# Arm Movement Speed Optimizations

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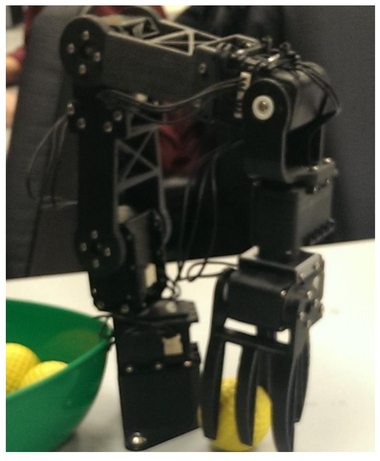
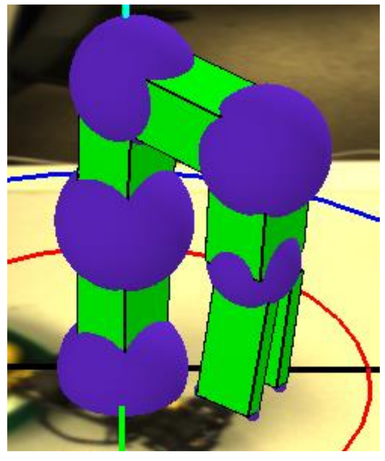
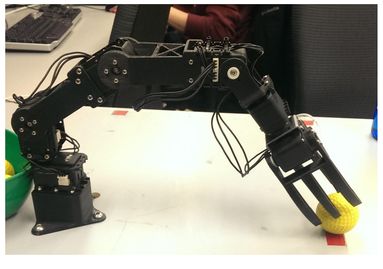
## Overview

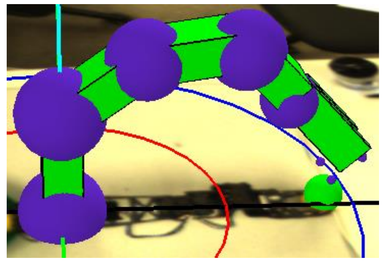
Solving a full fledged inverse kinematics problem is a difficult and time-consuming task. Instead, we have implemented two simple control laws with closed-form solutions to allow the arm to exhibit a sufficient range of motion. Our solution is much simpler and nearly as good as the optimal one. We have optimized these control laws to make our system competitive with fully actuated systems.

## Two Control Laws









**“Down-wrist”**

- Claw perpendicular to table
- Servos 1 and 2 actuated
- Short range of motion

**“Fixed servo 2”**

- Servo 2 fixed close to zero radians
- Servos 1 and 3 actuated
- Long range of motion

## Overview

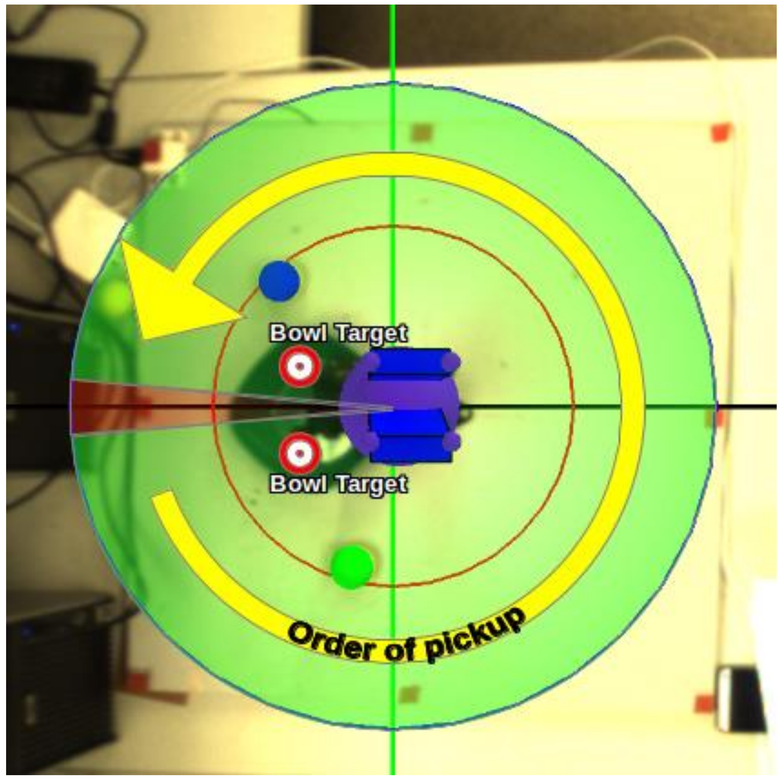



Figure 1. Ball retrieval order

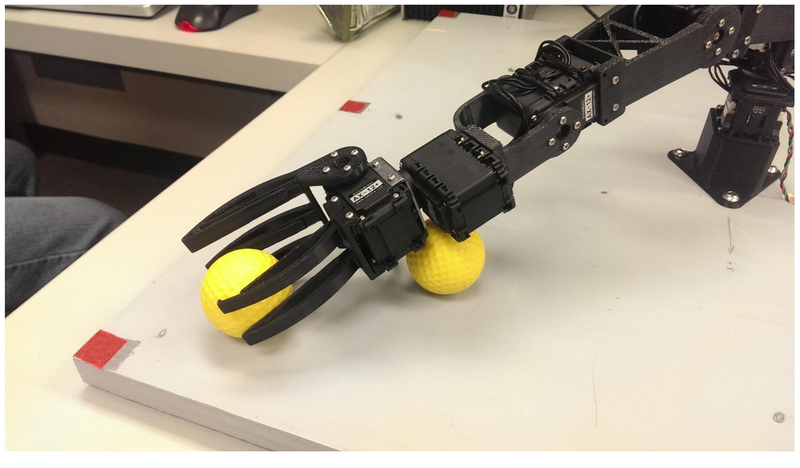


Figure 2. Failure case for unoptimized ball retrieval

## Optimizing Order

The order the balls are retrieved is extremely important to optimize speed and avoid knocking balls away.
We implemented the following optimizations:

- Pick up balls in a counter-clockwise order. This allows the arm to reduce the amount of redundant movement between balls.
- Favor closest ball to the arm in Euclidian distance if two balls are close to each other on circular path. This avoids collisions such as the one shown in Figure 2.

Using these two rules, our simple motions are nearly as good as the optimal motions.

## Two Bowl Locations

The arm rotates in a way that it doesn’t ever cross the axis that the bowl is on. Instead it picks the closest of the two bowl locations shown in Figure 1. We have bowl positions on either side of the bowl axis to allow the arm to always take the shortest path to the bowl.

## Results

The combination of these optimizations allow our two simple control laws to be competitive with a fully actuated system controlling all six servos. For purposes of the arm competition, we were tied for the most balls retrieved and would have retrieved more with a less conservative model. This shows that intelligent planning can make up for a limited range of motion.