COGS 200 **Notes** **November 18, 2014**

Readings Summary

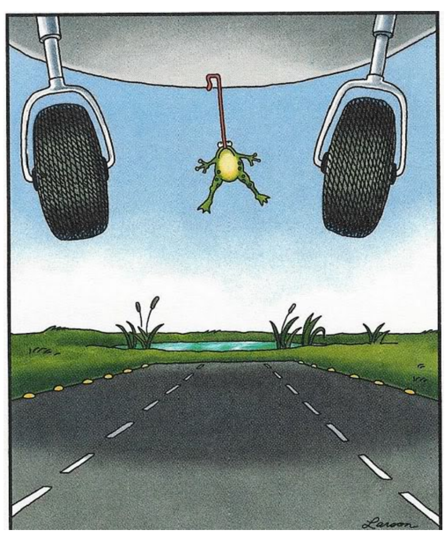
Mackworth, Alan K. (2009). "Agents, bodies, constraints, dynamics, and evolution." *AI Magazine* 30(1)7–28

- Article is about, "agents with bodies subject to constraints on their *dynamics* as they undergo *evolution"*
- An agent in an *active* environment *changes* that environment and, in turn, is *changed* by that environment as each evolves with *time*
- Mackworth's thesis is, "constraint satisfaction is central to intelligent behavior"
- Mackworth critiques Good Old-Fashioned AI and Robotics (GOFAIR)

Today's Learning Goals

1. To explore constraints on *embodied* robotic systems so that they can interact with (and survive in) the real world
2. Examine the role the external environment plays in cognitive systems
   — Simon's ant
   — Brooks' "intelligence without representation"
   — Mackworth's "situated agents and constraints"
3. To complete Bob's computer science "story" for COGS 200

Example 1: Far Side Cartoon (Bob's Coffee Mug)



Cartoon credit: Gary Larson, 1984

Example 1 (cont'd): The Frog's Eye

In the 1959 paper,

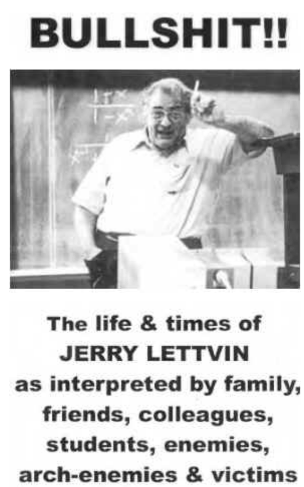
J.Y. Lettvin, H.R. Maturana, W.S. McCulloch and W.H. Pitts, "What The Frog's Eye Tells The Frog's Brain," *Proceedings of the IRE* (47)1940–1951, 1959. (reprinted here)

Lettvin and his co-authors provided the first demonstration of "feature detectors" – the idea that specific neurons respond to specific features of a visual stimulus, including edges and contrast, curvature, movement and changes in light levels

They described certain frog retinal fibers as "bug perceivers," groups of cells that respond preferentially to small, dark objects that enter the visual field, stop, and then move around intermittently

This work has had a profound and lasting impact on the fields of neuroscience, physiology and cognition

Jerome Lettvin (February 23, 1920 – April 23, 2011)



Program cover, Jerry Lettvin's memorial, September 25, 2011

A memorial service for Jerry Lettvin was held at MIT on September 25, 2011. In a blog posting that day, Patrick Winston included this story Jerry once told in Winston's class about the early frog work.

> One year he told the story of the German Scientists. To me, the story reflected what Jerry was all about: big ideas rather than incrementalism, blue-collar dress rather than sartorialism, meritocracy rather than pedigree.
>
> Here is the story as Jerry told it: He got a call one day from a friend in California. The friend said, "I have some foreign visitors who have not been able to duplicate your frog experiment. They are planning to publish a paper that claims your work is a fraud. Will you come show them the technique?"

> "Do they wear white lab coats?" Jerry asked.
>
> "Yes."
>
> "Are they Germans?"
>
> "Yes."
>
> "I'll come."
>
> Jerry spent some time deciding what to wear. He finally settled on a thoroughly stained yellow dress shirt and well-worn work pants.
>
> When he showed up, he was escorted into the experiment room. He reported that the place looked more like an operating room for open heart surgery on humans than a place to stick needles into the optic nerves of frogs.
>
> "We have assembled some instruments for you," said his friend, pointing to an immaculate tray of scalpels, clamps, and other paraphernalia.
>
> "That's ok," said Jerry, "I brought my own." Then, he reached into his pocket and pulled out a pair of needle-nose pliers and a pair of diagonal cutters.
>
> A minute or two later, with the frog prepared, the German scientists were waiting skeptically to see if anything at all would come out of the speakers attached to the amplifier attached to the needle Jerry had stuck into the frog.
>
> Then, Jerry passed black dot the size of a fly past the frog's eye.
>
> "Brrrrrrrrrrrrrrrrrup."

Lettvin was known for his consummate debating skills. At MIT, he was often conscripted (by faculty and students alike) to debate with anyone on any topic, often extemporaneously. Lettvin would take any side and, according to his son Jonathan, believed that, "if you can't argue your opponent's position, you have no right to your own argument."

On May 3, 1967, Lettvin debated Timothy Leary about the merits and dangers of the hallucinogenic drug LSD. On September 23, 2011, WGBH, the Boston PBS station, posted video of the Lettvin vs. Leary LSD debate to its OpenVault archive. The 1967 debate was held in MIT's Kresge Auditorium, coincidently the same venue as the MIT150 Celebration Symposium: Brains, Minds, and Machines, May 3–5, 2011, 44 years later.

Steven Pinker made an oblique reference to Lettvin during his introduction of the Keynote Panel: The Golden Age – A Look at the Original Roots of Artificial Intelligence, Cognitive Science, and Neuroscience. Pinker repeated the John F. Kennedy quote, made at a dinner honouring Nobel laureates of the Western hemisphere,

> "I want to tell you how welcome you are to the White House. I think this is the most extraordinary collection of talent, of human knowledge, that has ever been gathered together at the White House, with the possible exception of when Thomas Jefferson dined alone."

Pinker then mused about who the Thomas Jefferson equivalent might be for the current occasion and suggested some would nominate Jerry Lettvin.

Example 2: Colour Changing Card Trick

An interesting video of a card trick is on YouTube

Point your web browser to

http://www.youtube.com/watch?v=v3iPrBrGSJM

Watch carefully. Can you figure out the colour changing trick?

Video credit: Richard Wiseman
http://www.quirkology.com

Example 3: Change Blindness

Change blindness is the failure to detect changes that are easily seen once noticed. Consider the following example

Airplane

Note: The example shown in class, as well as other examples of change blindness, can be found at

http://www.cs.ubc.ca/~rensink/flicker/download/

Even though we, as humans, have a strong impression that we see everything that happens in front of us, this impression is false. There are limits to what we consciously perceive at any given time.

Video credit: Ron Rensink

Simon's Ant

At the beginning of Chapter 3 of his book, *The Sciences of the Artificial*, (3rd ed.), Simon asks the reader to consider the path an ant might make while moving across a wind- and wave-molded beach. The path, sketched on a piece of paper, is a sequence of irregular, angular segments not entirely random since there is an underlying direction towards a goal.

To quote Simon, "Viewed as a geometric figure, the ant's path is irregular, complex, hard to describe. But its complexity is really a complexity in the surface of the beach, not a complexity in the ant."

Simon imagines a robotic ant equipped with a few simple adaptive capabilities such as:

- when faced with a steep slope, try climbing it obliquely
- when faced with an insuperable obstacle, try detouring
- and so on...

and poses the question, "How different would its behavior be from the behavior of the [real] ant?"

Simon's Parable of the Ant

Hypothesis:

"An ant, viewed as a behaving system, is quite simple. The apparent complexity of its behavior over time is largely a reflection of the complexity of the environment in which it finds itself."

H. A. Simon, "The Psychology of Thinking," Chapter 3 of *The Sciences of the Artificial*, (3rd ed.). MIT Press. 1996

Simon's Parable of the Ant (cont'd)

Hypothesis:

"Human beings, viewed as behaving systems, are quite simple. The apparent complexity of our behavior over time is largely a reflection of the complexity of the environment in which we find ourselves."

Hedges:

- Limit consideration to *Homo sapiens "thinking person"* (i.e., only look at cognition, not at behavior as a whole)
- View *"memory"* as part of the environment, more than as part of the organism

H. A. Simon, "The Psychology of Thinking," Chapter 3 of *The Sciences of the Artificial*, (3rd ed.). MIT Press. 1996

Example 4: Walter's *Machina speculatrix*

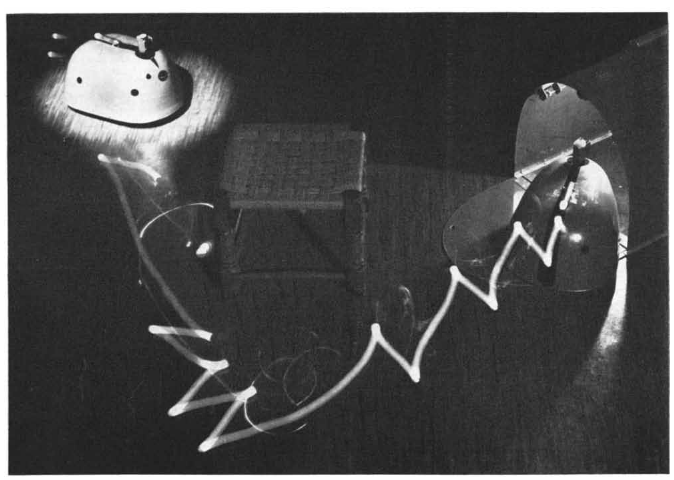


Image credit: W. Grey Walter, "A machine that learns," *Scientific American* 185(2)60–63, 1951

Brooks' "Intelligence without Representation"

Brooks' "Rethinking" the Organization of Intelligence (circa 1984)

- Most behaviour (i.e., what people do in their daily lives) is not problem solving or planning (in the traditional AI sense) but routine activity in a dynamic world
- An agent need not manipulate symbolic data structures at run time. But, an observer can still talk about an agent's beliefs and goals
- Testing ideas *requires* building complete agents which operate in dynamic environments using real sensors. Internal, complete representations of the external world *not necessary*

Architecture of GOFAIR

Brooks (like Mackworth) critiques the "horizontal" architecture of a GOFAIR robot

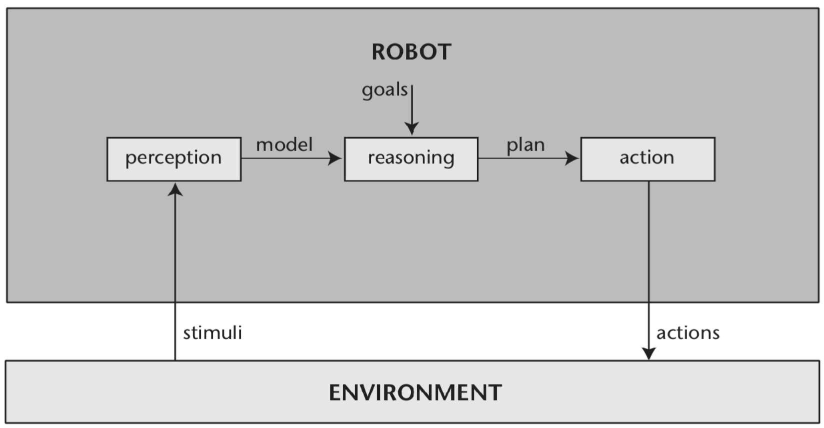
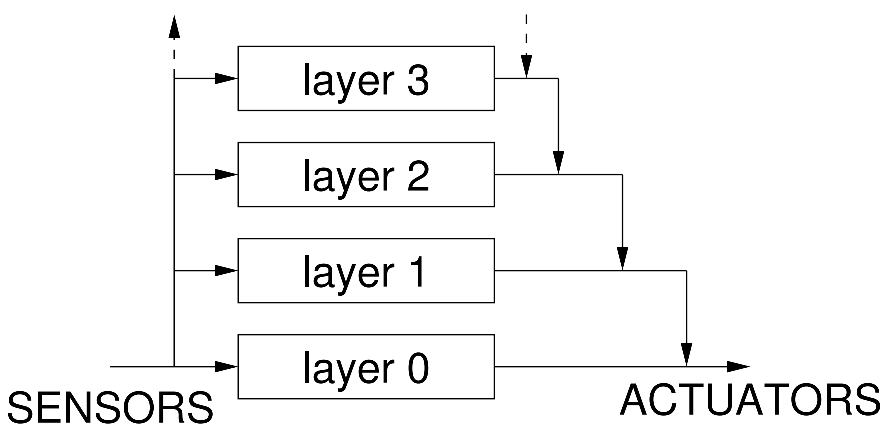


Figure credit: Mackworth, *AI Magazine*, 2009

Brooks' Subsumption Architecture



Idea: Make no distinction between different systems like "perception" and "cognition." Rather, have individual layers, organized vertically, each responsible for one activity

Brooks' Subsumption Architecture (cont'd)

- The robot is a collection of competing behaviours
- Multiple layers blur distinctions between where perception and action are occurring
- Sensor data is acted on by multiple layers working independently in parallel
- Low level activities allow fast reactions to dangerous circumstances without undue delay in data processing
- There's no central control, therefore less chance of total failure
- Each layer has its own goal. Each layer continuously monitors the environment and adjusts its output as needed
- Each layer has its own hardware. Adding a new layer doesn't slow down processing in existing layers
- The overall "purpose" of the robot is a property of the design of the higher-level layers

Brooks' Early MIT AI Lab Robots

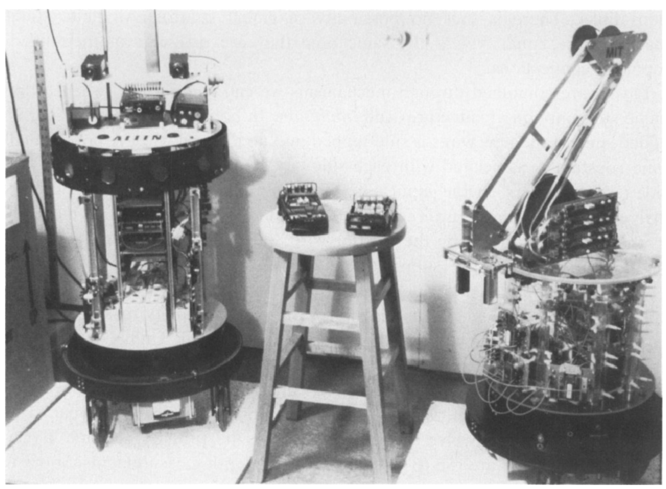


Figure credit: R. A. Brooks, "Intelligence without representation," *Artificial Intelligence*, 47(1-3)139–159, 1991

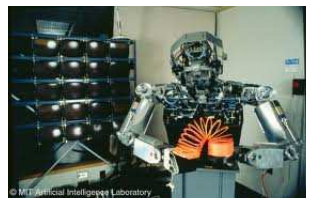
The left-most robot is the first built Allen (named after Allen Newell). The right-most robot is Herbert (named after Herbert Simon).

More Early Brooks' Robots...

Herbert

Genghis

Kismet



COG

Brooks' Key Principles

- *Situatedness*

  — The world is its own best model
- *Embodiment*

  — The world grounds regress
- *Intelligence*

  — Intelligence is determined by the dynamics of interaction with the world
- *Emergence*

  — Intelligence is in the eye of the observer

Situatedness

Robots are situated in the world. They do not deal with abstract descriptions, but with the here and now of the world directly influencing the behavior of the system

The world is its own best model

- A situated robot has input sensors and output actuators directly connected to the environment
- A situated robot responds directly to the environment in a timely fashion
- No intervening human control

Embodiment

Robots have bodies and experience the world directly. Their actions are part of a dynamic with the world and have immediate feedback on their own sensations

The world grounds regress

- Only an embodied agent is validated as one that can deal with the real world
- Only through a physical grounding can any internal symbolic system be given meaning

Intelligence

Robots are *observed* to be intelligent. But, the source of intelligence is not limited to the computational engine. It also comes from the situation in the world, the signal transformations within the sensors, and the physical coupling of the robot with the world

Intelligence is determined by the dynamics of interaction with the world

- *Homo sapiens* reasoning and language abilities are comparatively recent developments (in an evolutionary sense)
- Simple behaviours, perception and mobility, took much longer to evolve
- Look at simple animals (for inspiration)
- Look at the dynamics of interaction with the environment

Emergence

Intelligence emerges from the system's interactions with the world. It is sometimes hard to point to one event or place within the system and say that is why some external action was manifested

Intelligence is in the eye of the observer

- Intelligence emerges from (sometimes indirect) interactions among the system's components
- Individual components are simple
- Behaviour-based approach: intelligence emerges from interaction of simple modules (e.g., obstacle avoidance, goal finding, wall following)
- Resulting combined behaviour can appear intelligent

Mackworth's Situated Agents and Constraints

"Horizontal" Architecture of GOFAIR

Mackworth critiques the "horizontal" architecture of a GOFAIR robot

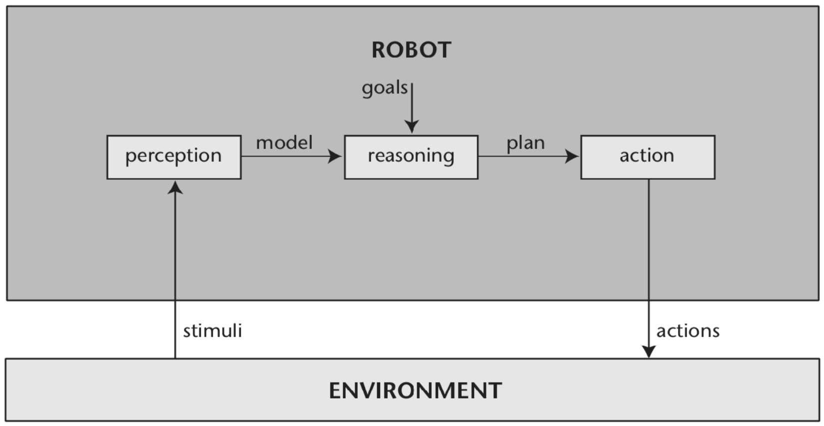


Figure credit: Mackworth, *AI Magazine*, 2009

Note: If we replace "robot" with "human" in Mackworth's diagram, we could also critique GOFCOGS

GOFAIR Metaassumptions

In a "cartoon" sense, a pure GOFAIR robot operates in a world that satisfies several metaassumptions:

- Single agent
- Agent executes actions serially
- Actions occur in a deterministic world
- World is a fully observable, closed world (i.e., Reiter's closed world assumption)
- Agent has a perfect internal model of infallible actions and world dynamics
- Perception is needed only to determine the initial world state
- A perfect plan to achieve the goal is obtained by reasoning, and executed in an open loop

Aside: The "closed world assumption" is the presumption that what is not currently known to be true is false. In contrast, an "open world assumption" holds that lack of knowledge does not imply falsity.

Mackworth's main critique of GOFAIR is that work in this paradigm typically fails to distinguish between the agent's world model and the world itself "because there really is no distinction in GOFAIR." Mackworth calls this "a classic mistake."

Mackworth claims that GOFAIR robots cannot play soccer! Thus, "robot soccer" is a way forward.

Robocup

RoboCup is an international competition (full name, "Robot Soccer World Cup")

The stated goal:

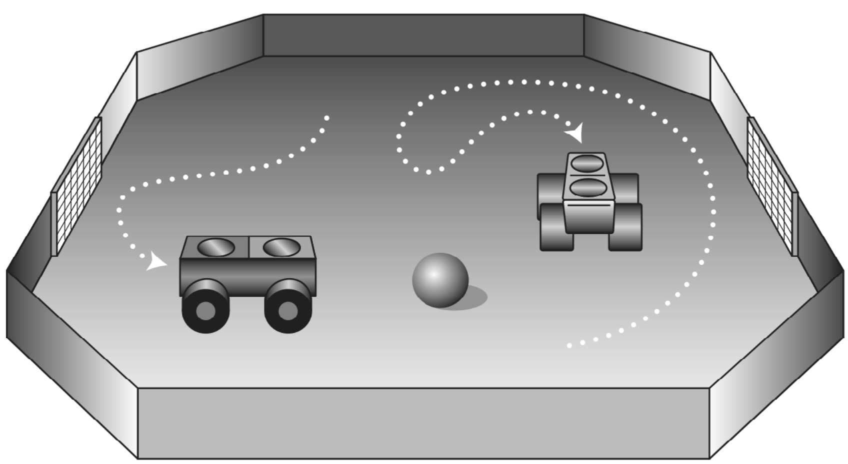
"By the middle of the 21st century (2050), a team of fully autonomous humanoid robot soccer players shall win a soccer game, complying with the official rules of FIFA, against the winner of the most recent World Cup"

Currently, RoboCup has multiple leagues and subleagues. Each team is fully autonomous in all RoboCup leagues. Once the game starts, the only input from any human is from the referee

The first Robocup competition was held in 1997 in Nagoya, Japan. The most recent Robocup competition was held in 2014 in João Pessoa, Brazil. The entry from Canada in the RoboCup@Home league is the UBC Thunderbots. Aside: The UBC Thunderbot team makes an annual pitch for volunteers.

Robot Soccer: Humble Beginnings

The world's first robot soccer game



Drawing credit: Jim Marin, ©2009

“Vertical” Architecture for Situated Agents

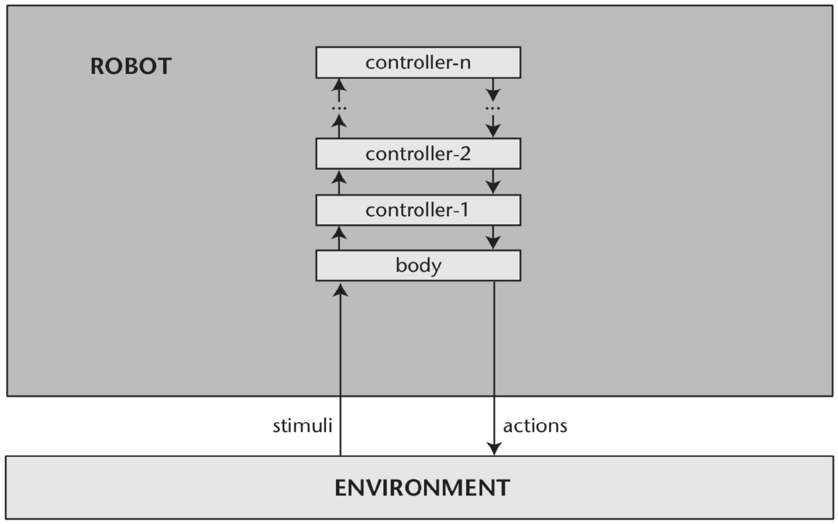


Figure credit: Mackworth, *AI Magazine*, 2009

(Prioritized) Constraint Satisfaction

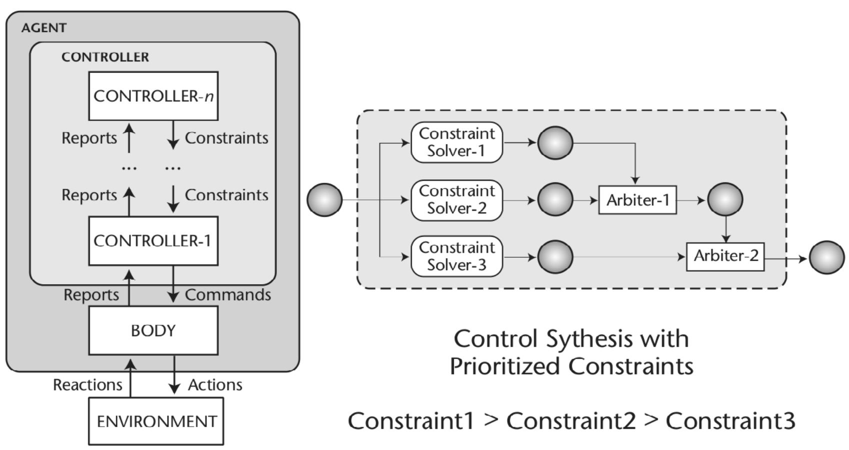


Figure credit: Mackworth, *AI Magazine*, 2009

Constraints in a Simple Robot

- Level 1: Ball in view
- Level 2: Orient toward ball
- Level 3: Move toward ball

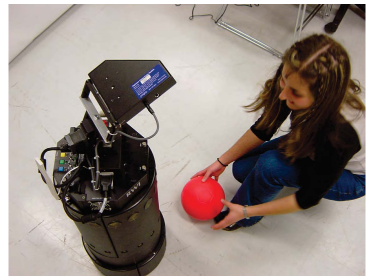


Figure credit: Mackworth, *AI Magazine*, 2009

Constraint-Based Agent (CBA) Framework

The "math" (i.e., formal methods for constraint-based agents) gets complicated. The CBA framework of Zhang and Mackworth consists of three components:

1. Constraint Nets (CN) for system modeling
2. Timed for-all automata for behavior specification
3. Model-checking and Liapunov methods for behavior verification

Constraint Nets (CN) are an architecture for distributed asynchronous programming languages. CN programs represent the robot body, the controller, the environment, and the constraints that are local on the structure and dynamics of each system. Timed for-all automata specify the behavior. Formal verification uses model checking or generalized Liapunov techniques taken from the standard control literature but generalized for symbolic as well as numerical techniques.

Bob's Computer Science "Story" for COGS 200

- Questions to ask about knowledge representation (KR):
  — What language is used?
  — What knowledge is represented explicitly?
  — How to reason (i.e., make explicit that which is implicit)?
- Distinguish actual knowledge of the world from an agent's belief about the world
  — frequentist versus Bayesian intepretation of probability
  — Chomsky versus Norvig
  — GOFAIR (fully observable, deterministic, closed world) versus Mackworth's CBA framework (robot soccer)
- Build robots (i.e., cognitive systems) to interact with the world
  — Situatedness (the world is its own best model)
  — Embodiment (the world grounds regress)