Fall 2013
ME 740
Project

The focus of the project is to perform analysis of the dynamics of bio-inspired quadruped robot as seen below. You may want to check Figure 1 to understand the skeleton of a quadruped. Here are general features of the robot, Figure 2:

- The motion can be described as planar
- The torso of the robot is supported by four legs.
- Each leg is composed of three links with two revolute joints that will be labeled:
    - hip joint (connecting torso and first link)
    - knee joint (connecting first and second links)
    - heel joint (connecting second and third links)
- Each leg has one motor at the hip joint that is capable of rotating clockwise and counter clockwise
- All the other joints are supported with torsional springs. The springs support the body and ensure smooth motion by storing springs. This design, if done correctly, should produce smooth motion.
- The gait pattern is shown in Figure 3. The two legs that are in contact with the ground create the forward propulsion. The two other legs move in the air to reach the ground when the other two legs finish their push. It is assumed that there is no slipping between the legs and the ground and that that there is no energy absorption during contact between the ground and the propulsion legs.

For this project, it is suggested to do the following:

- Assume each leg is composed of two links as a start
- Create the equations of motion of the robot dynamics
- Develop a computer program to simulate the motion. Dimensions and masses to ensure consistency.
- The values of spring stiffness are given as a starting point. You will need to identify the appropriate spring stiffness by studying static balance. *Extremely soft springs will result in the torso collapsing!* Similarly, extremely hard spring will provide no mechanism for energy storage.
- To approach the identification of the spring stiffness problem, you may need to do an analysis during which all legs should be on the ground. Study the behavior of the robot under gravity. Vary stiffness to assess performance.
- When developing the gait model, you may not want to start very ambitiously. Here are some suggestions:
    - Get rid of links 5, 8, 11, 14 (metatarsus/carpus). This will reduce each leg to two segments
    - Ignore the off-ground legs temporarily.
- Try to identify the torque ranges that would create a successful gait. For now, assume an open loop system. In real life, feedback control would be necessary.

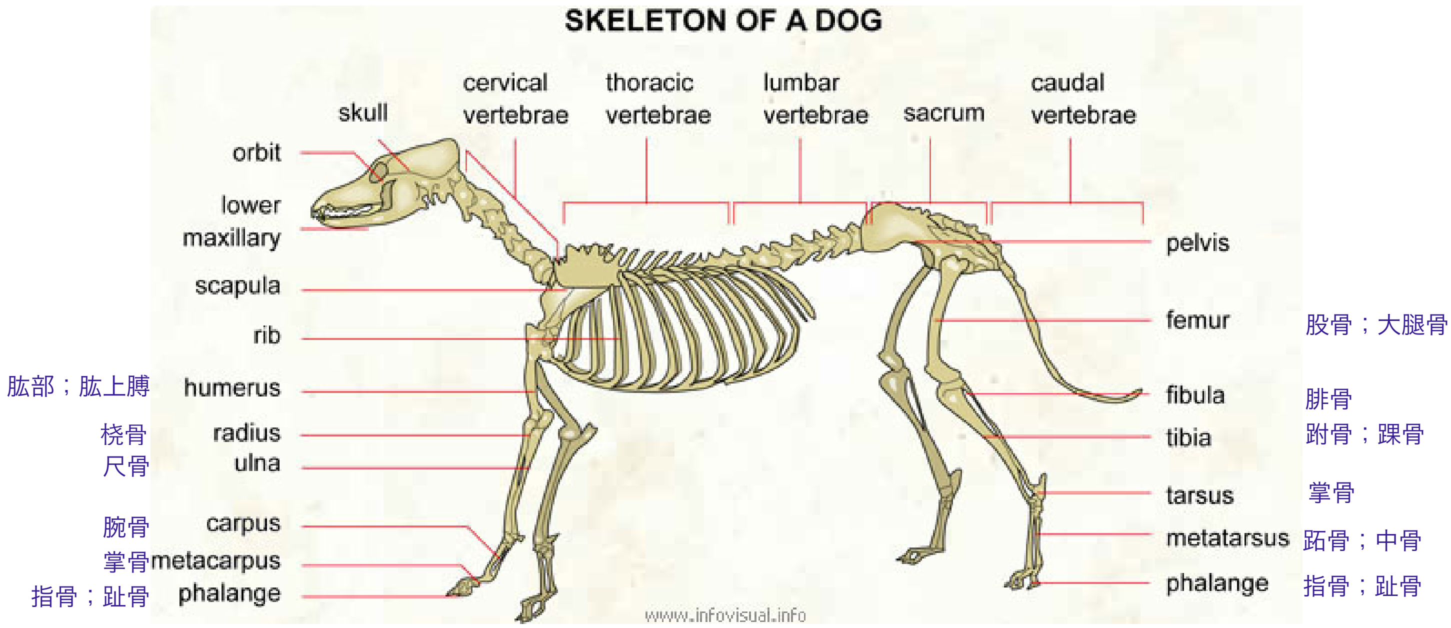

Figure 1. http://www.infovisual.info/02/070_en.html

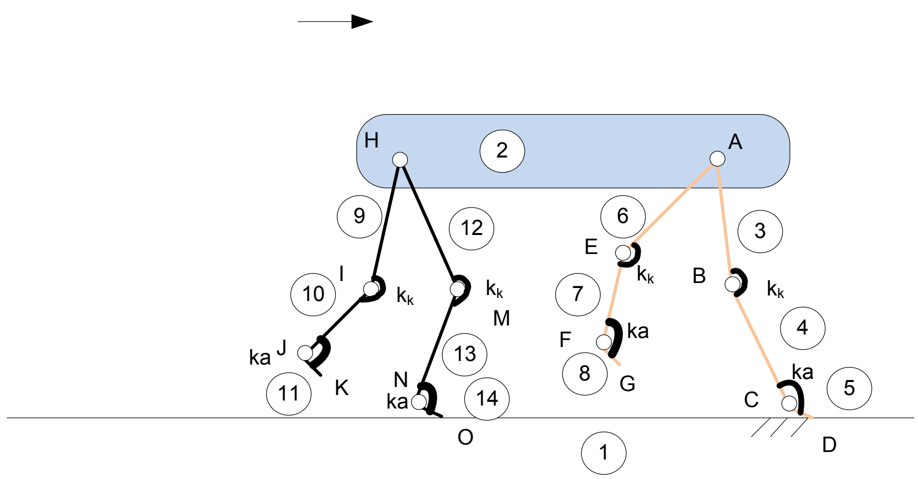

Figure 2

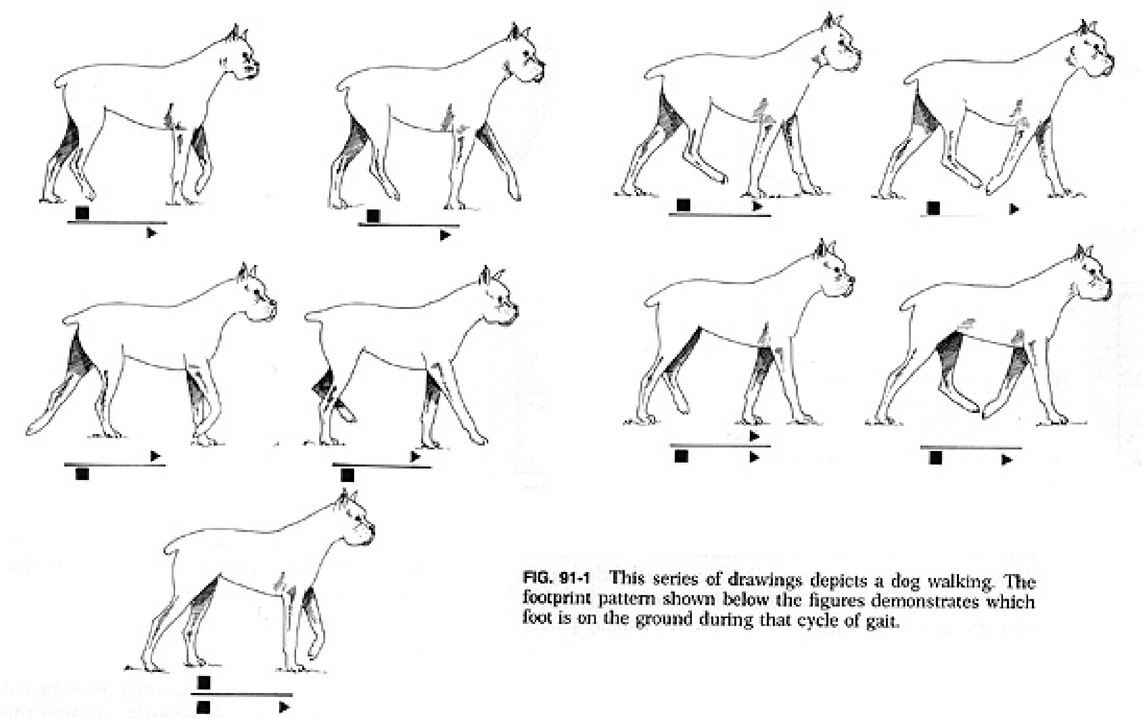

FIG. 91-1 This series of drawings depicts a dog walking. The footprint pattern shown below the figures demonstrates which foot is on the ground during that cycle of gait.

Figure 3. http://cal.vet.upenn.edu/projects/saortho/chapter_91/91f1.jpg

Data:

Links	Length (m)	Width (m)	Mass (kg)	Mass Moment of Inertia (kgm^2)
2 (torso)	0.65	0.15	28.5	1.06
3, 6, 9, 12 (femur/humerus)	0.21	0.025	0.625	0.0023
4, 7, 10, 13 (tibia/ulna)	0.24	0.025	1.250	0.0092
5, 8, 11, 14 (metatarsus/carpus)	0.10	0.025	0.3	0.0006

Knee Spring: 5 Nm/rad (compression only)
Ankle Spring: 1 Nm/rad (compression only)