Design robots that walk like humans (with a walking stick)

Goal:

The goal is to design robots that walk like humans by using the concept of *Analogical Reasoning* learned in class.

The challenge:

Walking upright on two legs is the trait that define humans from other animals, which freed our hands for creation. And of course this is not easy. Human ancestors took about three million years of training (evolution) to walk upright (Figure 1). Even in these days, the walking ability seems not come directly after birth, human babies still need to spend several month to learn how to walk under the help of their parents. Human walking is a very unique movement with a dynamic balance. Here I present how to use *Analogical Reasoning* to design robots that walk like humans.

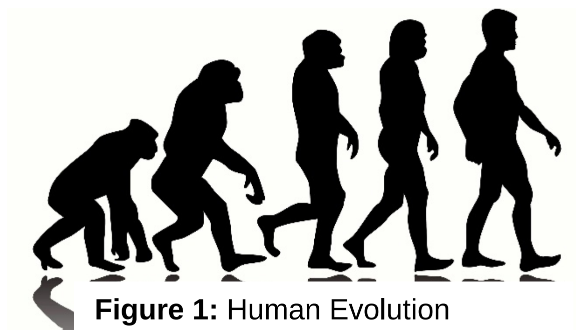


Figure 1: Human Evolution
(Figure from internet)

What's analogical reasoning?

When we compare two objects or two systems of objects and find various respects of similarity, thus we call these two objects or systems of objects as analogs. Analogical reasoning heavily relies on the identification of analogs and further infer information/properties from one to the other. Analogical reasoning is fundamental to human thoughts and usually involves following 5 steps:

1: retrieve (find analogs)

2: mapping (structural mapping attributes of analogs)

3: transfer (use information/properties from one of the analog to infer the properties of the other)

4: evaluation (use various standards to evaluate the correctness of transfer)

5: storage (store success cases for future use)

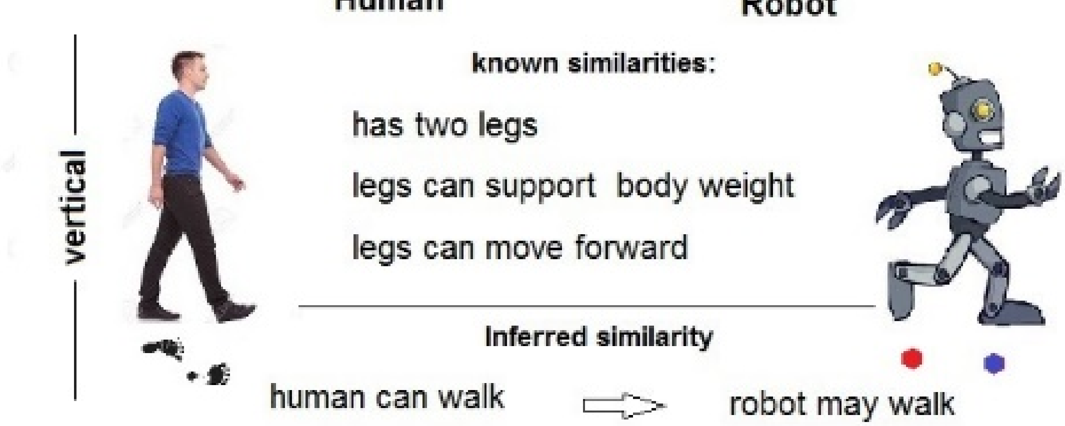
Design robots that walk like humans:

I will follow the exact 5 steps to design robots that can walk like humans.

[1. **Retrieve**] Since I am designing robots that will mimic human walking, the case I am going to retrieve is a walking human (as shown in Figure 2).

[2. **Mapping**] I first identified a series of unique features from a walking human that may be important for his walking ability. E.g. he has two legs, these two legs are strong enough that can support his body weight, and these two legs can move (forward or backward). To match such properties, my robot will also have two legs, these two legs are strong enough that can support robot's body weight, and robot's legs can move forward or backward (through some mechanical engineering design).

Figure 2



[3. **Transfer**] Due to the similarities between human and my robot, I infer that my robot can walk like humans.

[4. **Evaluation**] Obviously, my robot cannot pass the evaluation. The robot will fall very easily during walking.

Trouble shooting:

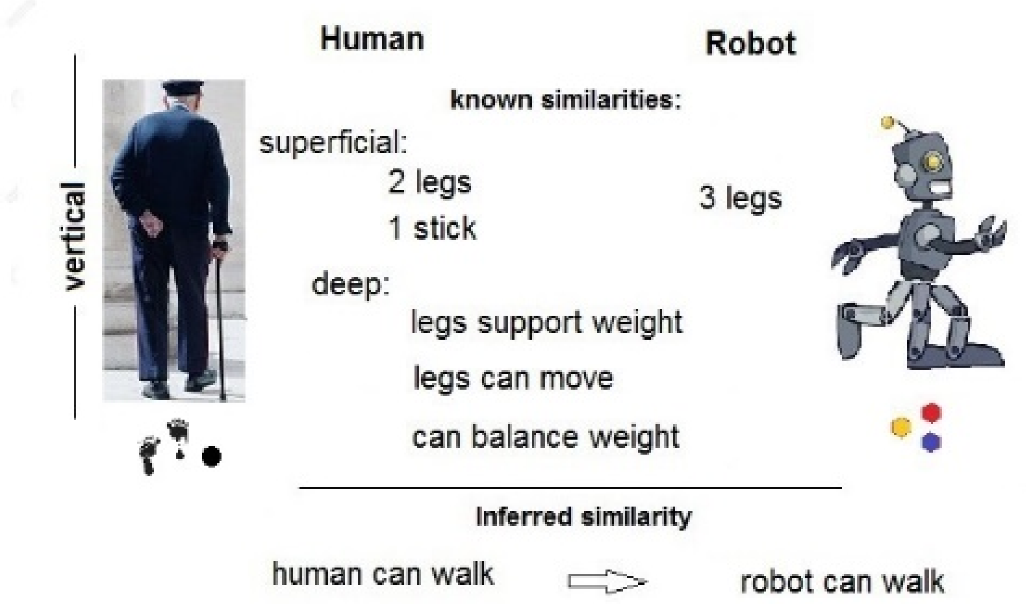
The problem is generated because I omit a very important feature about human walking, the dynamic balance. The way humans balance themselves during walking is very complicated. First, in human brain, through million years of evolution, some parts can sense the balance. Second, human brain can organize a dynamic balance through adjust movements of arms, body gestures. Unfortunately, my robot does not have such a system to keep a dynamic balance, thus it will fall during walking.

Alternative approach:

Building a humanoid walking robot is still very challenge. There are a few successful cases, e.g ATLAS, the walking robot that DARPA built with Boston Dynamics. These robots all have very complicated mechanical design to balance themselves during walking. Since I have no such knowledges, I will present an alternative approach. If it is difficult to build a robot that can sense balance and dynamically adjust balance, is it possible that I can build a robot does not (or has minimal) need to adjust the balance. There is a strategy that I can learn from senior people. Due to age-related issues, they start to have problem to balance themselves and usually choose a walking stick to balance/support themselves during walking. This inspired me to design a three-legged robot.

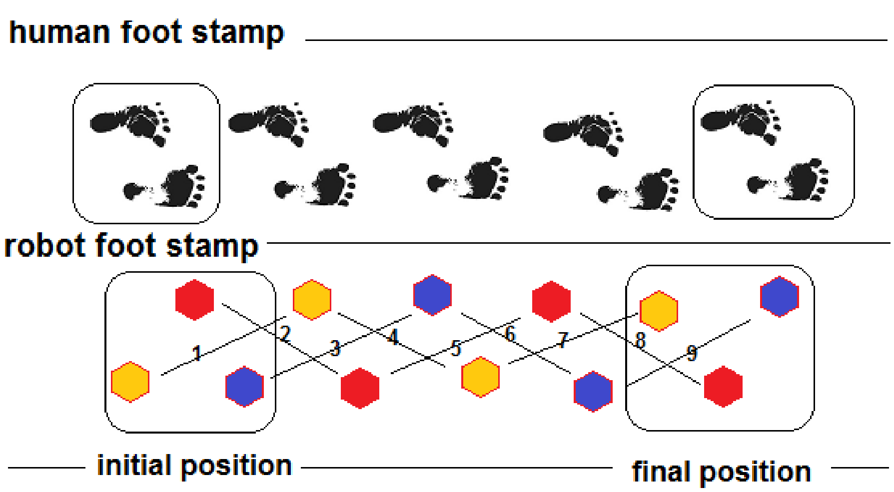
Design robots that walk like humans with a walking stick:

Figure 3



[1. **Retrieve**] This time, I retrieve the case of a walking senior person, who uses a walking stick to balance/ support himself during walking (as shown in Figure 3).
[2. **Mapping**] I identified a series of features from the walking senior person that may be important for his walking ability. He has two legs and a walking stick, these two legs plus the walking stick are strong enough that can support his body weight, these two legs and the walking stick can move (forward or backward), and with the help of the walking stick, it is very easy to keep balance. To match such properties, my robot will have three legs, these three legs are strong enough that can support robot's body weight, robot's three legs can move forward or backward, and these three legs balance the robot during walking.
[3. **Transfer**] Due to the similarities between human and my robot, I infer that my robot can walk like humans.
[4. **Evaluation**] My robot can walk and its foot stamps are shown in Figure 4.
[5. **Storage**] this design will be stored for future use.

Figure 4



Limitations:

So far, most robots' designs have even number legs (two legs to mimic human, or four legs to mimic animals). There must be a reason for nature to generate even number legged animals through evolution. In nature, there are rare examples for three-legged movement (tripedalism). One interesting example is the movement of kangaroos. They can use their muscular tails as the third leg to support / balance themselves during walking, and the advantages / disadvantages for such behavior are still not clear. To design a robot that mimic human or animal's movement, it is quite reasonable to let them have same number of legs as human or animals. But one question that I should ask is that whether the leg number similarity a superficial similarity or a deep similarity, and does the robots have to use the same number of legs as human/animals? My design of the three-legged robot of course need further examination.