

Advanced Controls Using WPILib

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WPILib
Development Team

Target zone 6 ball autonomous



WPILib
Development Team

Controls engineering in FRC

- Modeling
 - Equations representing how the robot behaves
- Localization
 - Where the robot is in 2D
- Motion planning
 - Planning how to get from here to there consistently
- Control
 - Actually getting there
- WPILib has features to make these easier!



Modeling

- What?
 - Equations that take in voltage and output sensor measurements over time
- Why?
 - More accurate drivetrain simulations
 - Controller autotuning with minimal trial and error



Modeling

- System identification
 - Use measured data from encoders and gyroscope to make a model that fits
- frc-characterization
 - The former lets you gather data to make a feedforward model
 - <https://docs.wpilib.org/en/stable/docs/software/wpilib-tools/robot-characterization/>
- LinearSystemId functions
 - Let you make a more general dynamical model for control later



Localization

- Using external measurements to obtain robot's position and heading on the field
- Why?
 - Dead reckoning with encoders alone accumulates error
 - If you can measure it, you can compensate for it with a controller



Localization

- DifferentialDriveOdometry class
 - Inputs: wheel encoders, gyroscope heading
 - Outputs: Robot position and heading
 - <https://docs.wpilib.org/en/stable/docs/software/kinematics-and-odometry/differential-drive-odometry.html>
- DifferentialDrivePoseEstimator class
 - Drop-in replacement for odometry class that lets you correct it with vision measurements
 - Compensates for CV pipeline delays!
 - https://docs.wpilib.org/en/latest/docs/software/advanced-controls/state-space/state-space-pose_state-estimators.html



Motion planning

- Why?
 - Smooth, predictable motion over time is desired
 - Only change the setpoint as fast as the system is able to physically move
 - Allows better open-loop control



1 DOF motion profiles

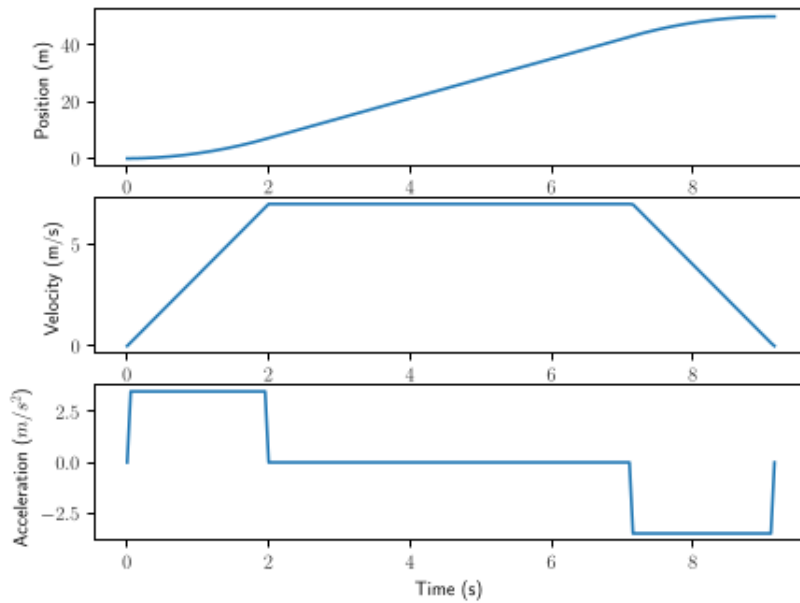


Figure 15.1: Trapezoidal profile

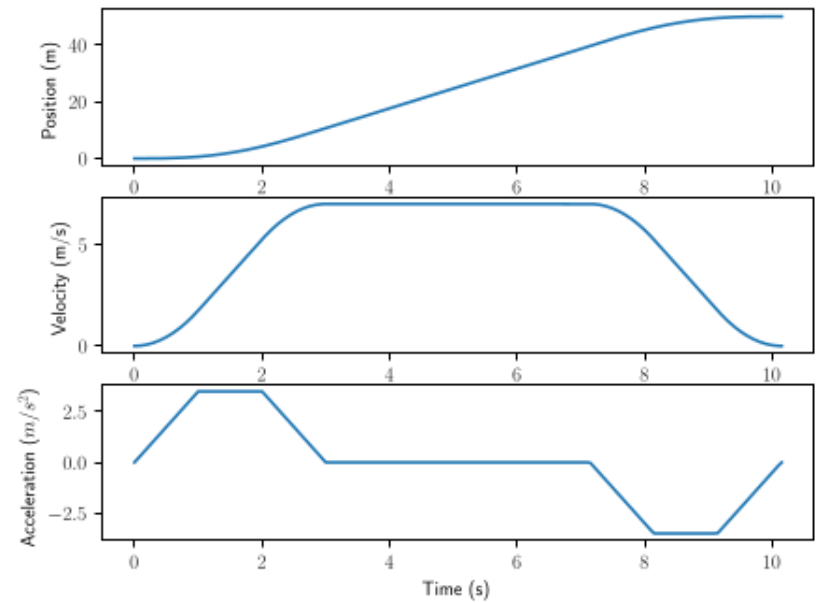


Figure 15.2: S-curve profile



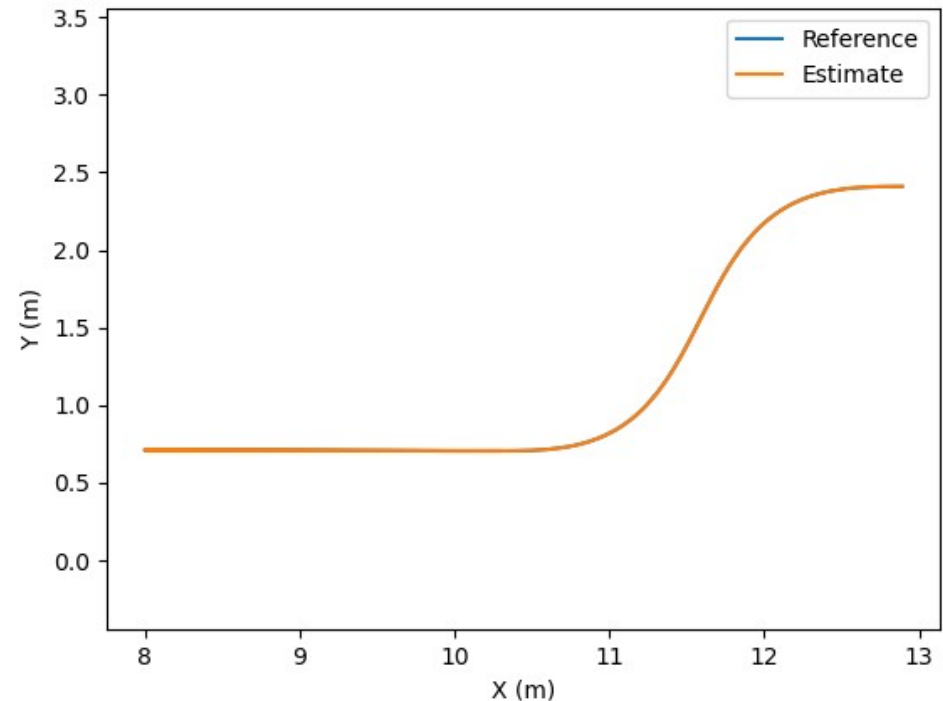
1 DOF motion profiles

- TrapezoidProfile class
 - <https://docs.wpilib.org/en/stable/docs/software/advanced-control/controllers/trapezoidal-profiles.html>
- ProfiledPIDController class
 - <https://docs.wpilib.org/en/stable/docs/software/advanced-control/controllers/profiled-pidcontroller.html>



2 DOF motion profiles

- Degrees of freedom for drivetrain are x and y axes
- Trajectory includes:
 - X-Y path
 - Wheel velocities
- TrajectoryGenerator class



2 DOF motion profiles

- TrajectoryGenerator class
 - <https://docs.wpilib.org/en/latest/docs/software/examples-tutorials/trajectory-tutorial/index.html>
 - <https://docs.wpilib.org/en/latest/docs/software/advanced-controls/trajectories/troubleshooting.html>



Control

- An application of algebra and geometry used to:
 - Analyze and predict the behavior of systems
 - Make them respond how we want them to
 - Make them robust to disturbances and uncertainty



Feedforward controllers

- Plant inversion
 - We know how the system behaves and how we want it to behave, so find a voltage that makes it behave that way
 - SimpleMotorFeedforward, ElevatorFeedforward, etc.
 - <https://docs.wpilib.org/en/stable/docs/software/advanced-control/controllers/feedforward.html>
- Unmodeled dynamics
 - Gravity compensation, gearbox friction



Feedback controllers

- Ramsete
 - Nonlinear control law for field position
 - RamseteController class or RamseteCommand
- PID controller
 - Commanded by Ramsete to go to wheel velocities
 - PIDController class or PIDSubsystem/PIDCommand
- Linear-quadratic regulator
 - P controller, but with gains chosen by math
 - LinearQuadraticRegulator class
 - Takes the model we got from frc-characterization!



More resources

- WPILib projects
 - <https://github.com/wpilibsuite/allwpilib>
- WPILib documentation
 - <https://docs.wpilib.org/en/latest/docs/software/examples-tutorials/trajectory-tutorial/index.html>
 - <https://docs.wpilib.org/en/latest/docs/software/advanced-controls/trajectories/troubleshooting.html>
- My book on controls engineering in FRC
 - <https://controls-in-frc.link/>

