


PSYCO 457
Week 10: Navigating – Three Views of Moving Through the World


The Disembodied Mind
 Reorienting With Disembodied Modules
 The Brain as Body
 Reorienting With Networks
 Embodied Robots
 Sense-Act Reorientation

The Western Self

- Western thought has a deeply entrenched distinction between the mind and body, or between the self and the world
- “The division [between mind and body] is so deep-seated that it has affected even our language. We have no word by which to name mind-body in a unified wholeness of operation” (John Dewey, 1928)
- “Consciousness is what makes the mind-body problem really intractable” (Thomas Nagel)




John Dewey



Thomas Nagel

The Disembodied Mind

- Our notion of the self distinct from the world, of the mind distinct from the body, is rooted in 17th century Cartesian philosophy
- “I think therefore I am”
- For Descartes, the essence of the soul was “only to think”, and the possession of the soul distinguished us from the animals (Descartes, 1637/1960). Because they lacked souls, animals could not be distinguished from machines: “If there were any machines which had the organs and appearance of a monkey or of some other unreasoning animal, we would have no way of telling that it was not of the same nature as these animals” (p. 41).
- In short, the soul or self or mind is not a machine – it is separate from the physical





Descartes

Disembodiment In The Matrix


- The notion of the disembodied mind is illustrated in the 1999 movie *The Matrix*, in which the characters don't experience reality – they instead experience a world simulated by their minds on the basis of input stimulation
- Spoon boy:** Do not try and bend the spoon. That's impossible. Instead... only try to realize the truth.
Neo: What truth?
Spoon boy: There is no spoon.
Neo: There is no spoon?
Spoon boy: Then you'll see, that it is not the spoon that bends, it is only yourself.

Mind






World

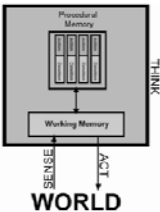


Cognitivism and Disembodiment

- Cartesian disembodiment is a central, tacit assumption of symbolic or classical cognitive science
- The mind works by using inputs to build a model of the world, and uses this model to plan action
- Sense-think-act cycle
- Hurley's “classical sandwich”




Susan Hurley




Example: Cognitive Map

- “The stimuli which are allowed in are not connected by just simple one-to-one switches to the outgoing responses. Rather the incoming impulses are usually worked over and elaborated in the central control room into a tentative cognitive-like map of the environment. And it is this tentative map, indicating routes and paths and environmental relationships, which finally determines what responses, if any, the animal will finally make.” (Tolman, 1948, p192)



Edward C. Tolman



Place cells in the hippocampus as the cognitive map

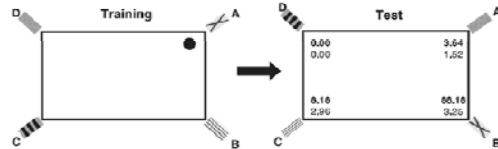
The Reorientation Task

- Find a reinforced location in an arena
- Use geometric information (shape)
- Use local information (wall color, landmarks)
- Later, reorient one's self to the goal location when placed in new arena
- How is this accomplished?
- What cues are used?
- What happens when geometric and local cues conflict?



Affine Transformation

- When landmarks are rotated, this is equivalent to an affine transformation of the entire shape of the arena. How will the agent reorient – will it use the landmarks alone?



Rotational Error

- Geometric cues on their own are ambiguous
- Rotational error: go to A and C mostly and equally, and rarely go to B or D
- Rotational error is often viewed as evidence of geometric cues being processed by a geometric module

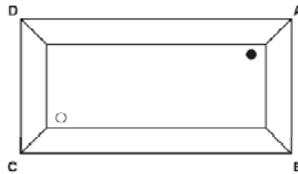


Figure 1 Schematic representation of the geometrical information which is available in a rectangular-shaped environment. The target filled dot stands in the same geometric relation to the shape of the environment as its rotational equivalent (open dot). Metric information (i.e. distinction between a short and a long wall) together with sense (i.e. distinction between left and right) suffices to distinguish between locations A-C and locations B-D, but not to distinguish between A and C, (or between B and D).

Geometric Representation

- Rotational error is often explained by appealing to geometric representations
- “One unit of the mind, which I will call the metric frame, encodes only the geometric properties in the arrangement of surfaces as surfaces. It encodes the shape of the environment, including the displacement properties in that shape” (Cheng, 1986)



Ken Cheng

SLAM: The Thinking Navigator

- To explain reorientation, and rotational error, by appealing to a geometric module is an example of exploiting disembodied sense-think-act processing
- Gallistel (1990, p. 121) notes “orienting towards points in the environment by virtue of the position the point occupies in the larger environmental framework is the rule rather than the exception and, thus, cognitive maps are ubiquitous.”
- Similar accounts for robots, such as SLAM (simultaneous localization and mapping), are common
- “Low level robots may function quite adequately in their environment using simple reactive behaviors and random exploration, but more advanced capabilities require some type of mapping and navigation system” (Milford, 2008, p. 10).



Randy Gallistel



Michael Milford

Against The Disembodied

- Classical cognitive science, with its tacit views of disembodiment and logicism, is comfortable with the notion of mind as “software” running on a computer
- Connectionism has reacted strongly against this view
- “These dissimilarities do not imply that brains are not computers, but only that brains are not serial digital computers” (Churchland, Koch & Sejnowski, 1990)
- “Classical rule-and-symbol-based AI may have made a fundamental error, mistaking the cognitive profile of the agent plus the environment for the cognitive profile of the naked brain” (Clark, 1997)



Patricia Churchland



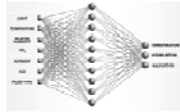
Andy Clark

Connectionist Cognitive Science

- Connectionism can be viewed as a perspective on mind that abandons Descartes, and instead accepts Locke
- “No man’s knowledge here can go beyond his experience”
- Artificial neural networks are viewed as blank, neuronally inspired, slates that can be shaped by the environment
- The result is a messy, distributed set of pattern recognizing associations compatible with the brain, and incompatible with logicism

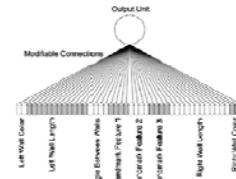


John Locke



A Reorienting Network

- Connectionism has been used to explore the reorientation task
- Dawson et al. defined the reorientation task for a very simple kind of artificial neural network, the perceptron
- The perceptron was reinforced at the correct location, and not at the other locations
- The perceptron generated a wide variety of reorientation task phenomena



Nonmodular Reorientation

- The table below shows how the perceptron generates effects that might be interpreted as revealing a geometric module in a version of the reorientation task that provides both geometric and featural cues
- However, Dawson et al. point out that the perceptron necessarily uses nonmodular, associative treatments of all available cues

Table 4
Average responses of perceptrons to each arena location in Session 10. Location 4 was the reinforced location (i.e. the reward center)

Response type	Arena location	Arena condition			
		Objects in original location	Objects moved to location on right	Objects removed from original and added to location	All objects removed
Perceptual activity	Near	0.04	0.45	0.04	0.05
	Intermediate	0.09	0.29	0.40	0.40
	Far	0.05	0.01	0.05	0.04
	Correct	0.99	0.28	0.49	0.49
Choice rate	Near	0.04	0.45	0.05	0.05
	Intermediate	0.08	0.28	0.49	0.49
	Far	0.05	0.01	0.05	0.07
	Correct	0.95	0.38	0.48	0.49

Embodying The Internal

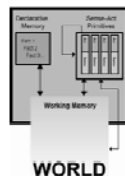
- On the one hand, connectionism can be viewed as taking embodiment more seriously than can classical cognitive science
- This is because connectionism views the embodiment of the brain as critical to cognition
- On the other hand, connectionism is disembodied in the sense that it does not pay attention to the relation of the brain to the world at large
- “Highly artificial choices of input and output representations and poor choices of problem domains have, I believe, robbed the neural network revolution of some of its initial momentum. [...] The worry is, in essence, that a good deal of the research on artificial neural networks leaned too heavily on a rather classical conception of the nature of the problems” (Clark, 1997)



Andy Clark

The Extended Mind

- Embodied cognitive science views the mind as being scaffolded by, and leaking into, the world
- One cannot define the mind without defining the body and the world as interacting
- “Advanced cognition depends crucially on our abilities to dissipate reasoning: to diffuse knowledge and practical wisdom through complex social structures, and to reduce the loads on individual brains by locating those brains in complex webs of linguistic, social, political, and institutional constraints” (Clark, 1997).
- “By failing to understand the source of the computational power in our interactions with simple ‘unintelligent’ physical devices, we position ourselves well to squander opportunities with so-called intelligent computers” (Hutchins, 1995, p. 171)



Behavior-Based Robotics

- Behavior-based roboticists attempt to remove thinking or representation to speed processing up
- Why represent the world, when it can represent itself and be available to our active exploration?
- “In particular I have advocated situatedness, embodiment, and highly reactive architectures with no reasoning systems, no manipulable representations, no symbols, and totally decentralized computation” (Brooks, 1999, p. 170).
- “Consciousness is not something the brain achieves on its own. Consciousness requires the joint operation of brain, body, and world” (Noe, 2009, p. 10)



Rodney Brooks



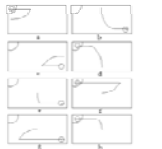
Alva Noe

Evolving Reorientation

- Nolfi uses simple robots with an array of sensors capable of detecting walls, and controlling the speed of motors
- He has used evolutionary computation to develop a controller that delivers rotational error
- "The sensory states of the robot permit it to indirectly measure the relative lengths of walls without directly comparing or representing length. It will use this sensed information to follow the long wall, which will necessarily lead the robot to either the goal corner or the corner that results in a rotational error, regardless of the actual dimensions of the rectangular arena" (Dawson, Dupuis & Wilson, 2010)



Stefano Nolfi



The robot follows the long wall and reaches the goal corner. The path is shown in a rectangular arena. The robot starts at the bottom left corner and moves clockwise, following the walls. The path is shown in a rectangular arena. The robot starts at the bottom left corner and moves clockwise, following the walls. The path is shown in a rectangular arena. The robot starts at the bottom left corner and moves clockwise, following the walls.

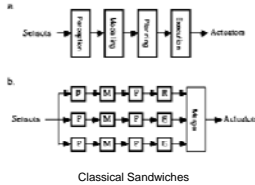
Case Study: antiSLAM

- Can we build a navigational robot that does not do SLAM, that does not build and use cognitive maps, but just reacts to its environment as it seems to navigate through it?
- Can we build it from LEGO, and abandon Nolfi's evolutionary approach?
- Can it generate rotational error in the reorientation task, without using representations?



Layers Of Behaviors

- The *subsumption architecture* is an explicit reaction against the classical sandwich, and was pioneered by Rodney Brooks
- antiSLAM is programmed using a particular instance of the subsumption architecture



Classical Sandwiches



Subsumption Architecture

antiSlam Level 0

- "We start by building a complete robot control system which achieves level 0 competence. It is debugged thoroughly. We never alter that system" (Brooks, 1999, p.10)
- Our choice for Tortoise Level 0 is *drive*

Feed the distance from each ultrasonic sensor to a motor. The robot is wired contralaterally, and thus avoids all walls equally. As a result, when it reaches a corner, it slows down and ends up stopping in the corner "for free".

```
task DriveRight(){
  while(true){
    OnPwr(RightMotor, RightSpeed);
  }
}

task DriveLeft(){
  while(true){
    OnPwr(LeftMotor, LeftSpeed);
  }
}
```

Level 1: Escape Corners

- AntiSlam Level 1 is *escape*

```
/*-----Level 1: Escape-----*/
If the motors move less than a stated threshold over a delay period,
the robot's sensors are temporarily overridden (zero sensitivity) as it
spins around. It ends up pointing approx. 45 degrees from the corner
when normal operation resumes.
*/

int Threshold, Delay;

task Retreat(){
  long RotCount;//Tracks motor rotation.
  while(true){
    RotCount = MotorRotationCount(LeftMotor) + MotorRotationCount(RightMotor);
    Wait(Delay);
    if((MotorRotationCount(LeftMotor)+MotorRotationCount(RightMotor)-RotCount)
    < Threshold){ //If, after Delay, the motors haven't moved enough:
      PlayTone(440, 500); //Beep to indicate feature flipping
      Sensitivity = 0; Reverse = 35; //Disable sensors, enable spin term
      Wait(4000); //Time to spin in milliseconds
      Reverse = 0; Sensitivity = 1; //Return to default settings
      ResetRotationCount(LeftMotor); ResetRotationCount(RightMotor);
      Wait(500);
    }
  }
}
```

Level 2: Follow Walls

- AntiSlam Level 2 is *Follow Walls*

```
/*-----Level 2: Follow-----*/
Introduce a bias in the robot's movement. This bias varies depending on its
preferred side (which sensor it reads), and results in the robot turning toward
a wall. The bias overcomes its natural wall aversion (level 0), causing it to
follow a wall more closely on one side.
*/

//Return the value of the sensor nearest the wall.
int Nearest(bool hand) { //Note: "nearest" is defined by which handedness the robot's using.
  True = left.

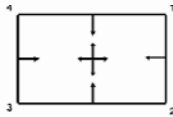
  if (hand) return SensorUS(LeftEar);
  else return SensorUS(RightEar);
}

bool preferred;

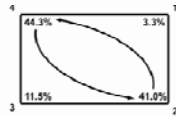
task Seek(){
  int bias;
  while(true){
    bias = Nearest(preferred) * (-1) + 40; //Linear function! Wall dist. -> bias
    if (bias < 5) bias = 5; //Constraint: No zero or negative biases
    //Assign the bias to the correct motor and unbias the other one.
    if (preferred) (RightBias = bias/ LeftBias = 0)
    else (LeftBias = bias/ RightBias = 0);
  }
}
```

antiSLAM's Rotational Error

- Using Levels 0 through 2 alone, antiSLAM will generate rotational error, without using cognitive maps, and without relying on associative cues



Starting States for antiSLAM



Locations of tumarounds

Level 3: Move To Light

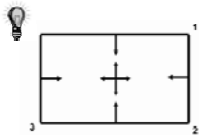
- AntiSlam Level 3 is *light attraction*
- Light sensors affect motors to attract robot to light, while interacting with other levels
- Nolff's robots were not sensitive to features
- Now a lit corner can be described as the "place with the correct landmark"

```

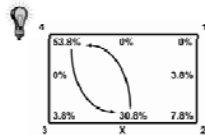
//Level 3: Feature
//Add and read the light sensors (eyes) as a percentage based on "Vision"
//a sensitivity term, such that more light = more speed. Since the connection is contralateral, this results in the
//robot turning toward sources of light = more speed.
//However, level -1 weights this visual sense with the earlier ultrasonic sense,
//allowing both terms to influence the robot's final behavior.
//in Vision: //The strength of the light sensors is percent.
task see(){
//Data the strength of the robot's visual response to a scaled percentage.
while(true){
LVis = Sensor(LeftEye)*Vision/100;
RVis = Sensor(RightEye)*Vision/100;
}
}
    
```

Light Cooperates With Geometry

- We can test antiSLAM when the light cue cooperates with geometric information
- Using all 3 levels, antiSLAM prefers the lit corner
- Note how its trajectory is altered compared to the previous study



Starting States for antiSLAM



Locations of tumarounds

Light Competes With Geometry

- When cues are in conflict, antiSLAM generates animal-like behavior that reflects combined influences of local and geometric features
- It prefers the light, but also generates rotational error
- It also generates very complex trajectories – data not typically reported in animal studies
- Note that all of this was obtained "for free" by building a robot that would follow walls, escape corners, and be attracted to light
- Might navigation be scaffolded exploration?

