What has Evolution to say about Embedded Systems?

1953 Miller–Urey

\[ \text{ammonia} + H_2 O + H + CH_3 \rightarrow \text{energy} \]

-4.6B rocks - primordial soup

-3.5B single celled organisms

-2.5B photosynthetic plants

-0.5B fish, vertebrates, insects, reptiles, dinosaurs, mammals

-0.002B man

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The Human Age

Brooks, Morevec, et. al.

...moving about in our complex environment well enough to survive and flourish is the toughest problem that life on earth has yet faced...

...this is where evolution has concentrated most of its effort.

figuring out how to build “embedded systems” - to combine computation, control, signal processing, mobility, and embodiment - is where mother nature spent most of her time so far
Embedded Systems - Lecture Units

- environment
- mechanism
- kinodynamics
- signal detection
- electronics
- RT computing
- artificial intelligence
Early Embedded Control System
Grey Walter’s Tortoise

• 1953 - Product of cybernetic research
• One motor with 2 valve control circuit
• Two sensors: light and bump
• Light sensor always faced in direction of motion
• Behaviors
  – Seek light (rotates until light found)
  – Head toward weak light (once light found)
  – Back away from bright light
  – Turn-and-push to avoid obstacles: avoid obstacle overrode light response
  – Recharge battery - strong source perceived as weak light with low battery, once charged backs away from plug.

• From lowest level to highest:
  scan, move to/from light, avoid-obstacle
Early Embedded Control System
Grey Walter’s Tortoise

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Early Embedded Control System
Braitenberg’s Vehicles

- Simulation study (1984)
- Sensors mapped to motors via simple analog logic
- Synthetic psychology — seemingly complex behavior results from relatively simple sensorimotor transformations.
- Inhibitory and excitatory influences (sensors on motors)
- Range of vehicles created - e.g., Coward, Aggressor, Lover, Explorer.
- Inflexible custom machines
Example of Reactive Control

Braitenberg machines

(From Braitenberg 1984)
Example: Raibert’s Hopping Platforms

Project Concept

...Marketing has identified a significant market potential for an advanced robotic toy that can act as a playmate/assistant for children and adults.

- it must be capable of moving around in human-scale environments
  (mobility)

  *ubot video*

- it will use “emoting” to capture user attention and engage humans in a social context,

  *Leonardo video*

- ... and interacting manually with the user and the environment.

This last issue is the objective of the Torso Workgroup


**Torso Workgroup Task**

The design of the bi-manual “torso” is specified in terms of marketing behavioral targets, including a representative set of grasping tasks and objects.

1. **kinodynamics** -
   (a) a trunk rotation of $\pm 60$ deg measured relative to the drive wheels
   (b) the workspace of individual arms must include the floor in front and behind the robot, and must be able to reach vertical configurations
   (c) the bi-manual workspace must include:
      - a 6 inch deep region on the floor at zero trunk rotation
      - configurations that can be used to brace for a fall and right itself after a fall

2. **function** -
   (a) the device should be able to follow “hand-in-hand” behind a human client
   (b) must be capable of grasping a cylinder 2 inches in diameter and 2.5 inches tall on the floor

3. **Cosmetic** - arms should be as anthropomorphic as is practical