Control Update

Leonard Hall

Motor Mixer Development

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- Thrust lost detection
  - Increased thrust when motors are lost.
    - Hex 33% to 66%
    - Octo 50% to 66%
- Separate feedforward input
  - Better control of single and coax aerodynamic surface controlled aircraft
  - Ready for rpm gain scheduling for Helicopters
- ArduPilot motor ordering supported!!!!

- Looking forward to 2020:
  - Tri-copter motor mixer
  - ESC telemetry based motor loss support

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Attitude Controller Development

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- Dynamic Harmonic Notch
- PID filter design
  - Target low pass filter (FLTT)
  - Error low pass filter (FLTE)
  - D-term low pass filter (FLTD)
- Feed forward support and limiting
- Quaternion based attitude controller adoption has been smooth
- Tuning guide has been receiving positive reports
- System Identification mode

- Looking forward to 2020:
  - Yaw angle/rate for auto modes
  - Generic Auto-Tune including Feed Forward
  - Feed forward D term
  - Attitude feedback delay term

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Attitude Controller Architecture

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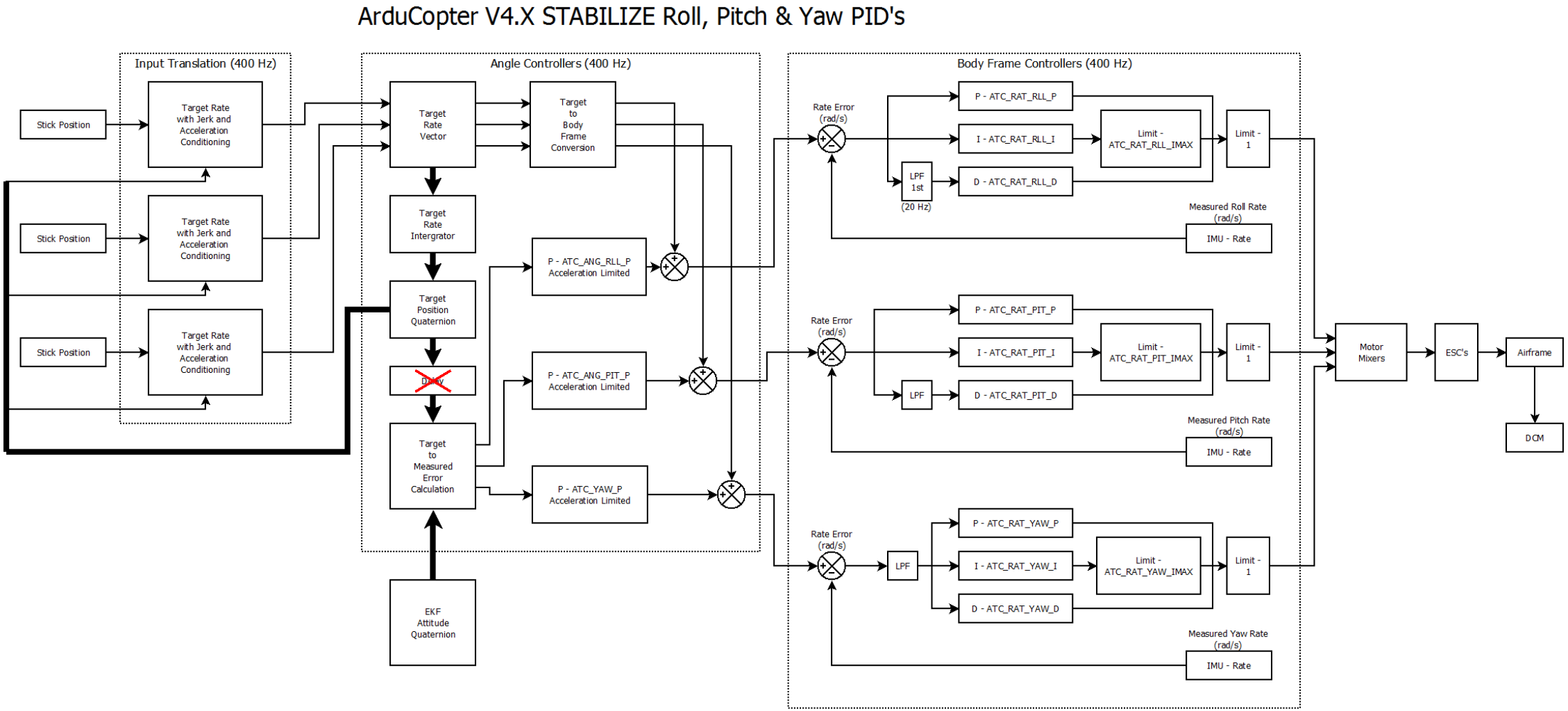

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Attitude Controller Architecture

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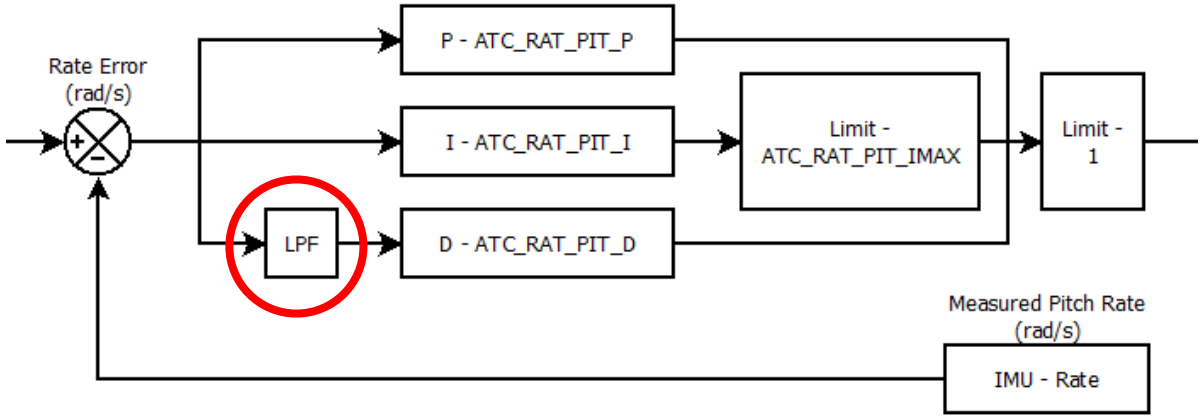
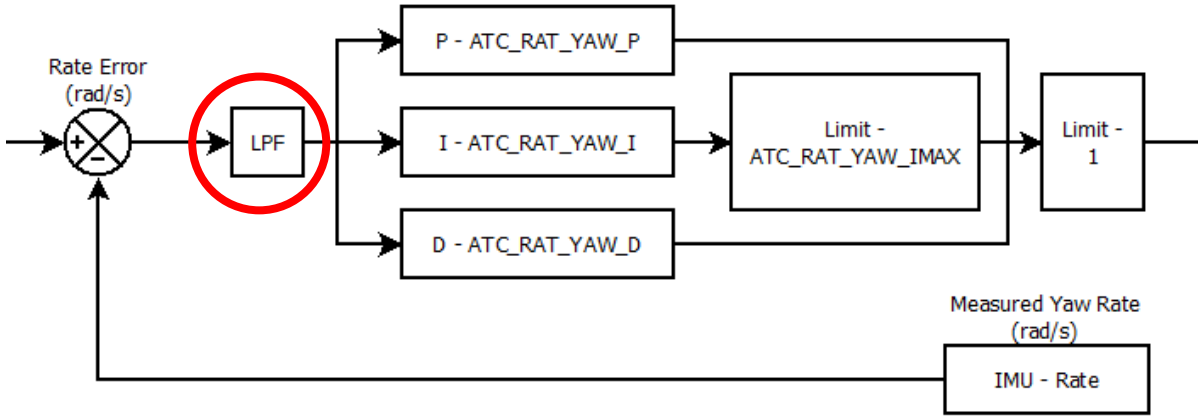
Roll and Pitch



Yaw



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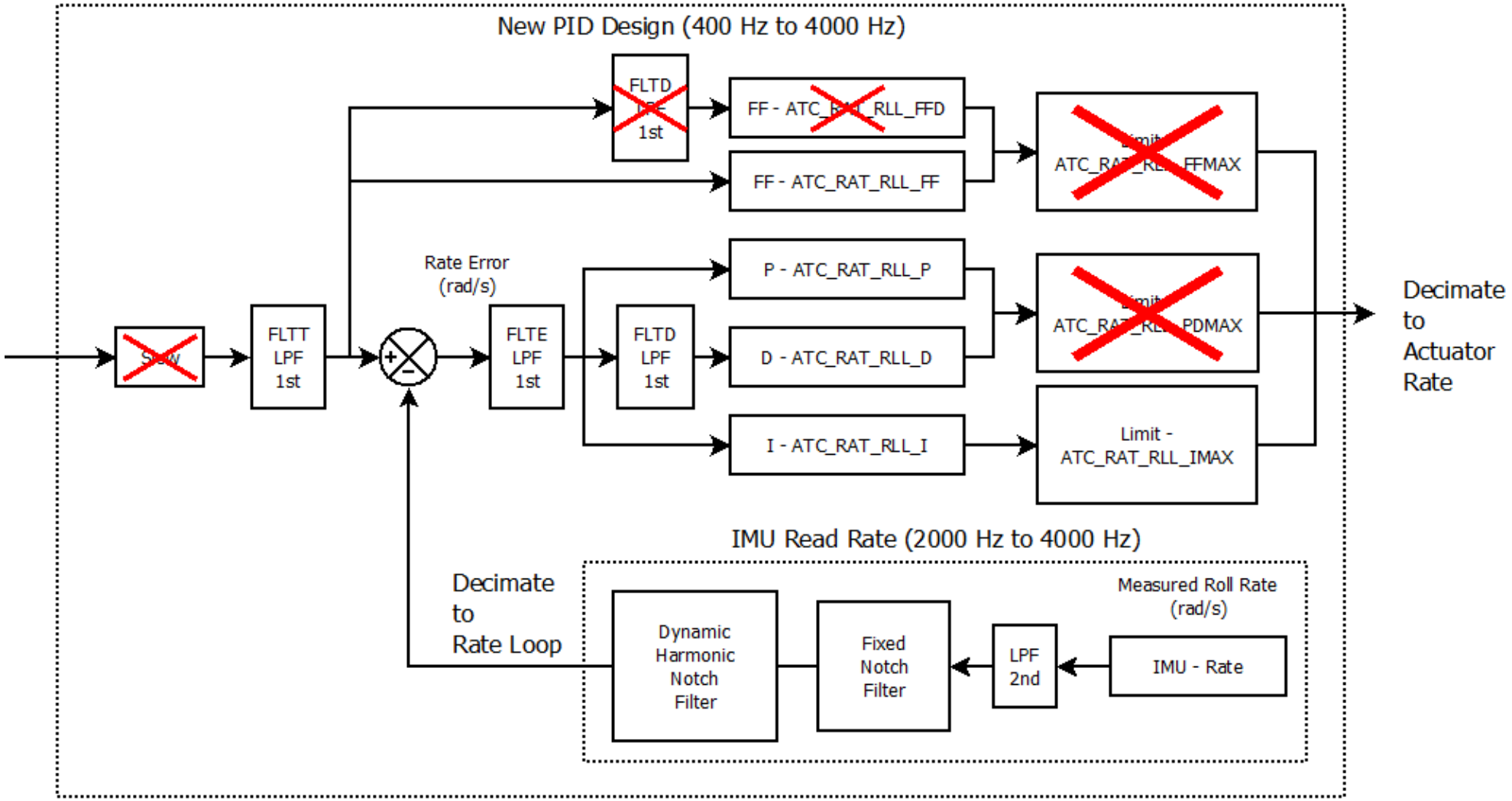
Attitude Controller Architecture



Position Controller Development

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- Little to no changes made in 2019….. But lots of work to prepare for 2020!

- Looking forward to 2020:
  - Position, Velocity and Acceleration PID objects to get filtering and general structural enhancements.
  - Rewrite of Z-Axis control law to provide additional tuning flexibility.
  - Improved limit and EKF reset handling.
  - Support for three axis feed forward architecture for Position, Velocity and Acceleration.
  - Structural changes to support a generic acceleration to attitude translation.

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Navigation Controller Development

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- A few structural and parameter changes but mostly transparent to the user... But lots of work to prepare for 2020!

- Looking forward to 2020:
  - Complete navigation controller rewrite
    - Trigonometric S-Curve based navigation
    - Trigonometric S-Curve based spline segment generation
    - Input shaping based Guided Mode

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Navigation Controller Requirements

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- Defines the straight segments
  - Smooth and efficient speed control
  - Maintains maximum speed given defined kinematic limits
- Defines the corner geometry
  - Achieve minimum distance from the waypoint
  - Smooth and efficient:
    - corner geometry,
    - speed control,
    - steering rate control.
  - Be free of sharp discontinuities and transients

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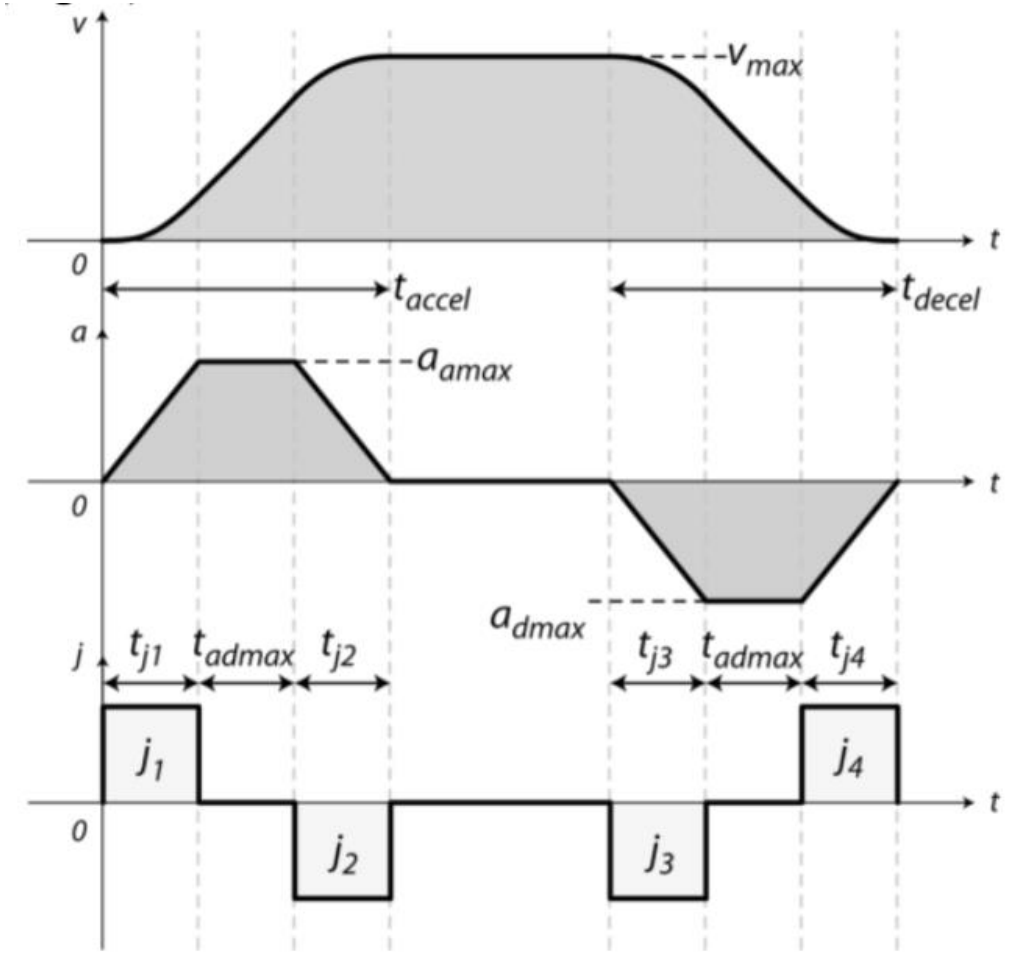
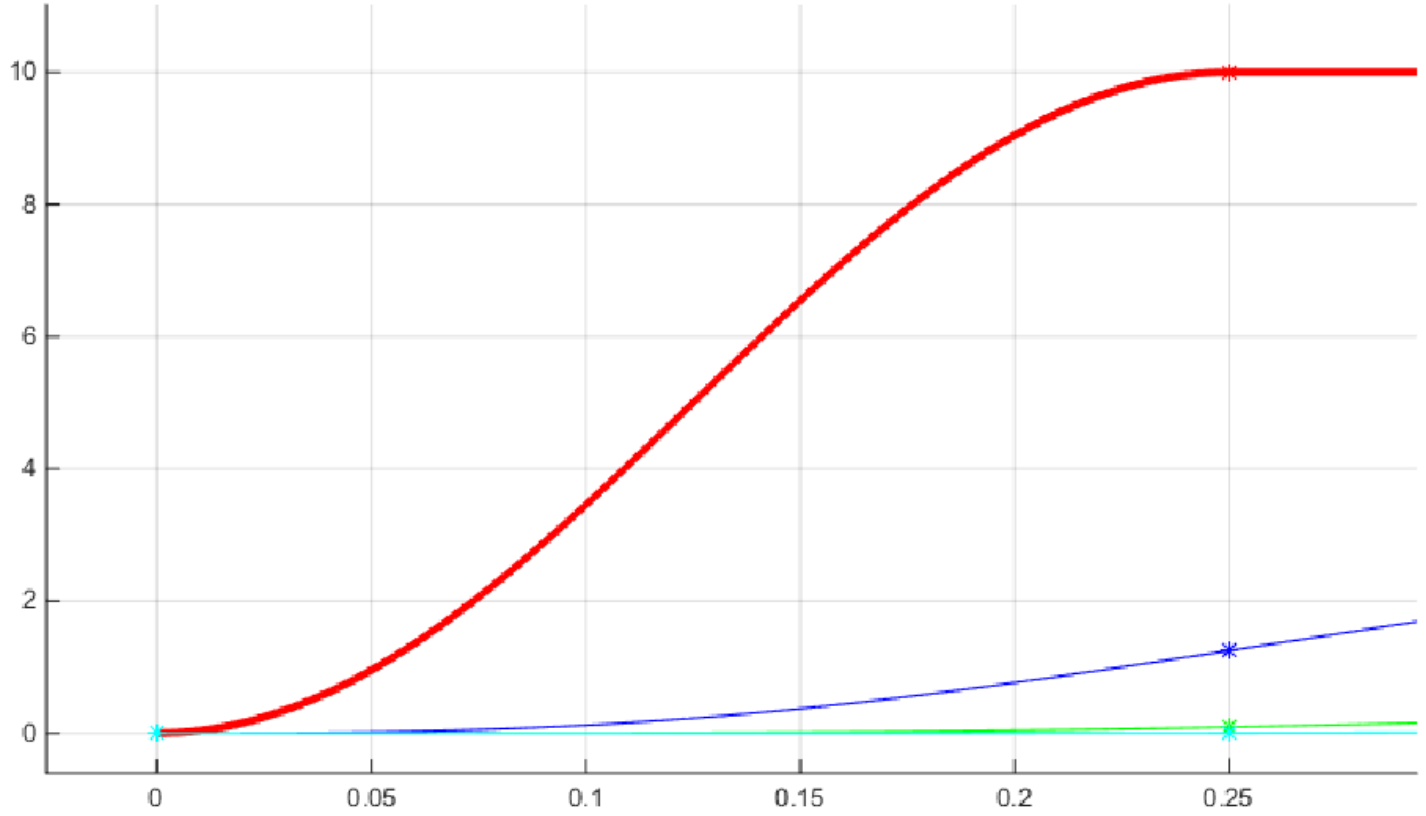
The solution : S-Curve



- Jerk
  - Rectangular
  - Defined maximum
- Acceleration
  - Trapezoidal
  - Defined max slope
  - Defined max value
- Velocity
  - Trapezoidal with rounded corners
  - Defined max slope
  - Defined max value

But can we do better……



Jounce formulation

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$$J(t) = \frac{J_p}{2}\left(1 - \cos\left(\frac{\pi}{T}t\right)\right)$$

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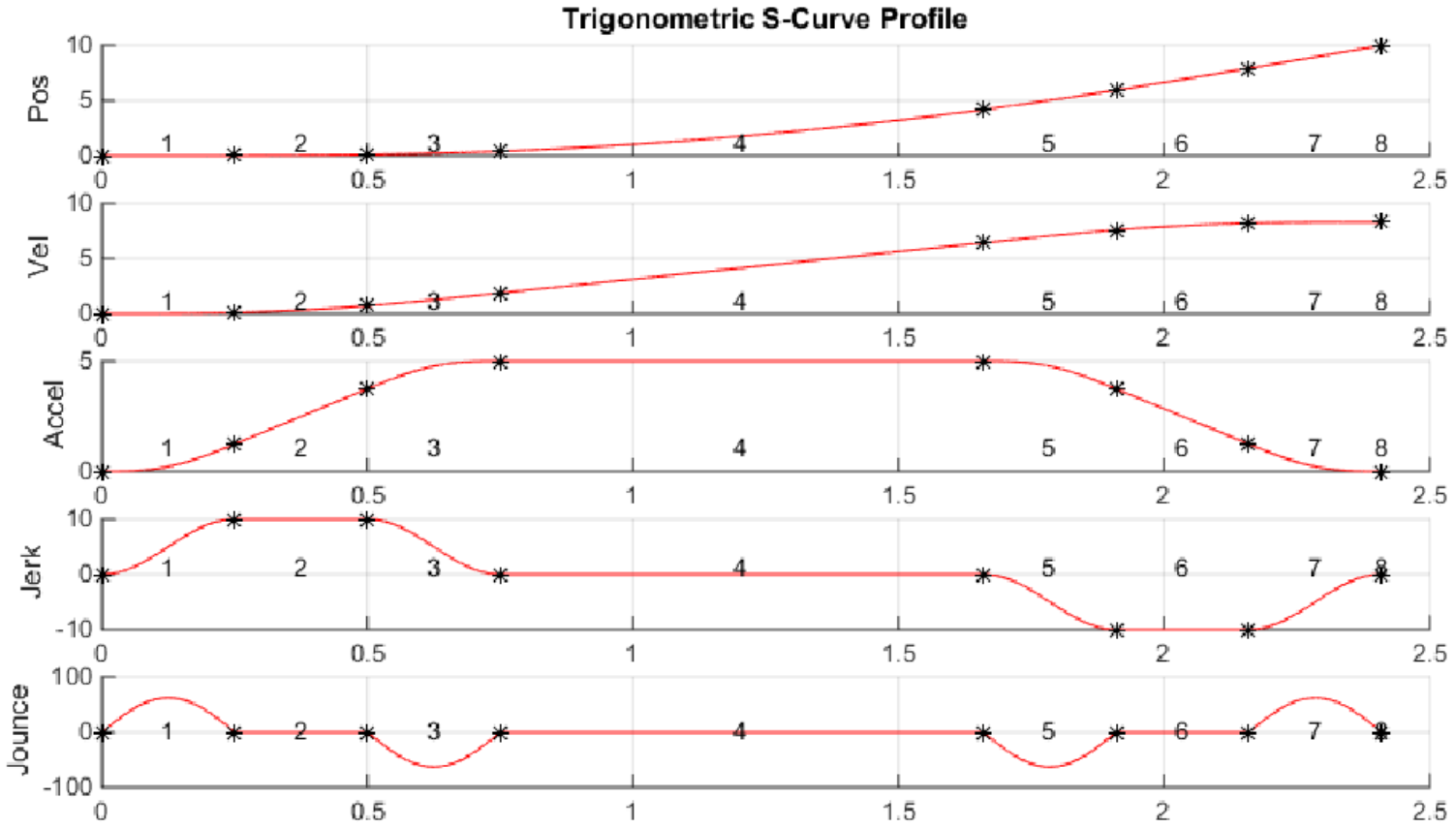
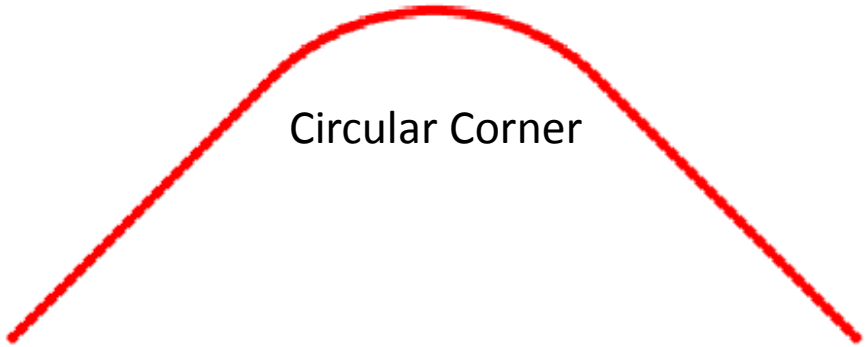
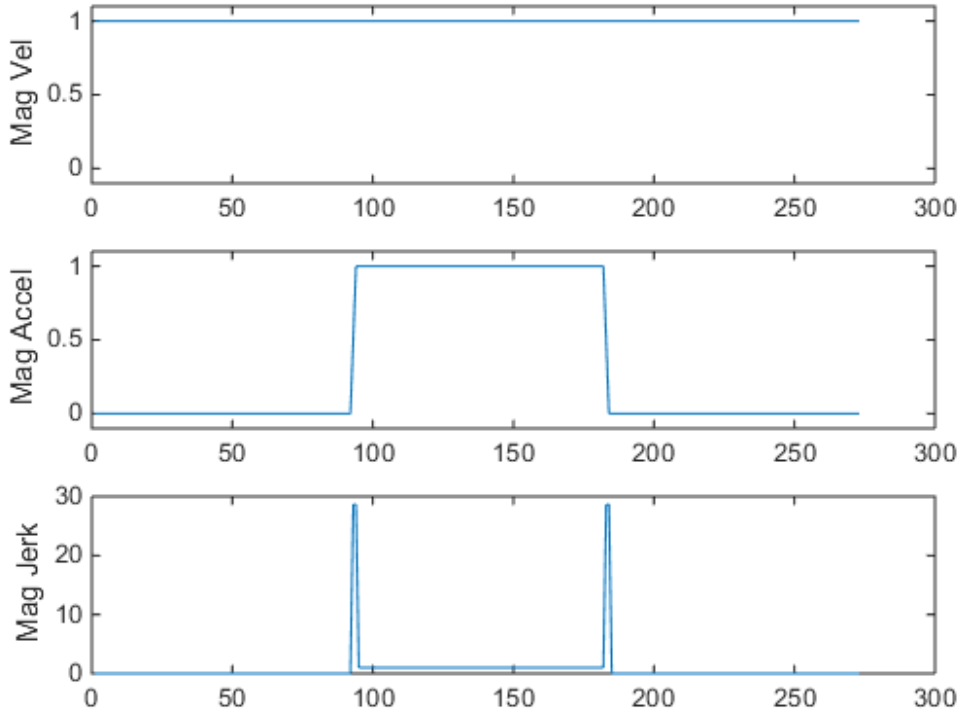
Trigonometric S-Curve Profile

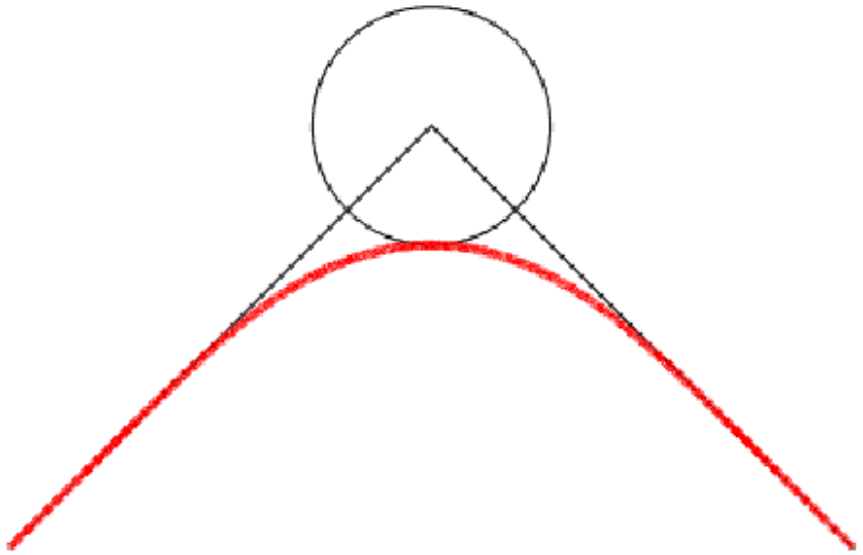


The Perfect Corner





What do we want from a corner?



- Follows the incoming track
- Continuous in:
  - Position
  - Velocity
  - Acceleration
  - More???
- A controlled turn rate
- A controlled distance from the waypoint
- Follows the outgoing track

And a good corner:
Two segment Trig S-Curve

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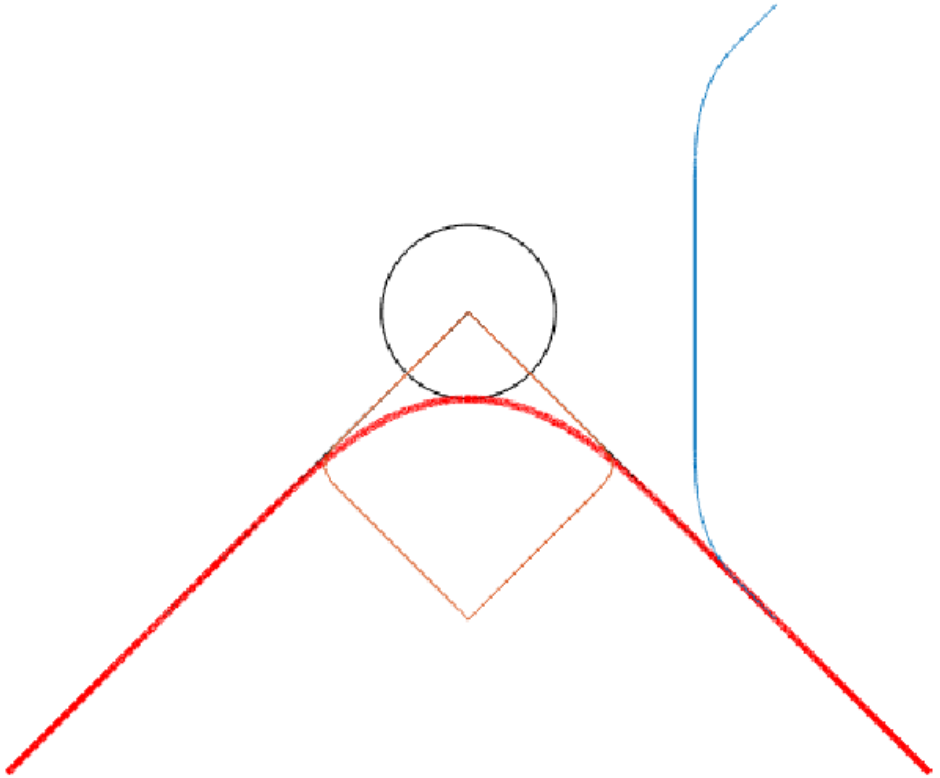

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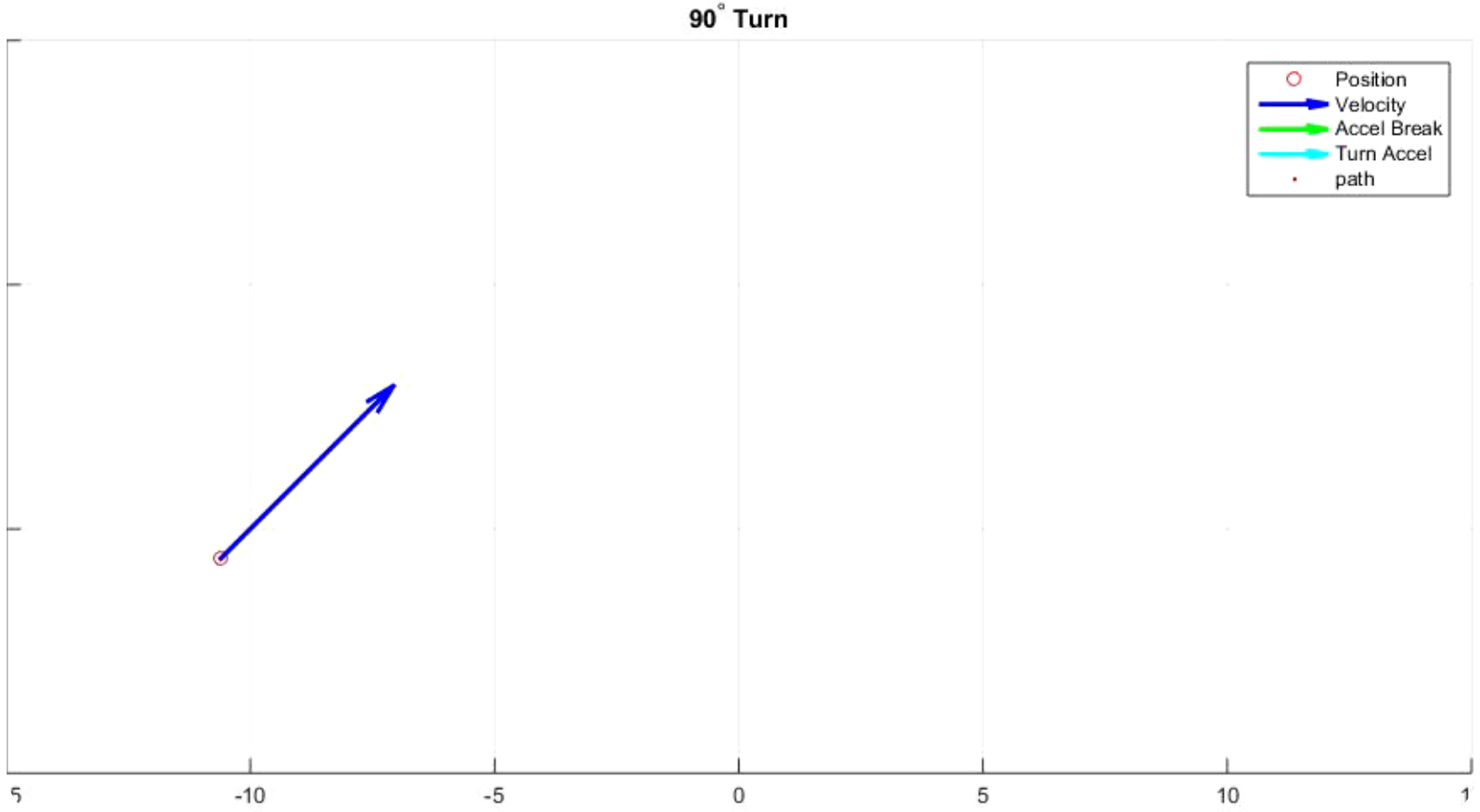
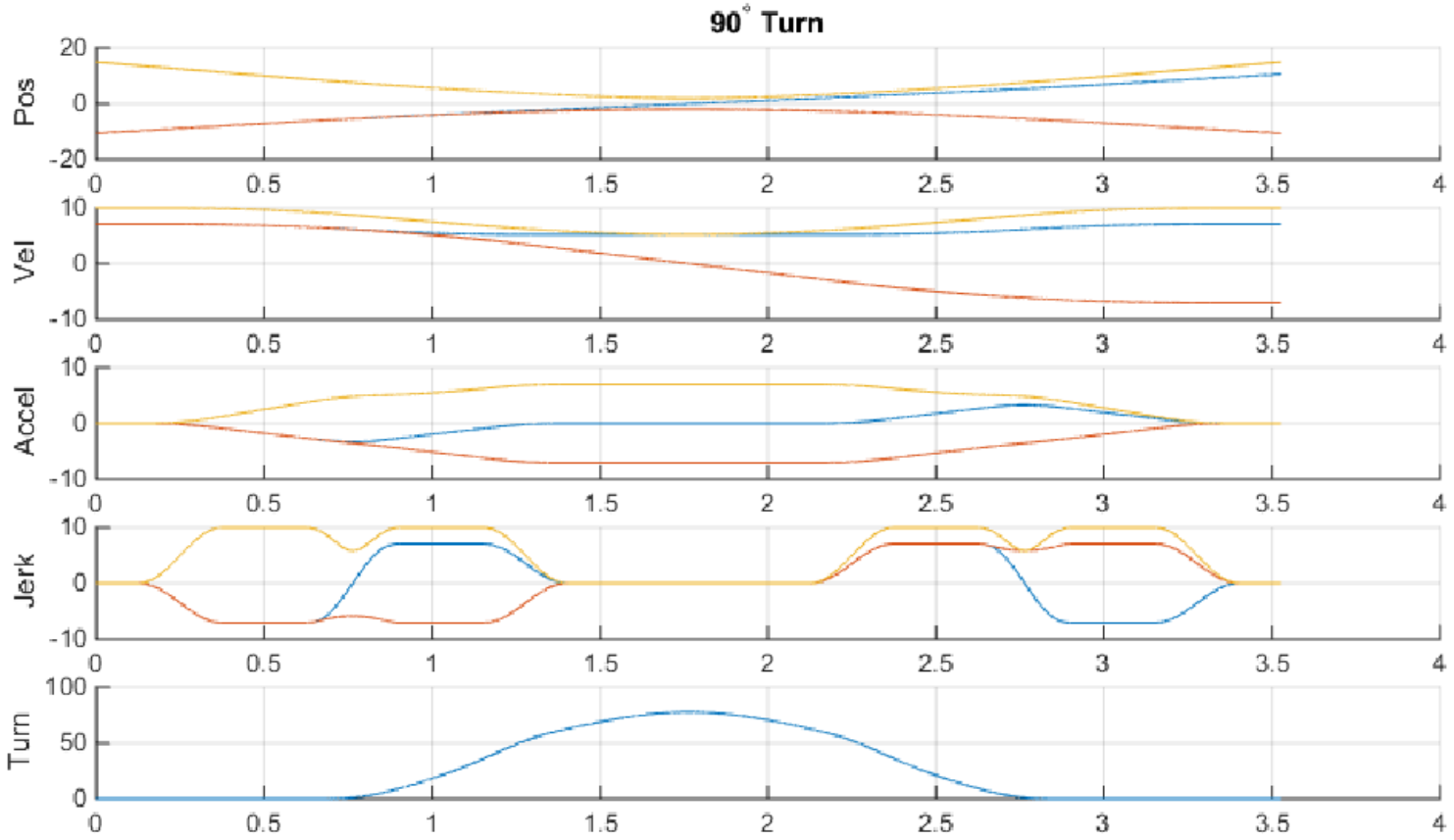
Trigonometric S-Curve Corner - 90°



Trigonometric S-Curve Corner - 90°



Spline Waypoints

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- Define curved segments defined by:
  - Entry and exit waypoints
  - Entry and exit velocity vectors
- Curve should be similar with different vehicle kinematic parameters but perhaps not identical.
- Curve should be optimized for maximum velocity based on vehicle kinematic parameters.
- Emphasis on not exceeding vehicle kinematic maximums.

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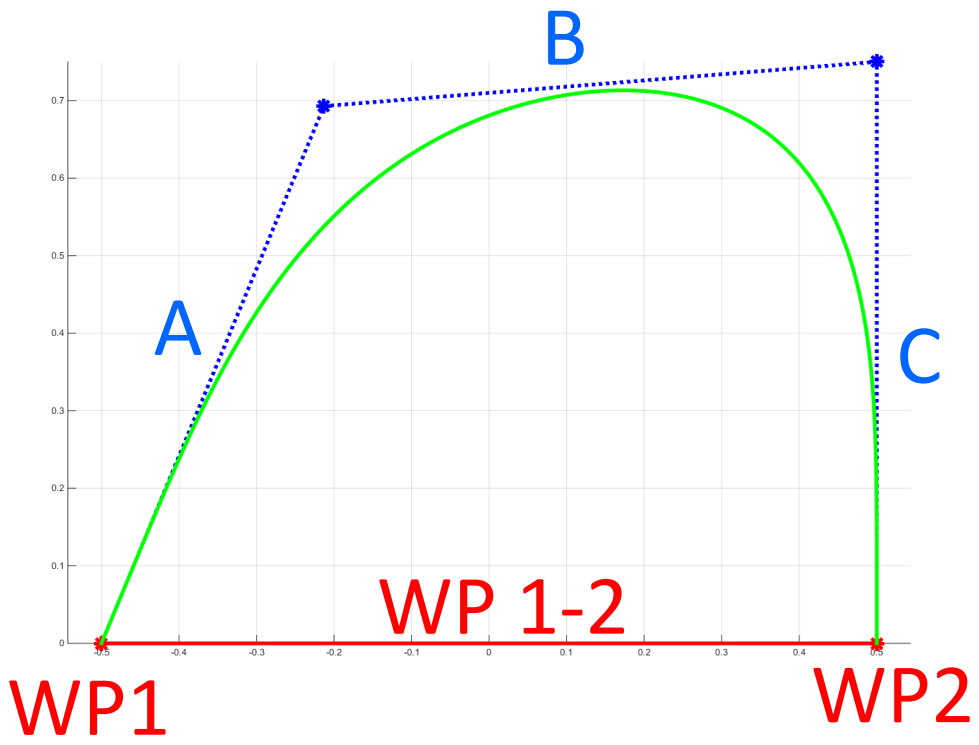
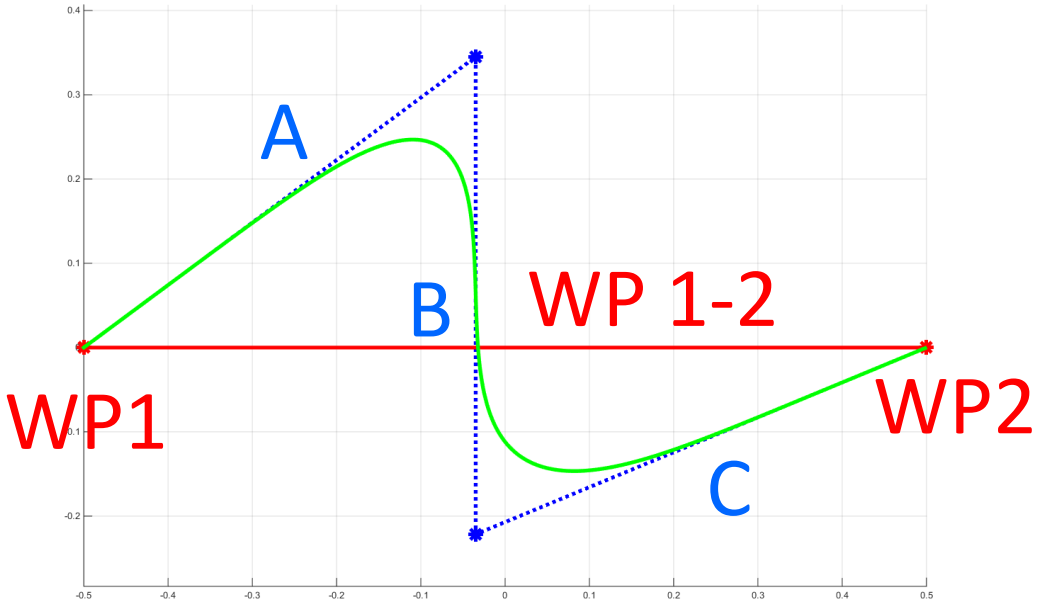
Spline Waypoints:
Three segment Trig S-Curve

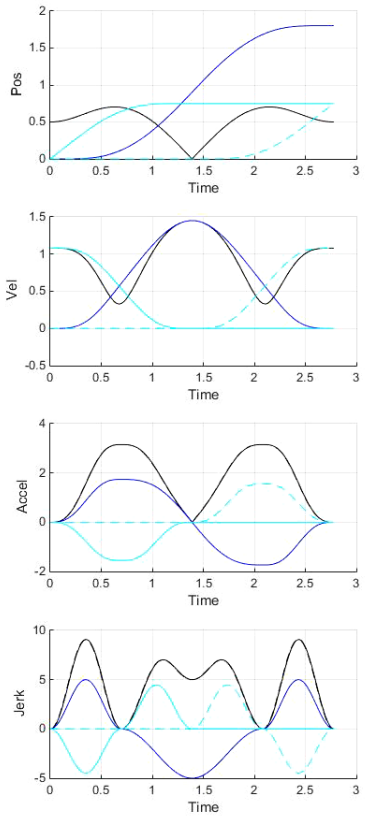


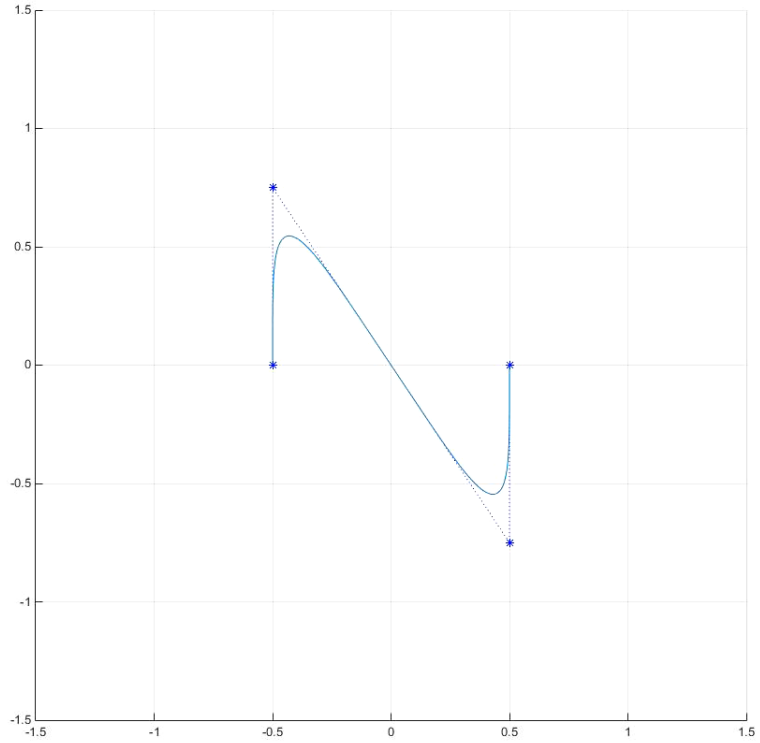
|A| = |B| = (¾)x|WP12|



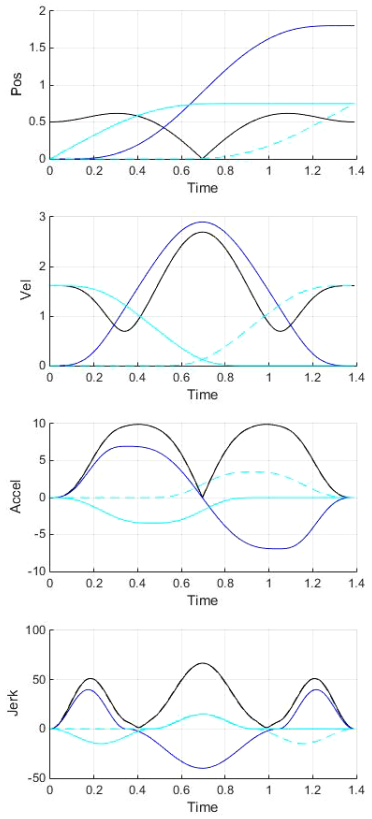
B is vertical

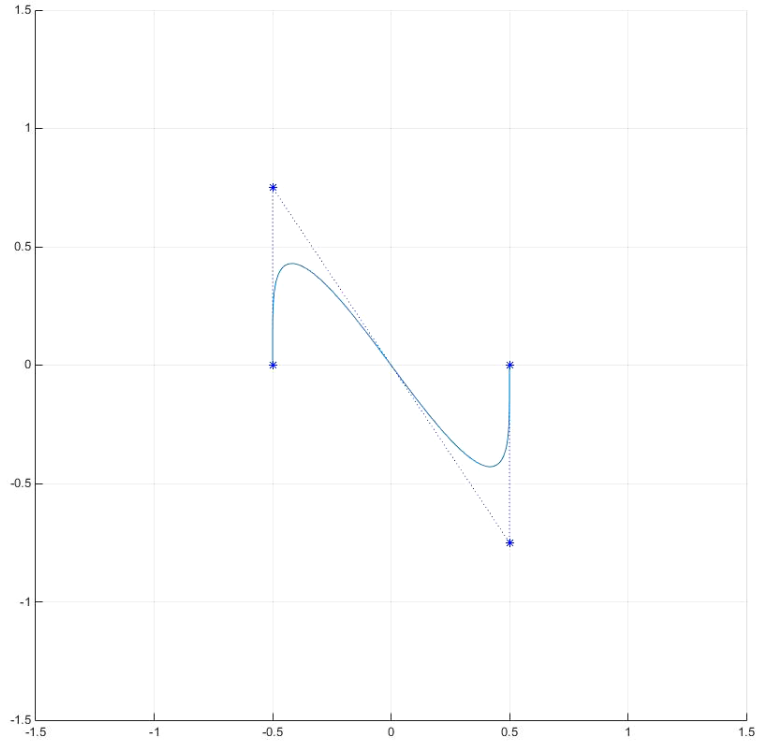
Spline Waypoints: Jerk Limited Three segment Trig S-Curve



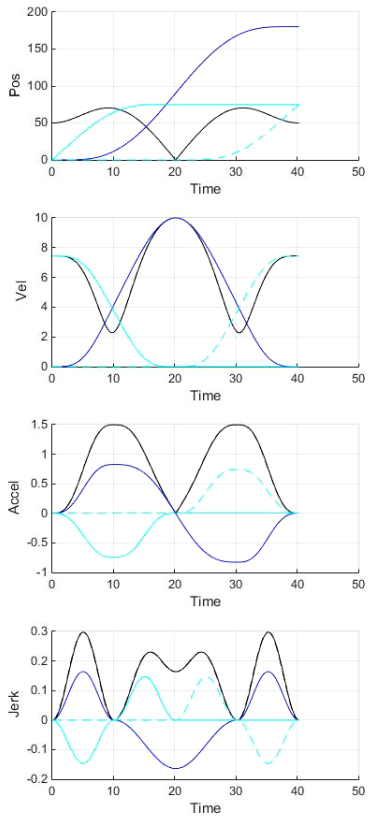


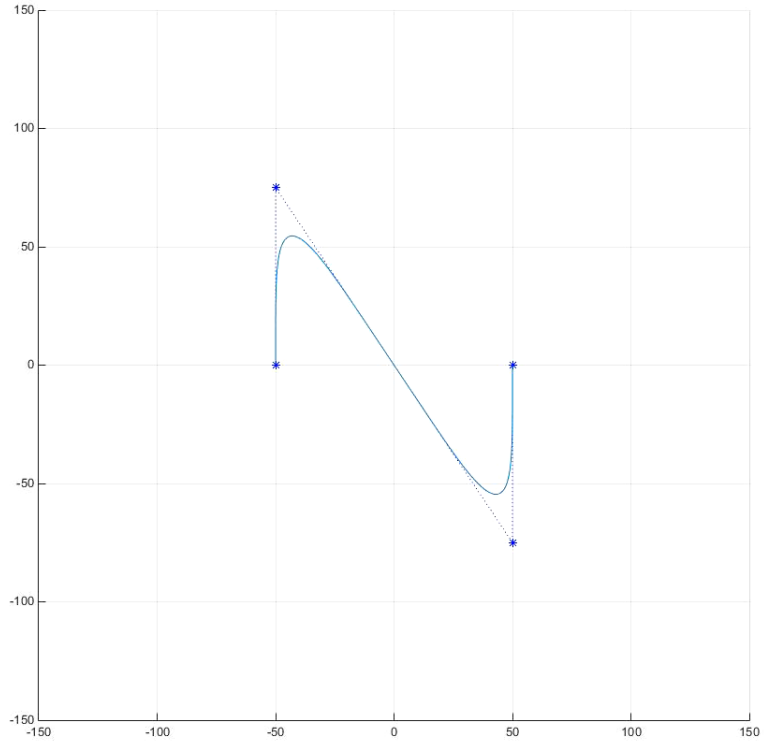
Spline Waypoints: Acceleration Limited Three segment Trig S-Curve





Spline Waypoints: Velocity Limited Three segment Trig S-Curve





2020 Advancements

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- ESC feedback motor loss compensation
- Automatic Dynamic Harmonic Notch Filter (FFT Driven)
- FFD (Feed forward D term)
- Attitude Stabilisation loop delay
- Yaw angle/rate command input
- Position controller rewrite (mainly Z axis and PID filter enhancement)
- Guided mode to use feed forward with error correction time constant.
- Trigonometric S-Curve based waypoint navigation

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Questions