Design and Development of a Precision Robotic Thrower and a Smart Target

Carolyn Christie
Advisor: Dr. A.A. Rodriguez

With the increasing availability of powerful low-cost computing, robotics is experiencing a new growth across a wide range of application areas [1]. This project is part of a series of research initiatives at ASU in the area of Flexible Autonomous Machines operating in an uncertain Environment (FAME) and the desire to build a robotic circus – one that can be used to inspire young kids to pursue careers in engineering as well as older engineering students to pursue advanced cutting-edge research. Toward this end, this project will focus on the specific goal of designing and developing a robotic arm that can precisely throw a ball [2]-[11] with an accompanying smart target [3], [8], [10], [11].

THROWING MECHANISM. The first phase of the project will focus on designing a throwing mechanism that can accurately achieve a desired initial speed $v_o$ and angle $\theta_o$. This will be done using a combination of stepper motors and a potentiometer for angular feedback [2],[4]. This will involve the development of a proportional plus integral plus derivative (PID) controller [22]. Several mechanisms and throwing cups will be examined [2]-[11]. The mechanism will be modeled and simulated using MATLAB/Simulink. An effort will be made to quantify uncertainty in achieving the desired initial speed $v_o$ and angle $\theta_o$.

TRAJECTORY MODELING AND DRAG. The second phase will involve carefully modeling the trajectory of a rigid aerodynamic ball [12]. Specifically, here we will examine how accurately one must model the drag force acting on the ball in order to accurately predict the planar trajectory that results from an initial speed $v_o$ and angle $\theta_o$. This will be done in combination with the designed throwing mechanism and a camera to capture the actual trajectory of the ball. By comparing the actual trajectory and a simulated trajectory, we will be able to accurately predict the drag force and the associated drag coefficient. An effort will be made in order to capture the uncertainty associated with the ball’s trajectory. This will involve the injection of a white noise process where drag enters the equations of motion [13].

HITTING THE TARGET. The third phase of the project will involve a static target. The goal, here, is to hit the target. Here, we will carefully examine two key metrics: accuracy (closeness to center) and precision (clustering) [8].

TARGET ANALYSIS. The fourth phase of the project will use the camera (30 frames per second) in order to analyze the target and automatically readjust the throwing mechanism for a more accurate throw [4]-[11].

SMART TARGET. The fifth phase of the project will involve designing and implementing a smart target employing a camera, two motors and a computer [14]-[21].

• The camera will be used to track the thrown ball.
• The computer will be used to process the ball images. Several search algorithms will be examined in order to quickly find the ball within the image plane. The key idea here is to
use the results of the prior search in order to assist with the next search. By so doing, the search can be fast and accurate.

- A Kalman filter will be implemented [14] in order to clean up the noisy images and more accurately estimate the state (xy-coordinates) of the ball. An extended Kalman filter may also be used here [16], [18] to generate better state estimates. The better the estimates, the better we can “track the ball.”
- The above state estimates will be used to send voltage input signals to the motors in order to properly position the target (left-right and up-down). The target will be light in order to limit the size and cost of the required target positioning motors.

**FINAL REPORT AND POSTER.** All results will be documented in a final report as well as on the required poster. The work will be submitted for publication in the proceedings of the American Control Conference (ACC) and the Frontiers in Education (FIE) Conference. Other publication venues will also be examined.

This project will serve as an excellent step toward my short-term goal of pursuing a direct PhD in the area of precision robotics. For my PhD work, I intend to pursue the development of a robotics circus. Ultimately, my goal is to become a professor of electrical engineering at a Research 1 university in the area of robotics.

**FURI ADVISOR.** Dr. Rodriguez has worked in the area of FAME for over 30 years. He has supervised over 50 graduate theses and over 300 projects. Relevant theses are as follows: [23]-[26]. Recently, Dr. Rodriguez led a team of ASU students to become finalists in the ASU ASURE 2017 Innovation Challenge. He is also the PI of a 5 Year, $5M NSF funded Scholarship program. Each scholar is required to work on a career-shaping project. The proposed FURI will permit me to work with Dr. Rodriguez alongside a team of highly motivated graduate and undergraduate students – all working in the area of intelligent autonomous systems. I especially look forward to developing a fleet of FAME and the planned robotic circus.
REFERENCES
23. Zhichao Li -Modeling and Control of a Longitudinal Platoon of Ground Robotic Vehicles, August 2016
24. Jesus Aldaco - Image Processing Based Control of Mobile Robotics, August 2016
# PROJECT TIMELINE FOR

**Design and Development of a Precision Robotic Thrower and a Smart Target**

Carolyn Christie, Electrical Engineering (Advisor: Dr. Armando A. Rodriguez, Electrical Engineering)

**Semester: Spring 2018**

<table>
<thead>
<tr>
<th>Item</th>
<th>Time Period (2018)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select Texts</td>
<td>October 2017</td>
</tr>
<tr>
<td>Literature Survey</td>
<td>October-January 2018</td>
</tr>
<tr>
<td>Review Work Completed to Date</td>
<td>January-February 2018</td>
</tr>
<tr>
<td>Select and Test Throwing Mechanism Design</td>
<td>February –April 2018</td>
</tr>
<tr>
<td>Model Trajectory of Rigid Ball</td>
<td>February-April 2018</td>
</tr>
<tr>
<td>Design of Smart Target</td>
<td>March - April 2018</td>
</tr>
<tr>
<td>Finalize All Testing</td>
<td>April 2018</td>
</tr>
<tr>
<td>Write Final Comprehensive Report</td>
<td>April-May 2018</td>
</tr>
</tbody>
</table>