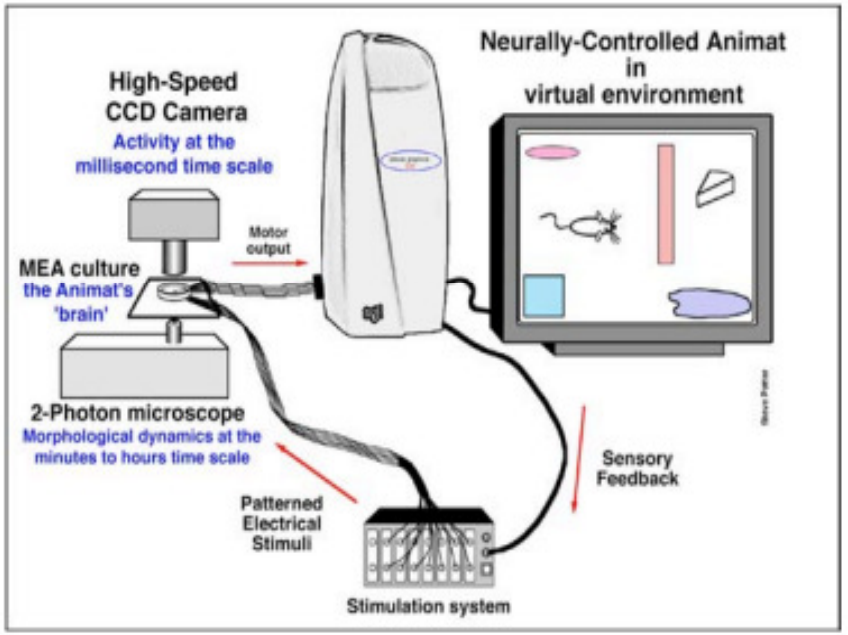
- Cultures are restricted to a 2D structure
- Can only record and stimulate clusters of neurons, not individuals
- We don't know how information is encoded in the brain, so input/output mapping is semi-arbitrary
- Learning in biological neural nets is poorly understood, so inducing purposeful learning is difficult

The Neurally Controlled Animat: Biological Brains Acting with Simulated Bodies

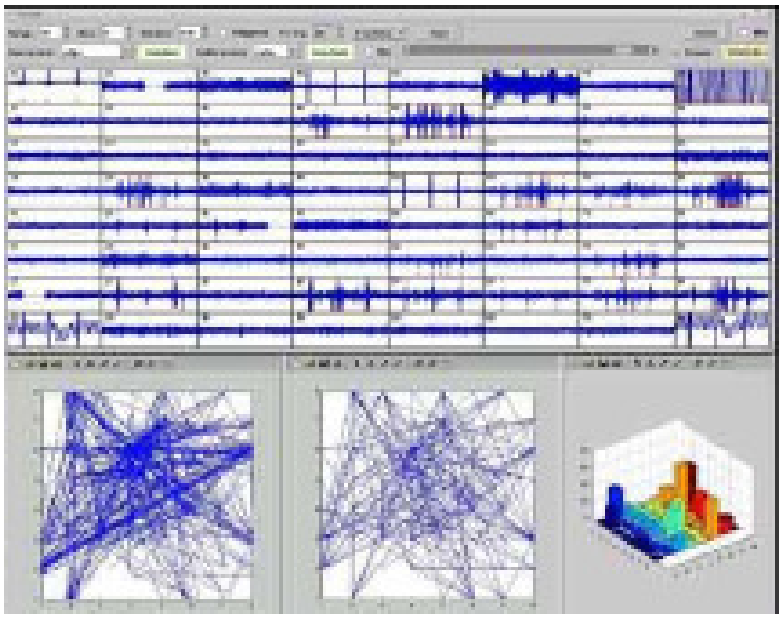
Demarse, Wagenaar, Blau, and Potter (2001)

Neurally-Controlled Animat

- Neural culture used to control an animat in a simulated environment
- Environment was a simple room with obstacles
- Preliminary experiment, so no particular goal besides creation



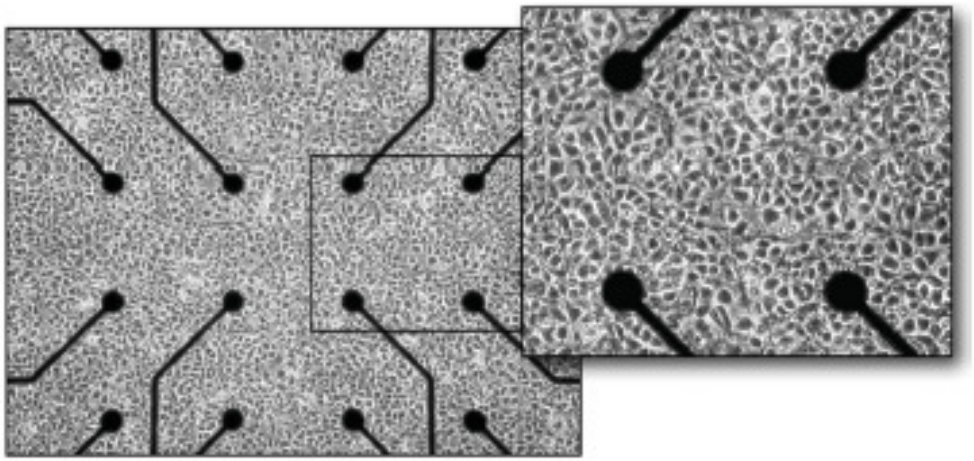
Mapping Activity to Movement

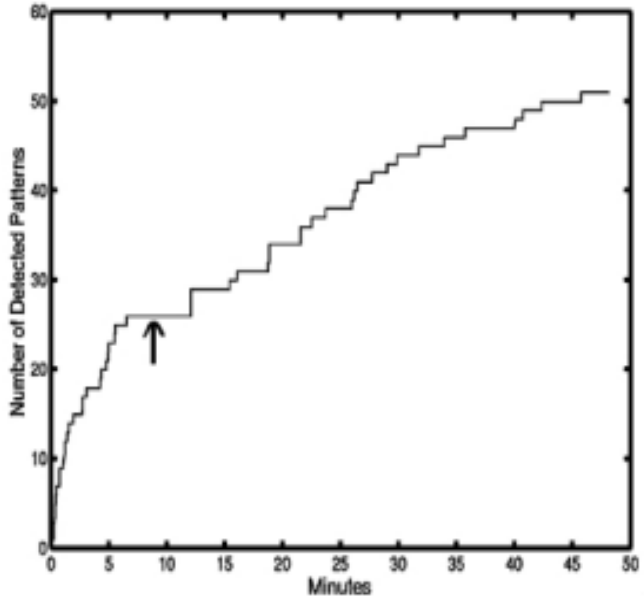


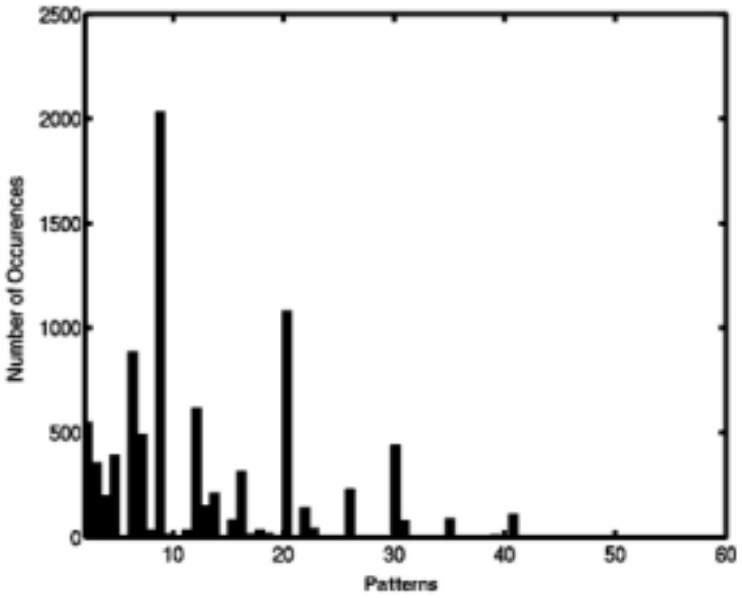
- Activity at each electrode integrated and exponentially decayed following each spike
- Every 200ms, activity sampled and clustered into patterns
- Patterns are arbitrarily assigned movement direction

Feedback

- Feedback provided for movement in each direction, as well as collision with objects and walls
- 5 channels used for feedback, one for each type
- Movement feedback occurred 100ms after pattern detection

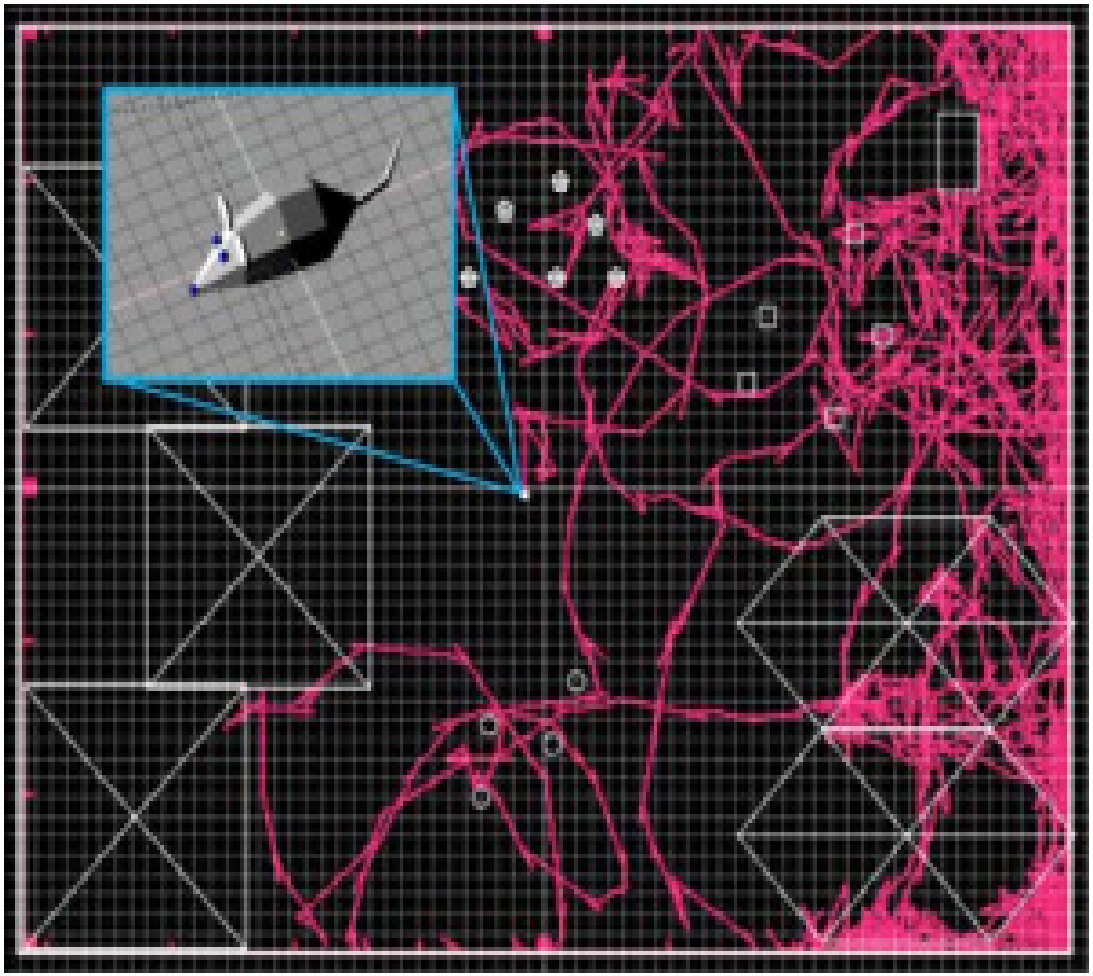






Results

- Clustering algorithm run for 8 minutes without feedback, and then run with feedback for ~1 hour
- Number of patterns grew once feedback kicked in
- Patterns often occurred in sequences of two or three which would repeat, and then reassemble
- Learning occurred, but not in any sort of purposeful way



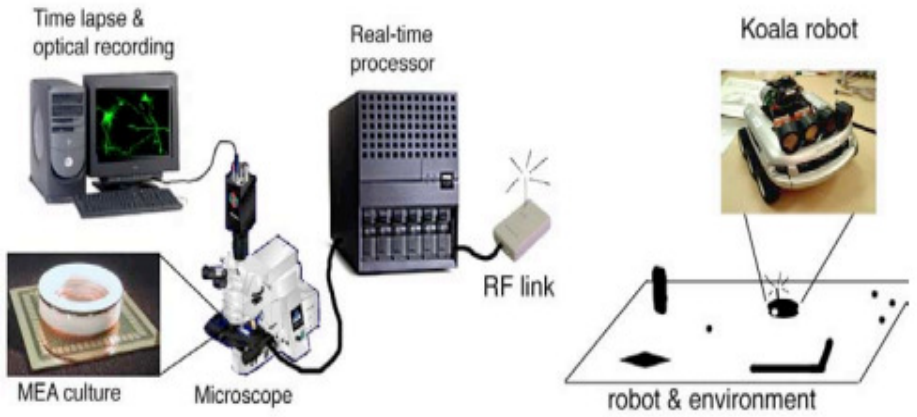
Neurally Controlled Simulated Robot:

Applying Cultured Neurons to Handle an Approach / Avoidance Task in Real Time

and a Framework for Studying Learning in Vitro

Shkolnik (2003)

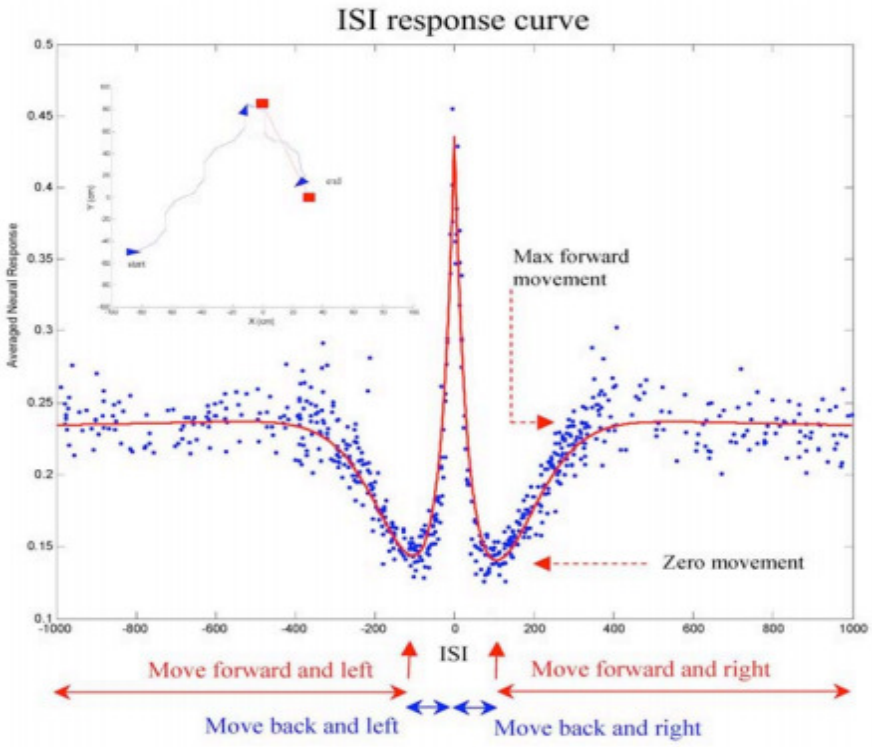
Neurally-Controlled Robot



- Mobile robot control designed for approach and avoidance
- Mapped movement onto a repeatable neural response

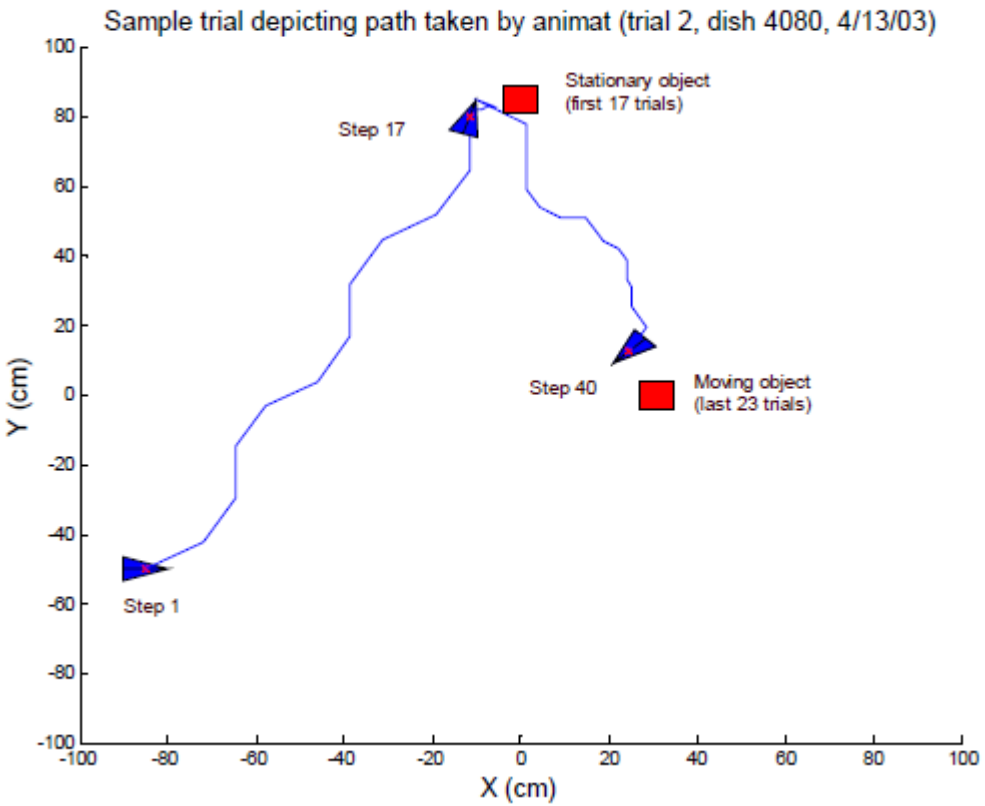
Input/Output Mapping

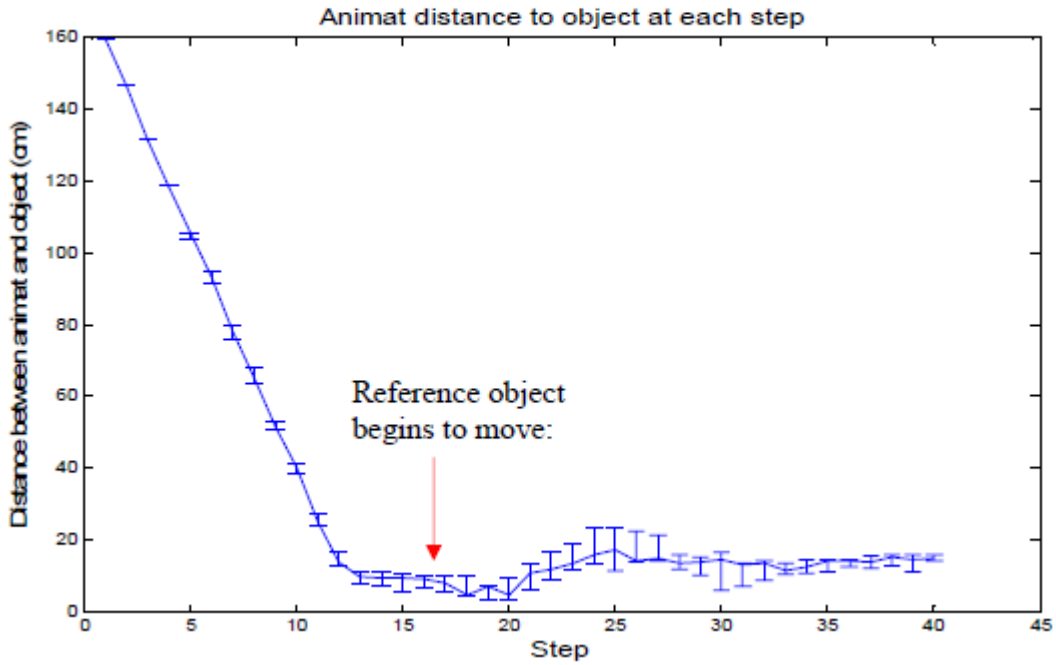
- Network produced a consistent response to pairs of stimuli separated spatially and temporally by an inter-stimulus interval (ISI)
- Length of ISI proportional to distance from other robot
- Response defined by average firing rates 100ms following the stimuli
- Distance and direction can be decoded from neural response



Results

- Successfully maintained desired distance from moving target
- Learning occurred, but not particularly purposeful

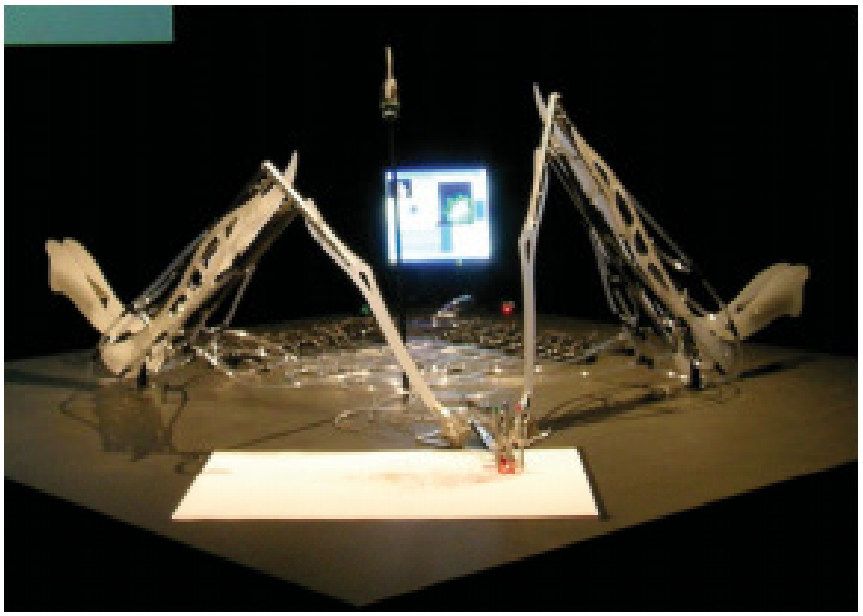




MEART: The Semi-Living Artist

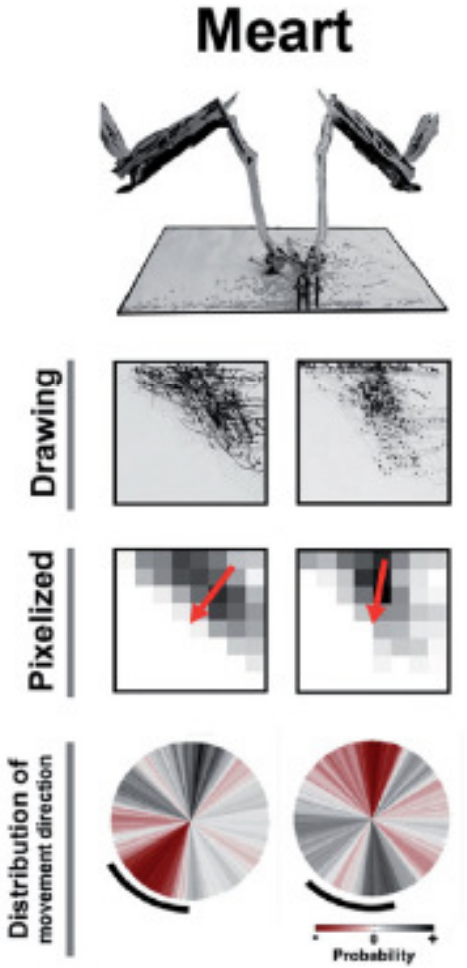
Bakkum, Gamblen, Ben-Ary, Chao, and Potter (2007)

MEART: The Semi-Living Artist



- MEA connected to two robotic arms which can draw on a canvas
- Remote connection: MEA at Georgiatech, arms at various exhibits
- Attempt at goal-oriented training

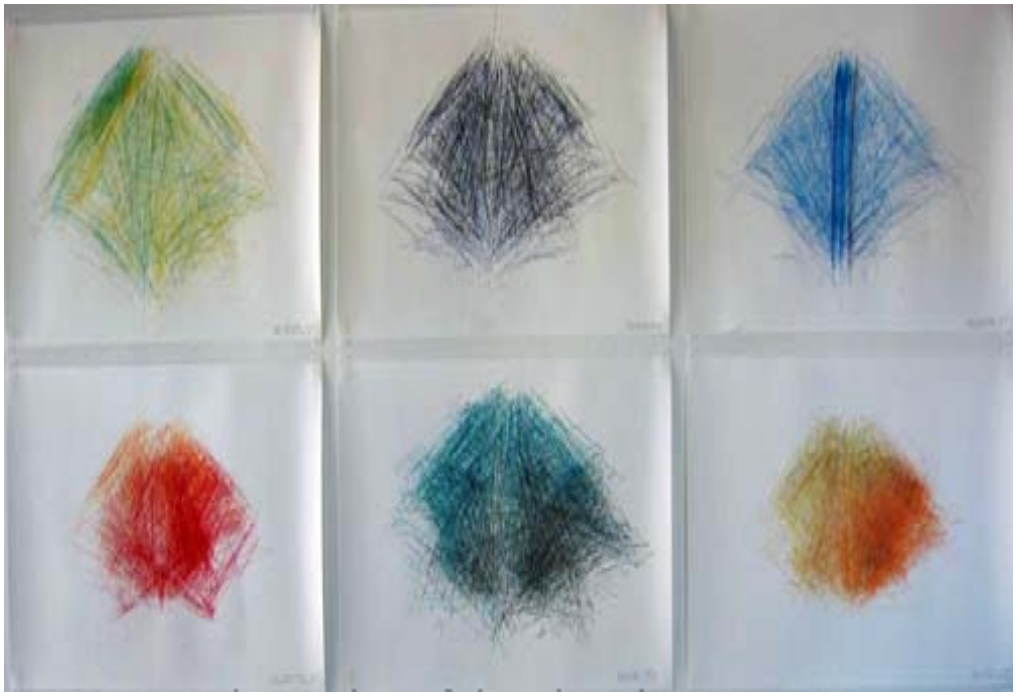
Motor Mapping



- Uses population vector coding, based on current theories of mapping in the motor cortex
- Vector sum of spatial locations of electrodes weighted by activity used to determine next arm movement
- Network input has varied between exhibitions

Portrait Series

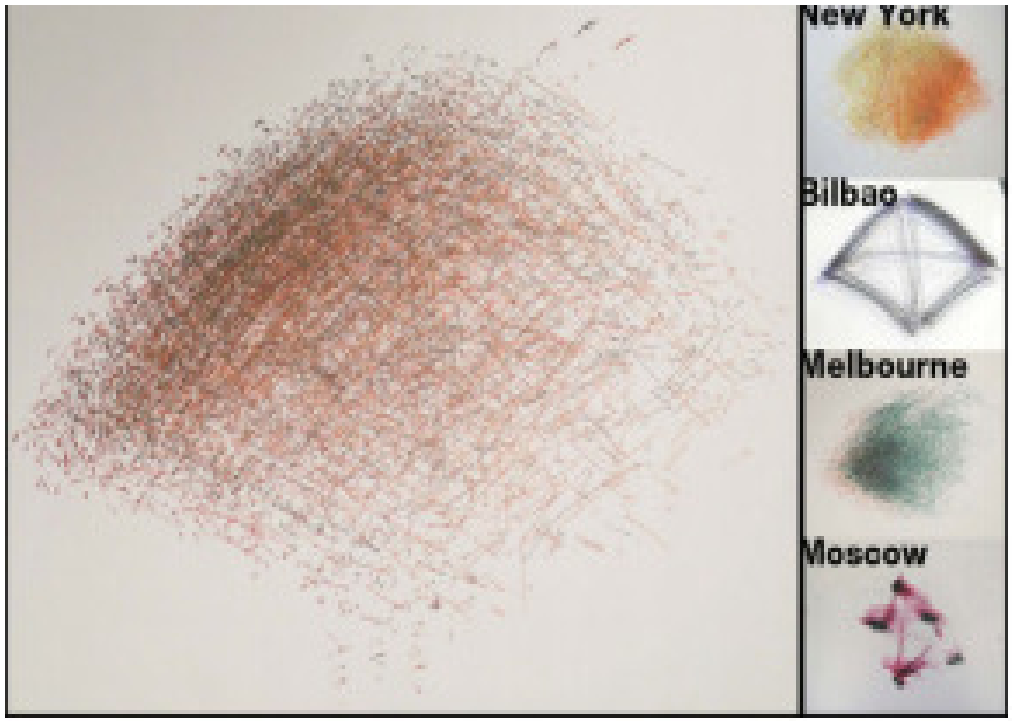
- A picture of a person is taken and reduced to 60 pixels
- Every 5 min a picture of current progress in the drawing is taken, and also reduced to 60 pixels
- Error matrix calculated by comparing the two, and then directly mapped to the 60 electrodes




philip
jenny
douglas
henry & jonnette
cindy
chase

Black Box Series

- Attempt to train MEART to fill in a black square
- Picture of progress taken at 5 minute intervals
- If majority of markings in box, leave it alone
- If not, plasticity induced by patterned training stimulation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