Velocity Profile Generation

Course 4, Module 7, Lesson 5

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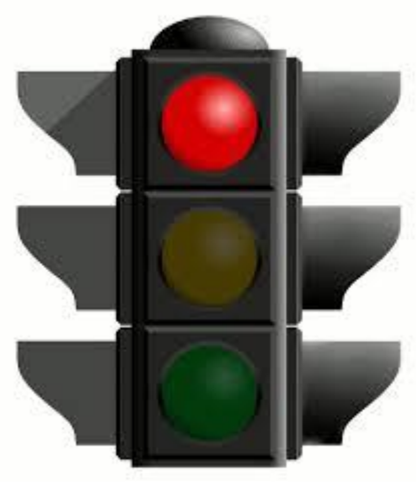
Learning Objectives

- Know how to use leading vehicle time-to-collision (TTC) to inform velocity profile generation
- Know how to use reference velocities from behavioural planner in velocity profile generation
- Integrate comfort constraints into velocity profile generation
- Know how to implement a linear ramp and trapezoidal velocity profile

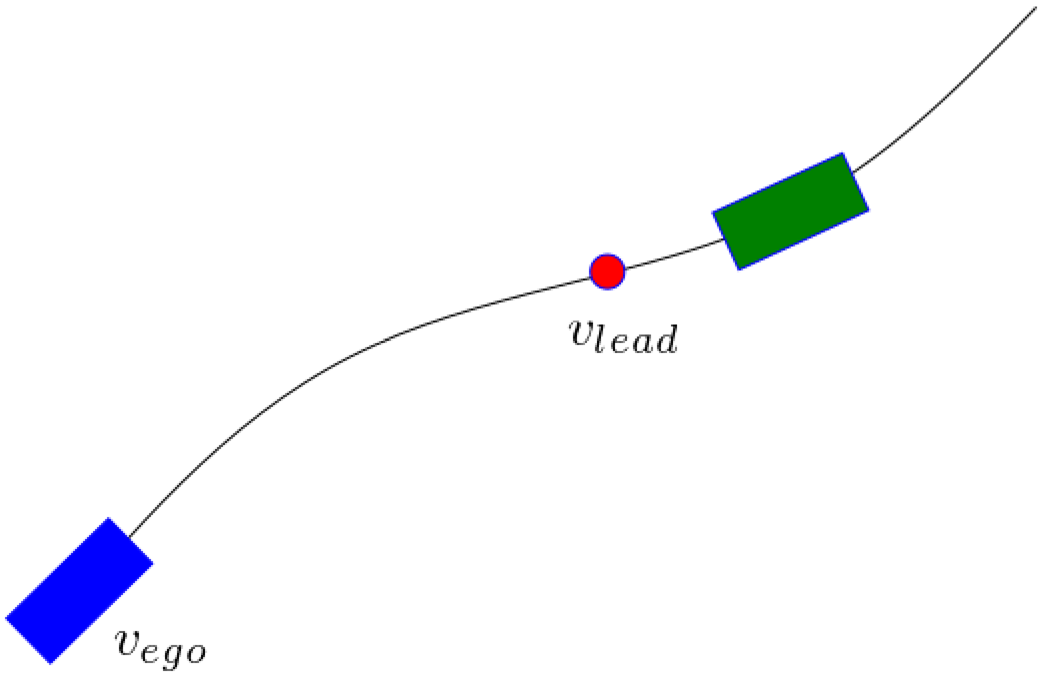
Behavioural Planner Reference Velocity

- Need to compute reference velocity
- Can use the speed limit of the road as a starting point
- Behavioural planner maneuver will also influence reference velocity
  - E.g. a stopping maneuver requires us to stop



Dynamic Obstacles

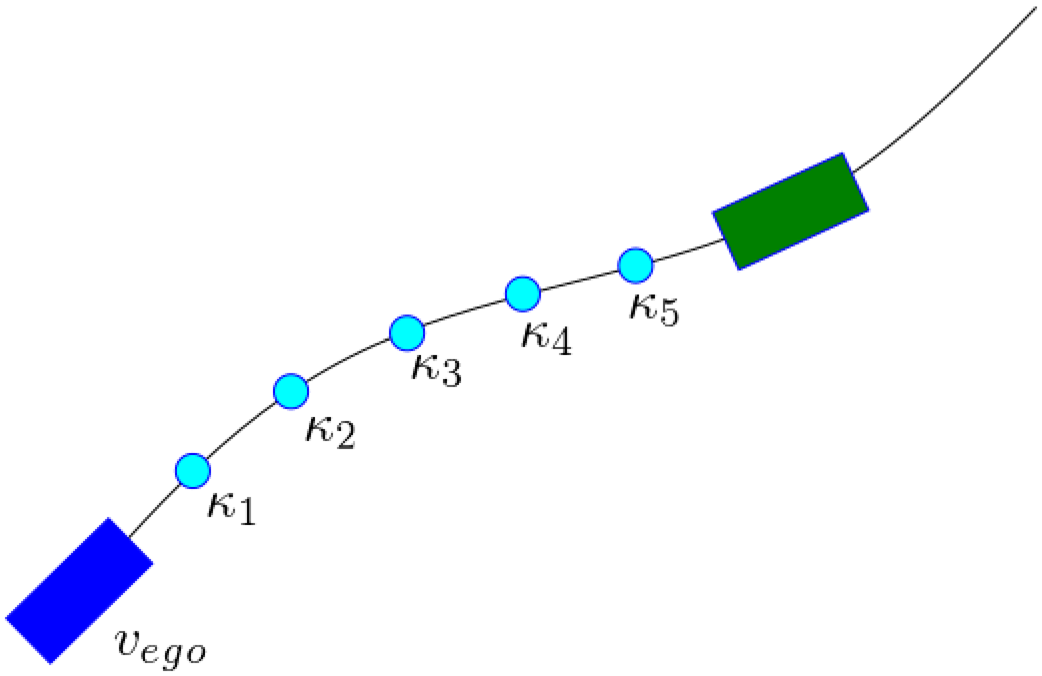
- Lead dynamic obstacles regulate our speed to prevent collisions
- Time to collision is an important metric to preserve when driving with lead vehicles
- Need to reach the red point at lead vehicle speed to ensure there is no collision



$$TTC = \frac{v_{ego} - v_{lead}}{s}$$

Curvature and Lateral Acceleration

- Curvature recorded at intermediate points, κ_i
- Velocity bounded by maximum lateral acceleration from comfort rectangle
- Final velocity selected as minimum of BP reference, lead vehicle speed and curvature speed limit

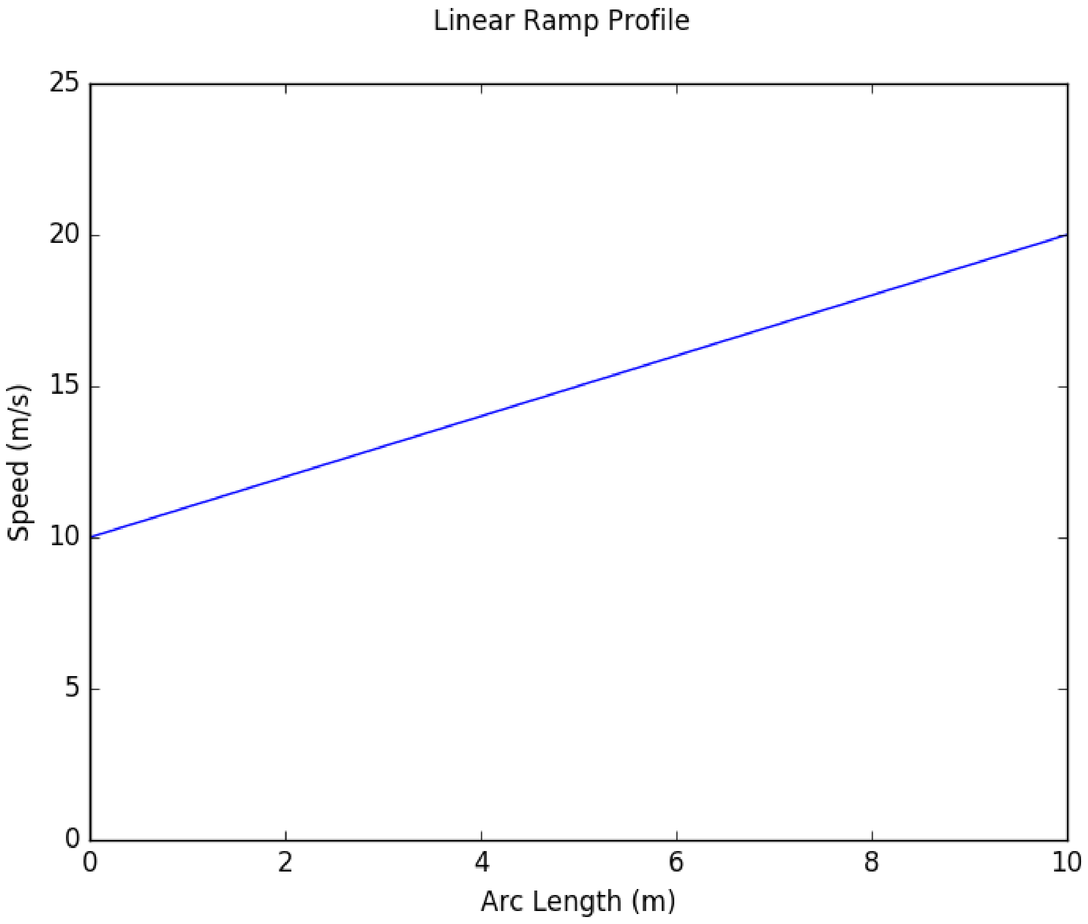


$$v_k \leq \sqrt{\frac{a_{lat}}{\kappa_i}}$$

$$v_f = \min(v_{ref}, v_{lead}, v_k)$$

Linear Ramp Profile

- Simplest shape is a linear ramp to our desired velocity
- We know the total arc length of our path s and our initial and final speed v_0 an v_f



Linear Ramp - Acceleration Calculation

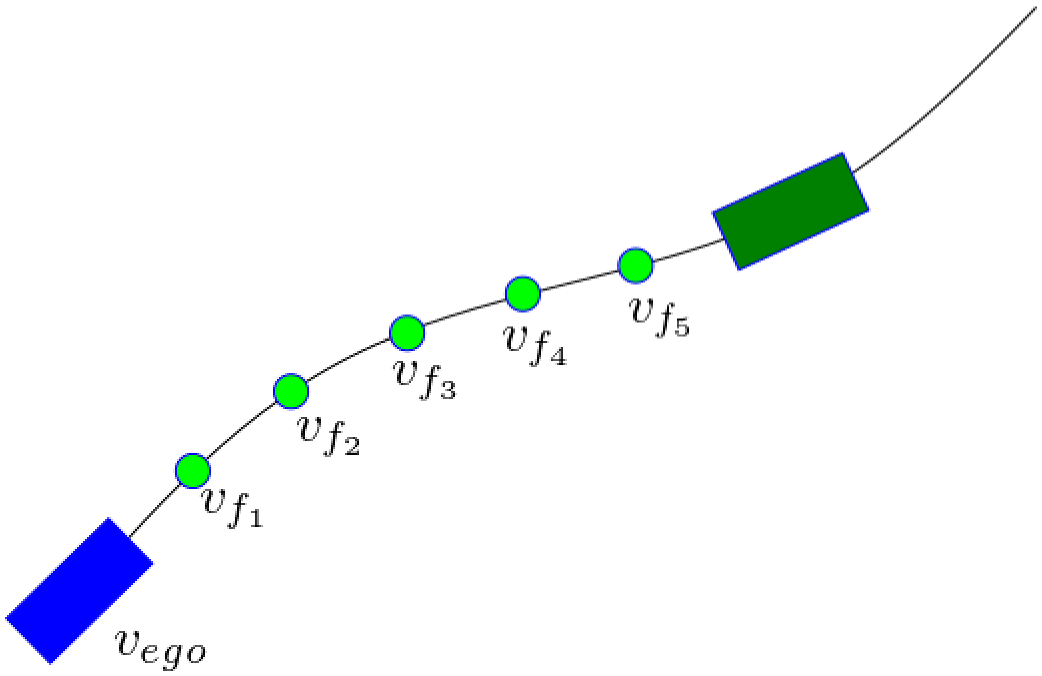
- Can calculate acceleration using initial and final velocity as well as path arc length
  - Need to be sure acceleration values don't exceed our comfort rectangle as discussed in Module 1
- If we clamp our acceleration, we can recompute the final velocity using the clamped acceleration for a

$$\frac{v_f^2 - v_0^2}{2s} = a$$

$$\sqrt{2as + v_0^2} = v_f$$

Linear Ramp - Velocity Calculation

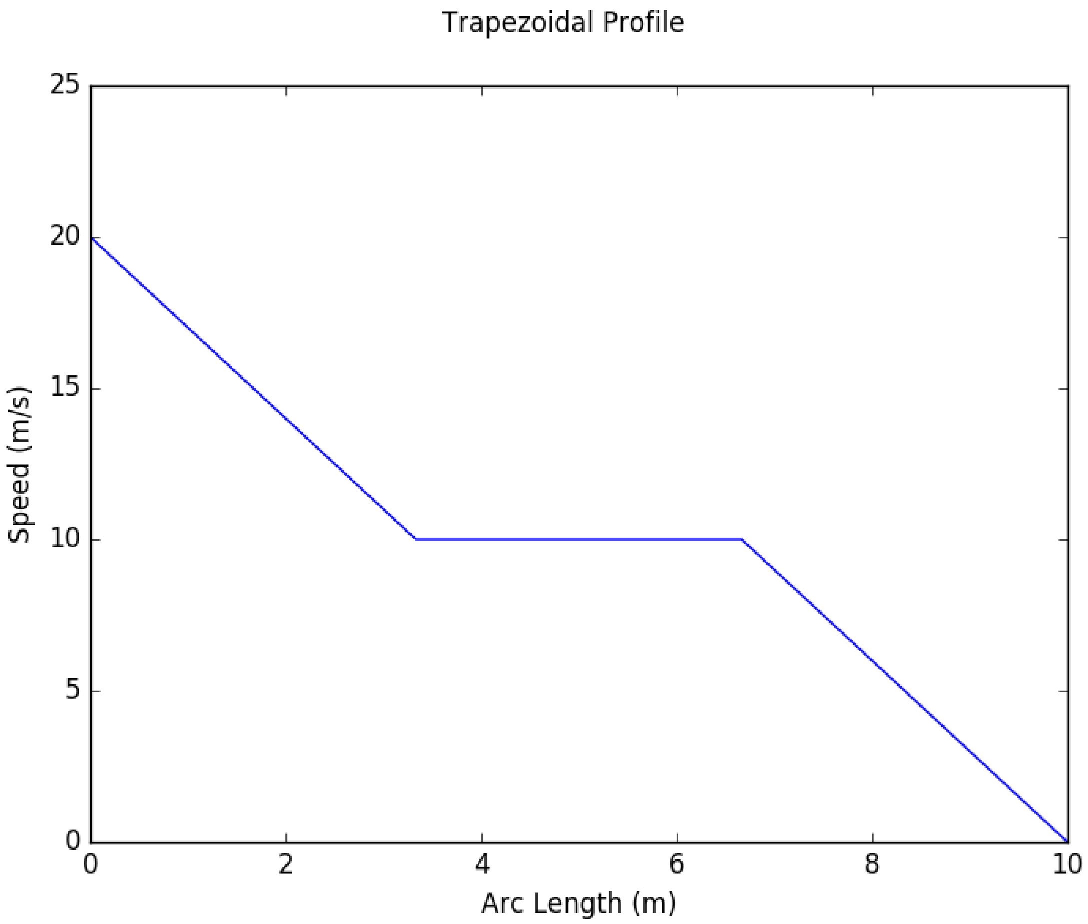
- For a given acceleration, we can then compute the velocity at each point by using the accumulated arc length s_i up to that point



$$\sqrt{2as_i + v_0^2} = v_{f_i}$$

Trapezoidal Profile

- Alternative profile is trapezoidal, car decelerates to slower speed before stopping
  - Useful for stop sign scenarios
- Deceleration chosen to be well within comfort rectangle to maximize passenger comfort



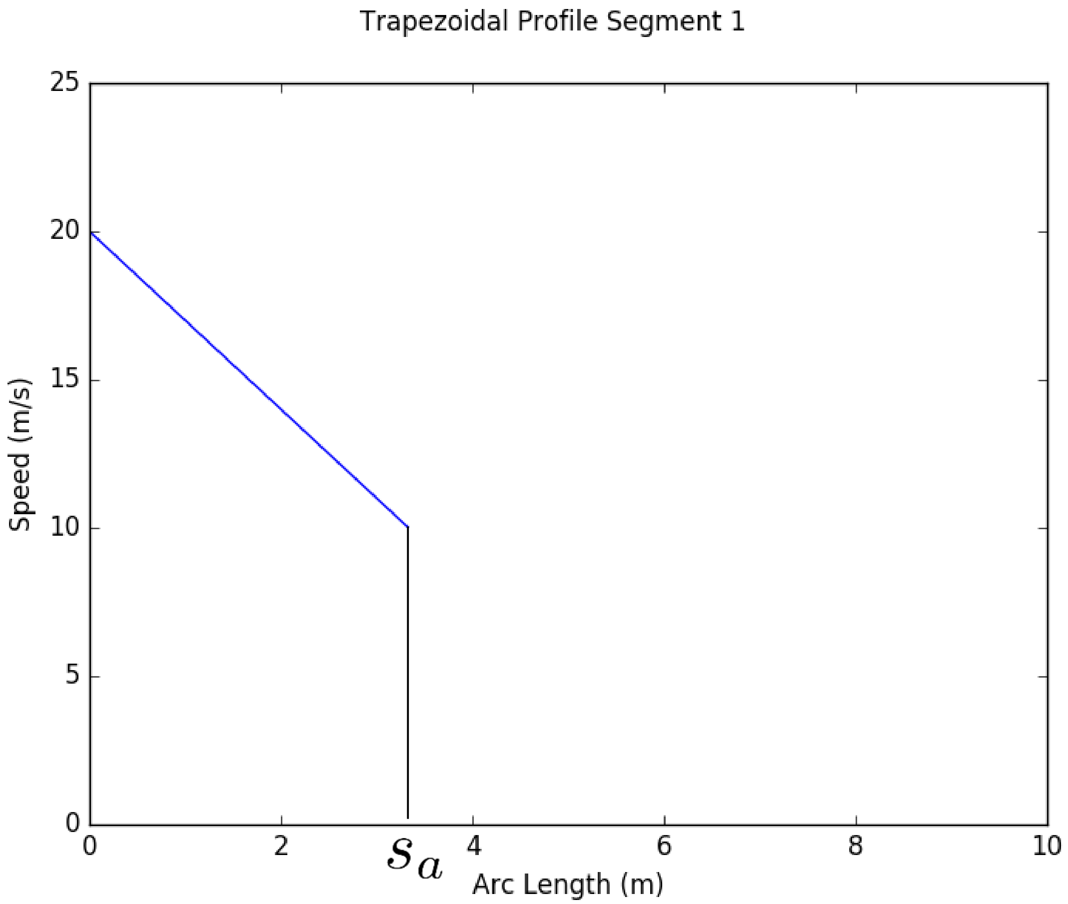
Trapezoidal Profile - First Segment

- First step is to determine distance required to reach transit velocity v_t using gentle deceleration a_0
- Can then compute linear deceleration for all points up to point of reaching transit speed

$$\frac{v_t^2 - v_0^2}{2a_0} = s_a$$

$$\sqrt{2a_0 s_i + v_i^2} = v_{f\,i}$$

$0 \sim s_a$



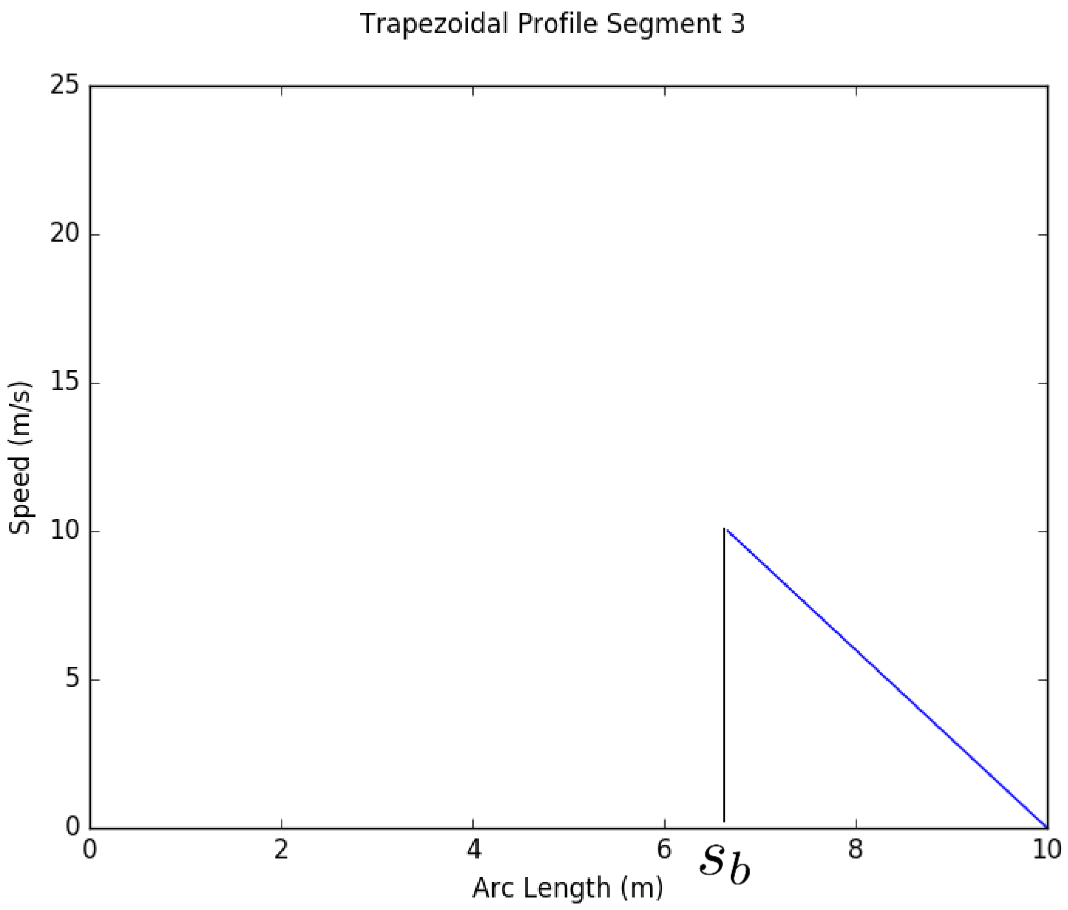
Trapezoidal Profile - Third Segment

- Can repeat a similar process to reach a stop from v_t using gentle deceleration a_0
- Need to first find point of initial deceleration s_b
- The points in between 1st and 3rd segment have constant velocity v_t

$$\frac{0 - v_t^2}{2a_0} = s_f - s_b$$

$$\sqrt{2a_0(s_i - s_b) + v_t^2} = v_{f_i}$$

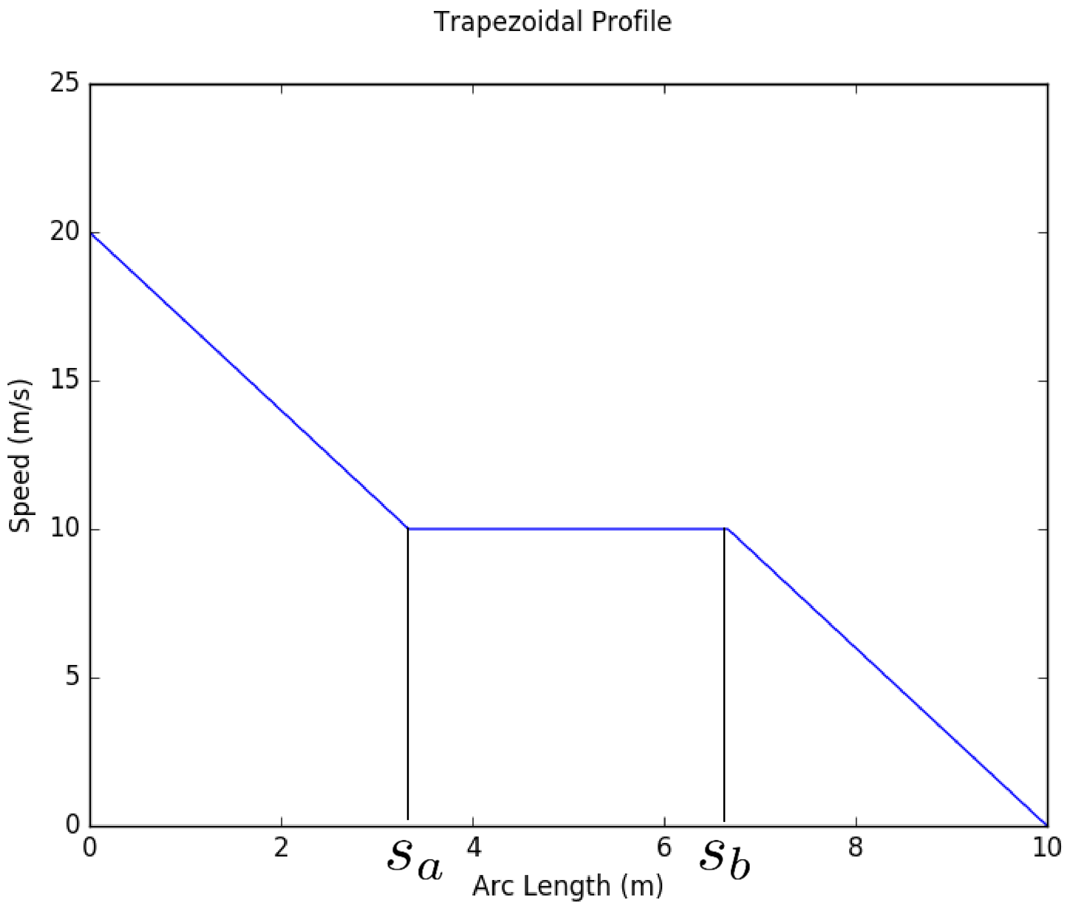
$s_b \sim s_f$



Trapezoidal Profile - All Segments

- Bringing in the constant velocity transit section, we have our full trapezoidal velocity profile

$$v_{f_i} = \begin{cases} \sqrt{2a_0 s_i + v_i^2}, & s_i \leq s_a \\ v_t, & s_a \leq s_i \leq s_b \\ \sqrt{2a_0(s_i - s_b) + v_i^2}, & s_b \leq s_i \leq s_f \end{cases}$$



High-order methods: biquadratic velocity planners

Summary

- Discussed how to incorporate behavioural planner reference velocity into velocity generation
- Discussed how to use TTC to inform velocity profile generation
- Integrated lateral acceleration constraints into velocity profile generation
- Showed how to calculate linear and trapezoidal ramp velocity profiles