PSYCO 457
Week 6: Thoughtless Walkers

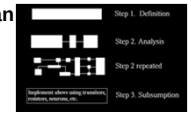
Analysis vs. Synthesis
Analysis Informing Synthesis
Synthesis Informing Analysis

Preliminary Discussion

- **Seeking comments or questions concerning the main themes of readings to this point in "From Bricks To Brains" and in "Embodied Cognition"**

Classical Analysis

- **Classical cognitive science has been successful, and is comfortable with an analytic approach to mind**
- **Reverse engineering**
  - **Collect data first**
  - **Build model from data**
- **Cummins' functional analysis**
  - **"Perhaps the most extensive use of the analytical strategy in science occurs in psychology, for a large part of the psychologist's job is to explain how the complex behavioral capacities of organisms are acquired and how they are exercised. Both goals are greatly facilitated by analysis of the capacities in question"**



Robert Cummins

Embodied Synthesis

- **Synthetic methods seem to be the province of embodied cognitive science**
- **Forward engineering**
  - **Build model first**
  - **Collect data from model**
- **Braitenberg's synthetic psychology**
  - **"We have to distinguish between the perspective of an observer looking at an agent and the perspective of the agent itself. In particular, descriptions of behaviour from an observer's perspective must not be taken as the internal mechanisms underlying the described behaviour" (Pfeiffer & Scheier, 1999)**

Christian Scheier

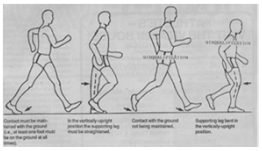
Rolf Pfeiffer

Synthesis Vs. Analysis?

- **Analytic and synthetic methodologies are not only associated with different schools of cognitive science, but are contrasted in the sense that one is argued to be better than the other**
- **However, it can – and should – be argued that the two approaches can complement one another**
  - **Pfeiffer and Scheier 1999**
  - **Dawson 2004**
- **Let's explore the mutual support of these approaches within embodied cognitive science**

Walking – By The Rules

- **Racewalking is a judged event that takes place over a closed loop course, with judges placed along the course**
- **Judges look for violations of two rules – bending the knee, and lifting**



A Walker's Obsession

- Once you learn to racewalk, you become obsessed about walking
- One consequence is that you spend a lot of time analyzing your own technique, and watching the technique of others in order to improve
- This follows a long tradition of the analysis of locomotion

Early Analysis Of Walking

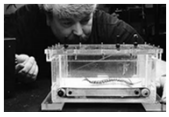
- Photographer Eadweard Muybridge was famous for his 19th century photographs that permitted the detailed analysis of movement
- He invented many new techniques for taking such photographs
  - Muybridge's photographs "are still the basic authorities on the movements and gaits natural to most animals, particularly to man and the horse. Despite the moving-picture and slow-motion cameras we now possess, little has been learned that Muybridge did not discover"

Eadweard Muybridge

Modern Analysis

- Muybridge's approach is still followed, but has advanced with new technologies
- Robert Full has done a great deal of research into biological motion in his Polypedal Laboratory
- This research uses high-speed video and force-sensitive media to provide detailed analyses of locomotion

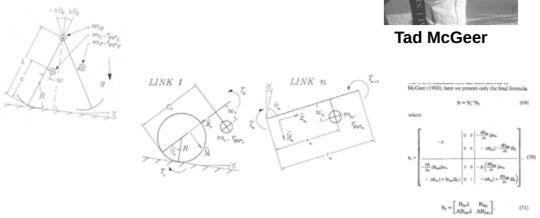
Robert Full



Formal Analysis

- Walking analysis does not have to be empirical – it can be very formal
- One example is McGeer's analysis how a spoked wheel can be translated into a walker

Tad McGeer

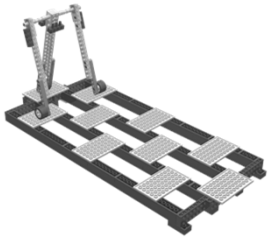


Informing Synthesis

- McGeer's analysis led to the creation of passive dynamic walkers
  - Active control is not required to generate such walking. "Gravity and inertia alone generate the locomotion pattern"
- McGeer's equations showed that such machines should walk, and constrained the search space for creating working examples
  - Collins et al. (2001, p. 612) "decided to forgo three-dimensional analytic modeling" and instead worked directly with physical components, using "trial, error, and correction to minimize three-dimensional effects" (p. 612).

LEGO Tinkering

- By taking advantage of prior analysis, and our ability to tinker with LEGO, we too can build our own passive dynamic walker
- Here is a video that demonstrates its behavior



Implications

- The LEGO passive dynamic walker illustrates analysis directing synthesis
- It also demonstrates inseparability of agent and environment
  - "Note that the four properties listed -- horizontal, flat, extended, and rigid -- would be physical properties of a surface if they were measured with the scales and standard units used in physics. As an affordance of support for a species of animal, however, they have to be measured relative to the animal. They are unique for that animal. They are not just abstract physical properties"

James J. Gibson

Synthesis Informing Analysis

- To this point, we have considered how analysis can inform synthesis
- Of course, it is also possible for synthesis to inform analysis – particularly in instances where "scaling up" makes analysis impractical or impossible
- Ashby faced this problem when studying interactions amongst machines
  - "When there are only two parts joined so that each affects the other, the properties of the feedback give important and useful information about the properties of the whole. But when the parts rise to even as few as four, if every one affects the other three, then twenty circuits can be traced through them; and knowing the properties of all the twenty circuits does not give complete information about the system."

W. Ross Ashby

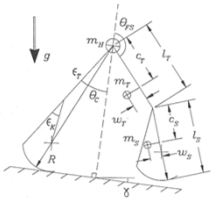
A Synthetic Example

- How did Ashby deal with the limits of analysis?
- By building an artifact that let him observe interactions between machines
- The homeostat revealed general principles that could later be pursued analytically
  - "A better demonstration can be given by a machine, built so that we know its nature exactly and on which we can observe what will happen in various conditions"

Ashby with his homeostat

Scaling Up Walking

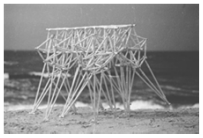
- McGeer's analysis of simple two-straight-legged walkers demonstrated enormous mathematical complexity
- Adding knees increases complexity
- Imagine the mathematical complexity involved in describing a multi-legged, multi-jointed walker!



The Great Pretender

- The synthetic approach can be used to create multi-legged walkers without extant analysis
- If they walk, then they point the way for later analyses
- Consider the work of Dutch sculptor Theo Jansen
- Rather than analyzing what makes a gait "lifelike", Jansen explored, from the ground up, configurations of tubing that resulted in amazingly lifelike, many-legged, walking sculptures

Theo Jansen



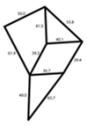
Strandbeest

Synthetic Strandbeest

- Jansen's approach to Strandbeest construction reflects many of the fundamental properties of the synthetic approach
  - "I want to make everything out of plastic tubing. Just as nature as we know it consists largely of protein, I want to make my own life-forms from a single material" (Jansen, 2007, p. 35).
  - "Remarkably, chance is more likely to play a role when there are restrictions. Financial restrictions, for example, may mean that drawers in the workplace stay closed. This necessitates looking for other possibilities elsewhere. During this search new ideas automatically emerge, ideas that are often better than the ones you first had. Again, the restrictions of the plastic tubing oblige you to look for technical solutions that are less than obvious" (p. 37)

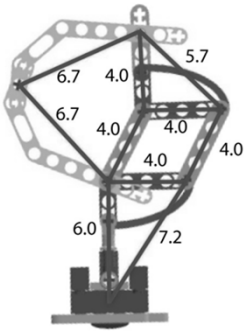
Walking Discoveries

- Jansen used genetic algorithms to determine the optimal lengths of different tubes used to make a leg
- His "holy numbers" are shown at the right
  - "It is thanks to these numbers that the animals walk the way they do" (Jansen, 2007, p. 57).



Holy Numbers and LEGO

- A leg that approximates Jansen's can be constructed from LEGO parts
- We can therefore explore Jansen walkers synthetically by building a LEGO Strandbeest
- What gaits will it produce? What mathematics must underlie its walking abilities?

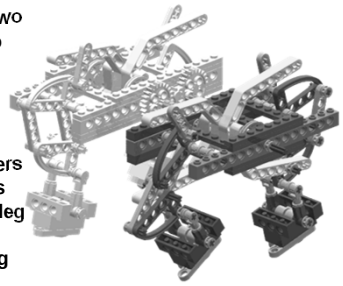


A Two-Legged Module

- The basis of the LEGO Strandbeest is a module composed of two flexible Jansen-like legs

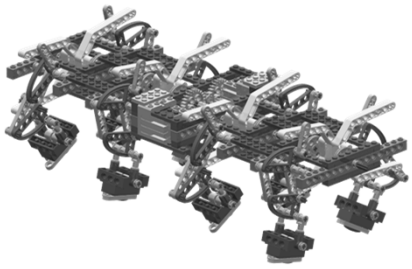
Quadruped LEGO Strandbeest

- A motor can drive two of these modules to create a quadruped walker
- With this simple machine, there a number of parameters to explore – such as the phase between leg modules – that can influence its walking gaits



Modular Octapod

- The LEGO Strandbeest is modular
- The quadruped can quickly be converted into an octapod
- Let's view a video of LEGO Strandbeest behavior



Rule-Governed System

- Charles Percy Snow wrote of two competing cultures, the sciences and the arts
- To some, the analytic and synthetic approaches reflect this same division
  - "Given the restrictions of this material [plastic tubing] I was forced to seek out escape routes that were neither logical nor obvious. The strategy I followed to assemble the animals is in fact the complete opposite of that taken by an engineer" (Jansen, 2007, p. 35).
  - Engineers build "devices that are first thought out and then assembled. That's how engineers work. They have ideas and then they make these ideas happen"

Mending The Rift

- **Edison told anecdotes that demonstrated the value of his practical intuitions over the analytic methods of the mathematicians that he hired**
- **But Edison realized the necessity of their formal methods!**
- **For full effect, analytic and synthetic methods must be used to complement one another**

Thomas Edison

Francis Upton