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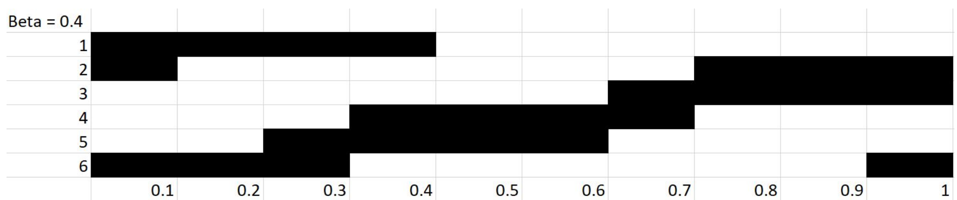
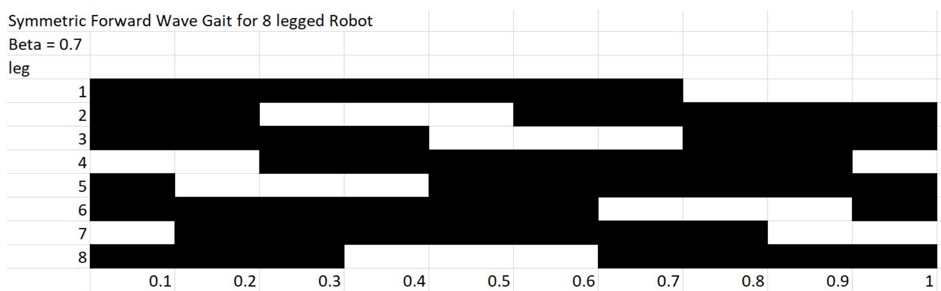
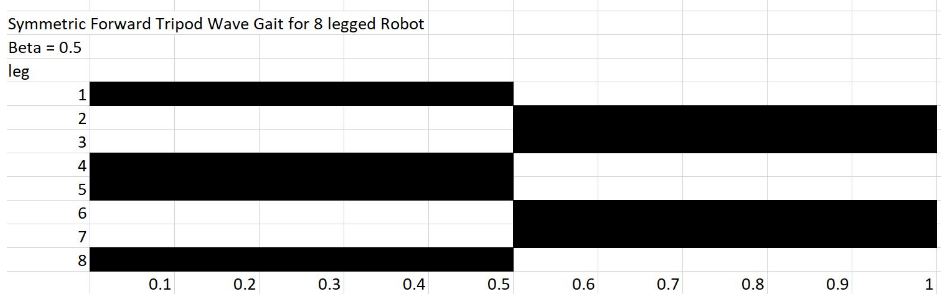
1)

Based on the definition of a stable walking robot given in lecture 11, where a robot is dynamically stable if there are at least three noncollinear legs with strictly positive foot forces at time instance t, we can take a look at the duty cycle charts that we learned about in the previous lectures and find the smallest duty factor that allows for three legs on different sides of the robot to be supporting at once. This makes sense logically as well, as three points of contact with the ground is the smallest case possible to allow for one to draw out the support polygon of the robot.



With a duty factor of .4 or 40%, we can see that this robot is obviously unstable. Comparing it to the graphs that we made from the past assignment with duty cycles of .7 and .5, shown below,





We can see that for all of the successful walking gaits have at least 3 legs on the ground at all time within the step cycle, while for our graph at 40%, 3 legs are on the ground simultaneously at only 3 points within our step cycle. As such, It is safe to assume that the minimum duty factor for a stable walking robot would be at .5, or 50%, as anything below that removes the robot's guarantee to always have three points of contact with the ground at all instances of the step cycle.

2)

$$u(t) = \frac{\beta(t)}{1 - \beta(t)} v(t)$$

Using the equation above, it is obvious that there is a proportional relationship between the foot speed u(t) and the robot speed v(t). As the duty factor β increases, that means that the ratio of the robot's supporting interval to cycle time increases as well, the robot would be supporting itself on its leg for longer periods of time. With the duty factor increasing, that would mean that the robot would need to move its feet faster to compensate for the longer support intervals, to keep up with v(t). Say, if you had a duty factor of 0.9, then the equation would be as follows.

$$u(t) \ = \frac{0.9}{0.1} * v(t)$$

This would mean that the foot speed would need to be 9 times larger than the robot's speed.

Given that we are trying to maximize the robot speed given a foot speed u(t), you simply need to approach the equation from the other perspective.

$$\frac{1-\beta}{\beta} * u(t) \ = v(t)$$

This equation shows that as beta increases, the overall robot speed slows down, thus, to maximize v(t), we need to minimize beta as much as possible. However, since we just showed that you cannot have a stable walking robot with a duty factor of less than 0.5, a duty factor of 0.5 is the best you can do, which results in a 1 to 1 ratio of foot speed to robot speed. Thus, the duty factor that results in the maximum speed/velocity for a stable walking robot would be 0.5.