# P3 A: Inverse Kinematics

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CS 3451

Project 3 Part A Module 2

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## Summary

The problem addressed in this phase of the project is to find a solution to calculate the points for the knee, ankle, heel, and toe. In the provided source code, all the points have been given default values so the user is able to drag the points around. If done so, the leg would no longer have the right proportions or dimensions. The task for this module is to calculate the points mentioned above with its proper coordinates and dimensions given the hip and the ball of the foot. Once everything is calculated accordingly, appropriate constraints will be set in place such that the user will no longer have the ability to manipulate the location of the knee, ankle, heel or toe.

**Solution**

The key component to this module is the triangleTip function. Given two known points and respective side lengths as the parameter, the third point of the triangle can be calculated. This function is called to find the ankle and the heel.

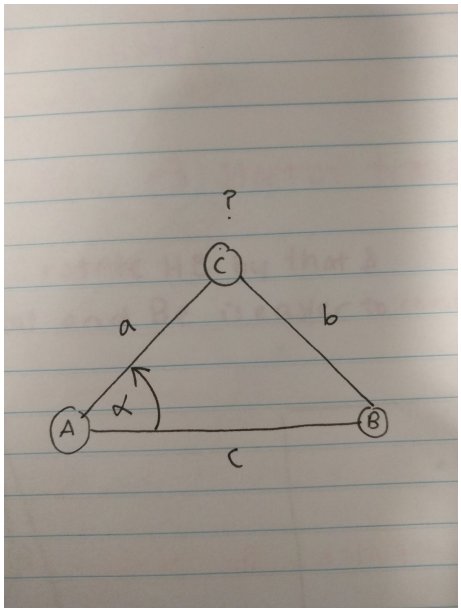
Here is a breakdown of what needs to be done:

- Set constraint on ball so that it is always on the floor.
- Set constraint on hip so that it is always at a constant level.
- Set constraint on Toe so that it is always a constant scalar value from the ball.
- Solve for the knee. This value should be the vector between the hip and ball rotated by a given angle.
- Implement the triangleTip function that takes in two points and the two respective side values to calculate the third point of the triangle using the law of cosines.
- Calculate the ankle by calling the triangleTip function on the knee point, ball point, length between knee and ankle, and length between ball and ankle.

- Calculate the heel by calling the triangleTip function on the ankle point, ball point, length between ankle and heel, and length between heel and ball.
- Constrain the heel so it doesn't fall below the floor.

Ball of the foot is constrained to the floor by setting the y value of the ball point to the height of the screen, minus the hard coded y value of the floor, minus the radius of the ball. Hip point is constrained to a given hip height. Set the y value of the hip equal to height of screen, minus floor, minus (height-_h). To solve for toe, make sure y value is height-floor and that x value is always a set number greater than the x value of the ball. The knee is the point calculated from vector from hip to ball rotated by the given hip angle with a magnitude of the provided hip-to-knee dimensions.

The triangleTip function will take in two points and two respective edge lengths. With what is provided, the third side length of the triangle can be calculated via the distance formula given the coordinate points of the two other points.



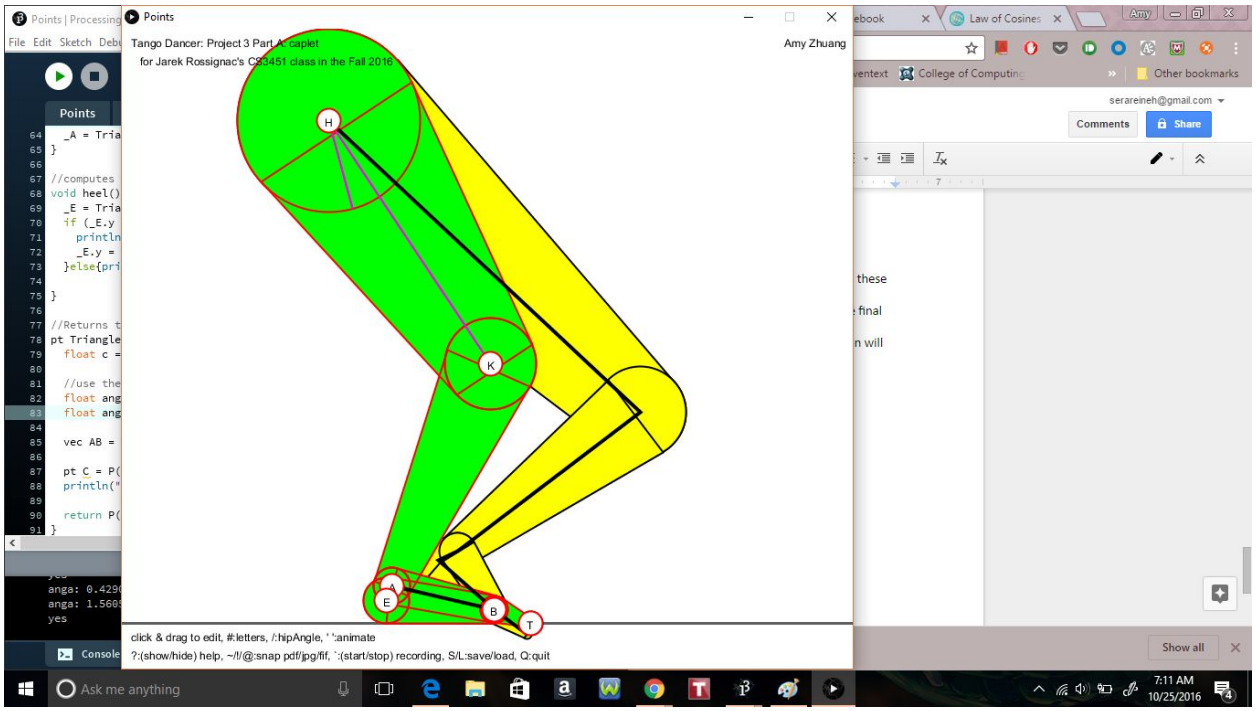

In the image above, the triangleTip functions returns point C, which is unknown. The knowns at this point are pt A, pt B, a, b, and c. Using the law of cosines, angle Cos(alpha) can be calculated.

$$\frac{-a^2 + b^2 + c^2}{2\,b\,c}$$

Taking the inverse cosine of this function will give you the angle alpha. To solve for point C, vector from A to B will have to be rotated an angle of alpha counterclockwise by a magnitude of a. This function will be used to find the ankle given the ball point and the heel point. This function will also be used to find the heel given the the ankle point and the ball point.

**Justification**

This solution first solves for the knee, ankle, and heel in that order. With each calculation, these values will have a definite point given the hip and the ball point. With what is implemented as the final solution, the user can still control the hip and ball point by click and drag, but the value in between will remain set by its calculations. Final result is as shown below:



In the image, the original leg is shown in yellow. Here, I have demonstrated that the knee point is not set with the proper dimensions. The green leg is the leg after all the proper functions have been called, displaying all of the correct dimensions of the leg.