NASCAR Refueling Challenges: The Strategy Behind a Pit Stop

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Outline

• Background
• Model Highlights
• Safety and Efficiency
• Proof Highlights
• Conclusion
Background

• NASCAR races
  • 36 total races
  • 34 oval tracks
  • .526 – 2.66 miles long
  • 188 – 500 laps

• Refueling rules
  • No sensors to monitor exact gas level
  • 24 gallons per pit stop
Model Highlights

• Controls
  • if fuel > fc * v * T; continue;
  • if fuel ≤ fc * v * T; fuel = max;

• ODEs
  • \( x' = v * dx \)
  • \( y' = v * dy \)
  • \( dx' = -dy \)
  • \( dy' = dx \)
  • \( fuel' = -fc * v \) (linear)
  • \( fuel' = -(fc * v * t + c) \) (quadratic)
Safety and Efficiency

• Stay on track
  • $x^2 + y^2 = rad^2$

• Sufficient fuel
  • $fuel \geq 0$

• Do not stop unnecessarily
  • \textit{if} $fuel > fc \times v \times T$; \textit{continue};
Proof Highlights (on track)

• Loop invariants
  • $x^2 + y^2 = rad^2$
  • $dx^2 + dy^2 = 1$
  • $dx \cdot v = -y$
  • $dy \cdot v = x$
  • $rad \geq 0$

• Differential Cuts
  • $dx \cdot v = -y$
  • $dy \cdot v = x$
Proof Highlights (sufficient fuel)

• Loop Invariants
  • $fc > 0$
  • $T > 0$
  • $fuelinit > fc \times v \times T$ (linear)
  • $fuelinit > fc \times v \times T^2 + c \times T$ (quadratic)
  • $max > vc \times v \times T$

• Differential Cuts
  • $fuel = fuelinit - fc \times v \times T$ (linear)
  • $fuel = fuelinit - (fc \times v \times T^2 + c \times T)$ (quadratic)
Conclusion

• Can CPS models help NASCAR teams?
  • Proof helps devise strategies
  • Use of algorithmic CPS controllers

• Future work
  • Acceleration/deceleration
  • Time constraints
  • Multiple cars
  • Tire degradation
Thanks!

The Strategy Behind a Pit Stop