EECS192 Lecture 12
Advanced Steering
April 13, 2021

Topics

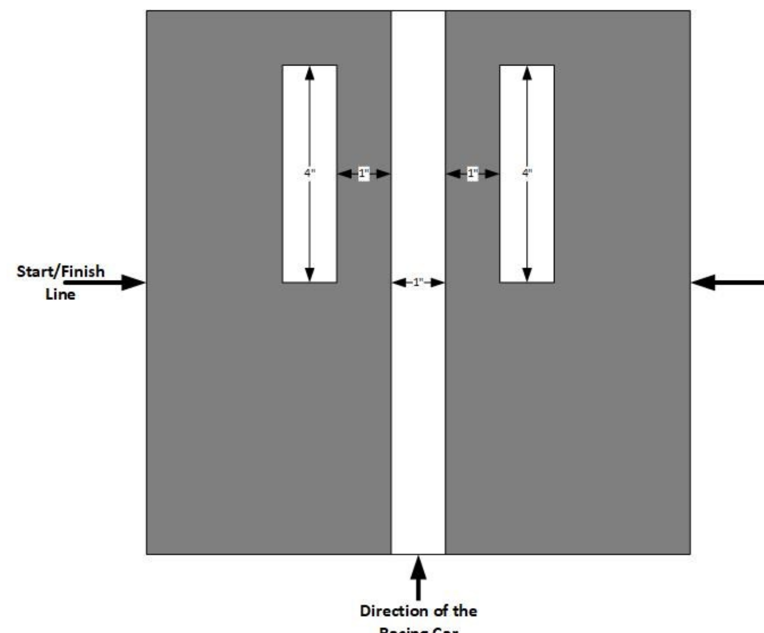
- Checkpoint 8: Step+ telemetry
- Progress report (due Fri 4/9 8 pm)
- Round 1 (simulation) in class 4/20 (was 4/13)
  - Submit Python 3.7 code, we run.
- Round 2 (live/hardware) in class 4/27
- Oral reports- submit pdf of ppt slides to BCourses by 5pm Tues May 4.
- Quiz 4 on steering 4/13
- Robustness (revisited)
- Brake Steering

# Checkpoint 8: Stopping (Fri 4/9)

Set up a straight or curved track with length sufficient for car to accelerate to (ideally) 2 m/sec or better and stop when it sees the stop pattern.

**Checkoff Procedure**

- C8.1 Show car driving on track and then doing emergency stop from remote command.
- C8.2 Show car driving on track and doing emergency stop when it crosses NATCAR stop marking of parallel lines. [Natcar Finish Line]
- C8.3 Show telemetry plot of speed and other relevant parameters.
- C8.4 All members must fill out the checkpoint survey before the checkoff close. Completion is individually graded.



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# Virtual Race Tues 4/20 in Class

# Goal: every team ``competes'' with control alg. on same track.

- Round 1 Race Track released for testing Saturday 4/17 5 pm (72 hours)
- Pre-submit your code on bCourses. Only submit your updated controller.py (we will let you know if it works if submitted by Sunday 4/18 6 pm)
- Your code must work on Python 3.x.
- You must be using the provided carInterface.py.
- You must not modify the call signature to SimulationAssignment.__init__, setup_car, and control_loop. We will be using a different __main__ block to run your code.
- You have 3 minutes of simulation time, with requests for re-runs handled in round robin order.
- Your code must run as a self-contained unit:
- Your code may not do disk operations (outside the csvfile.writerow) or network operations.
- If using memorization, your code must automatically (and without being restarted, or with command-line arguments, or any manual intervention in general) detect the end of a run and continue the next lap with whatever memorization-based algorithms you're using.
- As per NATCAR rules, you may not pre-program in data about the track.

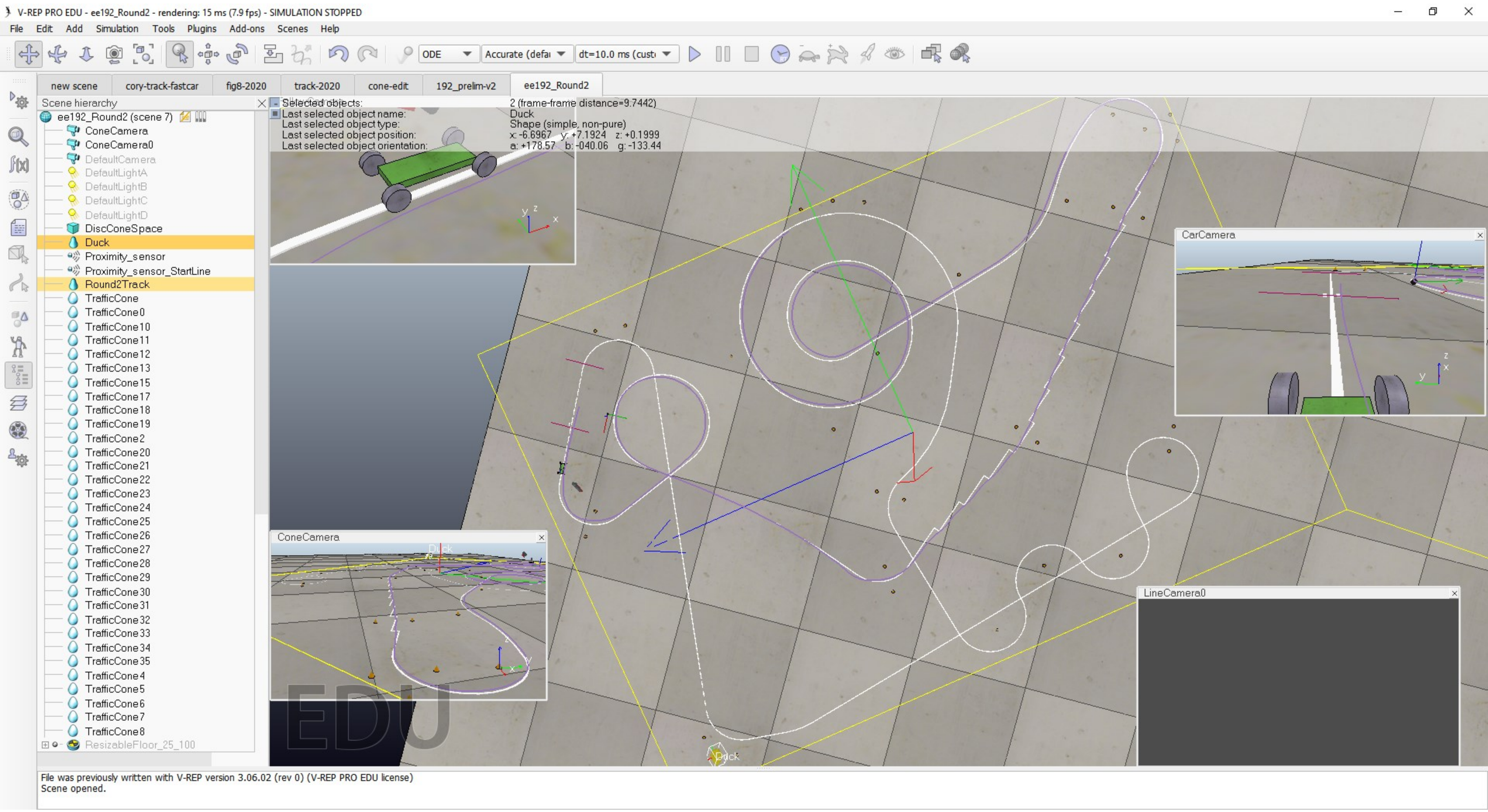
# Round 1 Deductions (+10 pts max)

| | |
|---|---|
| -0.3 points | Twitchy steering |
| -0.3 points | Goes wide on curves |
| -0.3 points | Oscillatory step response |
| -0.5 points | Hits cone(s) |
| -0.5 points | Ignores stop marks |

| | |
|---|---|
| -0.3 points | Slower than 2.5 m/s |
| -0.5 points | Slower than 1.5 m/s |

| | |
|---|---|
| -1 point | Does not finish track |
| -2 points | Finish < ½ track |
| - 3 points | Finish < ¼ track |

# Example Spring 2020 Sim Track



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# Spring 2021 Track v0

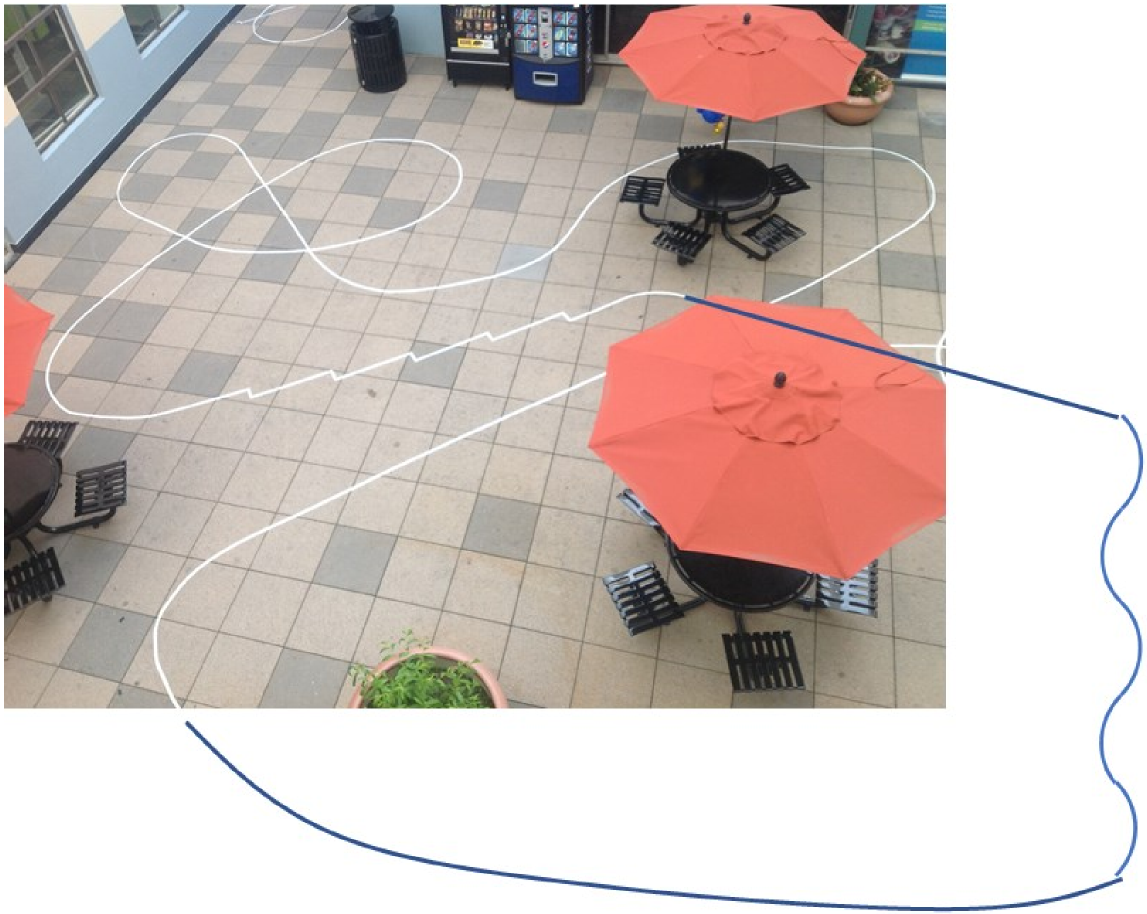
Thu and Friday 2-4 pm, supervised by staff member David Au.
All Covid protocols to be followed.
Details on Piazza when set up. Track avail April 15 (see signup list)

Floor tape applicator
Direction of application
(worked well on carpet-maybe problem in Courtyard?)

(Needs tweaking to make radii > 3 feet. Use string and chalk to mark 6 foot diam circle)

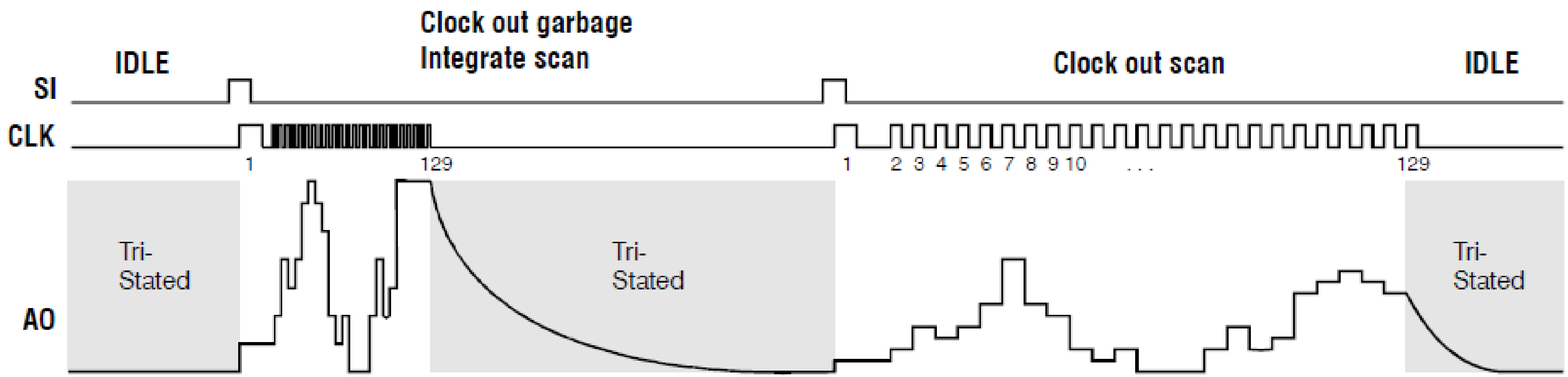
# Planned Cory Courtyard Track

Thu and Friday 2-4 pm, supervised by staff member David Au.
All Covid protocols to be followed.
Details on Piazza when set up. Track avail no later than April 15 (see signup for possible earlier times with Andrew)

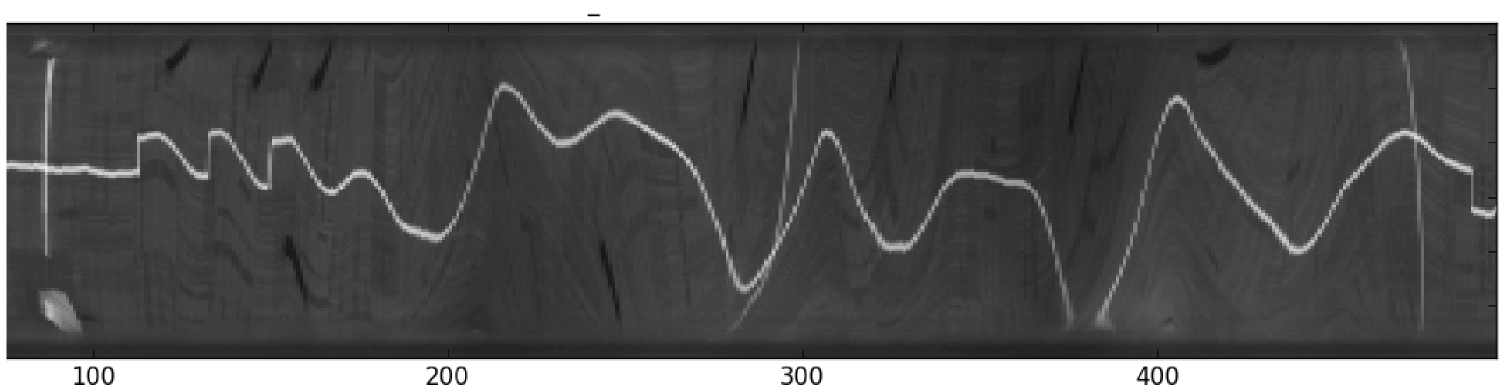


All curves minimum radius 3 feet (bigger radius is fine)
(use 3 foot string and mark circle with chalk)

# Automatic Gain Control




In all the discussion that follows, we will be using one-shot imaging.



# Round 2 Tues 4/27 5 pm

1) Video of best run(s) + telemetry plots
   - Will be shown in class and discussed
   - Can do live on personal track
   - Be prepared to explain plots of not clear
   - Use timer/distance to show speed

2) Can do Courtyard or personal track
   - score = max{Courtyard, personal track}

# Round 2 Cory Track Scoring (+20 pts max) (Draft 4/13)

| | |
|---|---|
| -0.5 points | Twitchy steering |
| -0.5 points | Goes wide on curves |
| -0.5 points | Oscillatory step response |
| -1 points | Ignores stop marks |

| | |
|---|---|
| -0.5 points | Slower than 2.5 m/s |
| -1 points | Slower than 1.5 m/s |

| | |
|---|---|
| -1 point | Does not finish track |
| -2 points | Finish < ½ track |
| - 3 points | Finish < ¼ track |

# Round 2 Personal Track Scoring (+20 pts max) (Draft 4/13)

## Step Response

| | |
|---|---|
| -1 points | Oscillatory step response |
| -1 points | Slower than 2.5 m/sec |
| -2 points | Slower than 1.5 m/sec |

## S Curve or Fig 8

| | |
|---|---|
| -0.5 points | Twitchy steering |
| -0.5 points | Goes wide on curves |
| -0.5 points | Ave speed Slower than 2.5 m/s |
| -1 points | Ave speed Slower than 1.5 m/s |

## Straight line- drag race

| | |
|---|---|
| -0.5 points | Twitchy steering |
| -2 points | Misses stop line |
| -0.5 points | Peak speed Slower than 2.5 m/s |
| -1 points | peak speed Slower than 1.5 m/s |

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# 10 Questions to Consider when Reviewing Code

Jacob Beningo

Embedded Systems Conference -2017

https://www.designnews.com/electronics-test/10-questions-consider-when-reviewing-code/143583201956491?cid=nl.x.dn14.edt.aud.dn.20170329

1. Does the program build without warnings?
2. Are there any blocking functions?
3. Are there any potential infinite loops?
4. Should this function parameter be const?
6. Has extern been limited with a liberal use of static?
7. Do all if … else if … conditionals end with an else?
8. Are assertions and/or input/output checks present?
9. Are header guards present? The guard prevents double inclusion of the #include directives.

*10. Is floating point mathematics being used?*

# Software Robustness

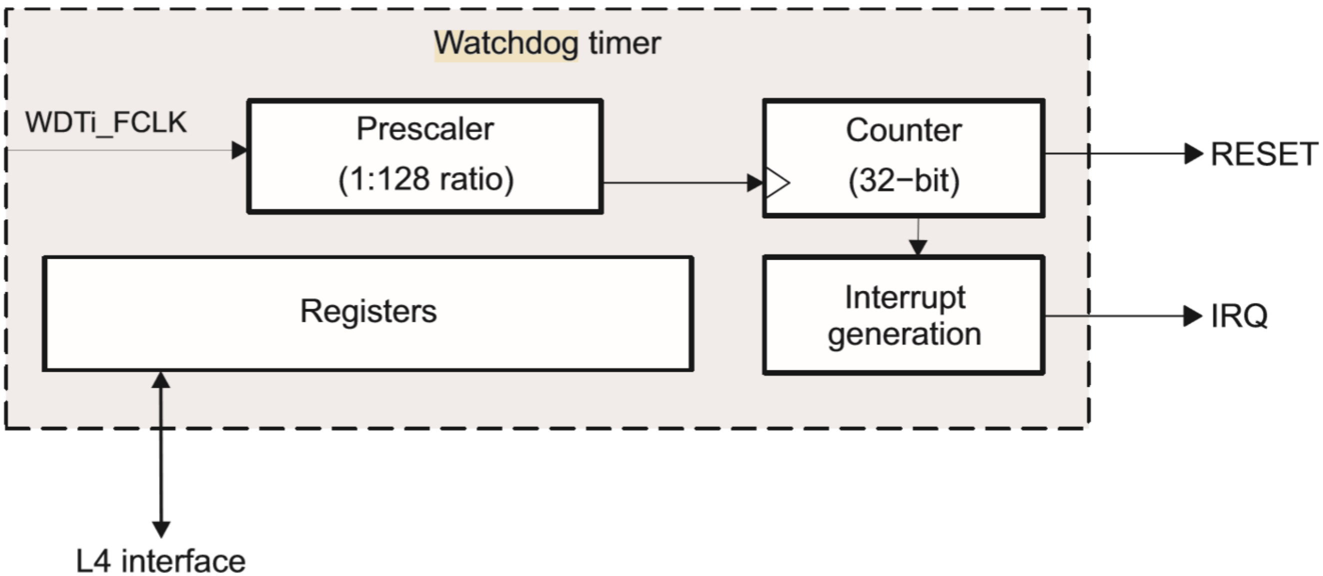
- Checksums for bit rot
- Lost track detection
- Autocalibration at startup
  - (sanity check for steering angle vs line error)
  - AGC
- State Observer/estimator
- Discrete State observer
- Watch dog timer/computer operating properly COP

# C.O.P. Watchdog timer

- Despite extensive software and hardware testing, faults will still occur in real devices. Even momentary noise spikes on a power supply can lock up a processor occasionally. Such events will occur on the power grid several times a year. Watchdog timers provide a last line of defense to prevent system failure with minimal hardware cost.
- https://developer.mbed.org/cookbook/WatchDog-Timer

# Watch Dog Timer (not ESP32 specific)

**Figure 20-94. 32-Bit Watchdog Timer Functional Block Diagram**



# Watchdog reset

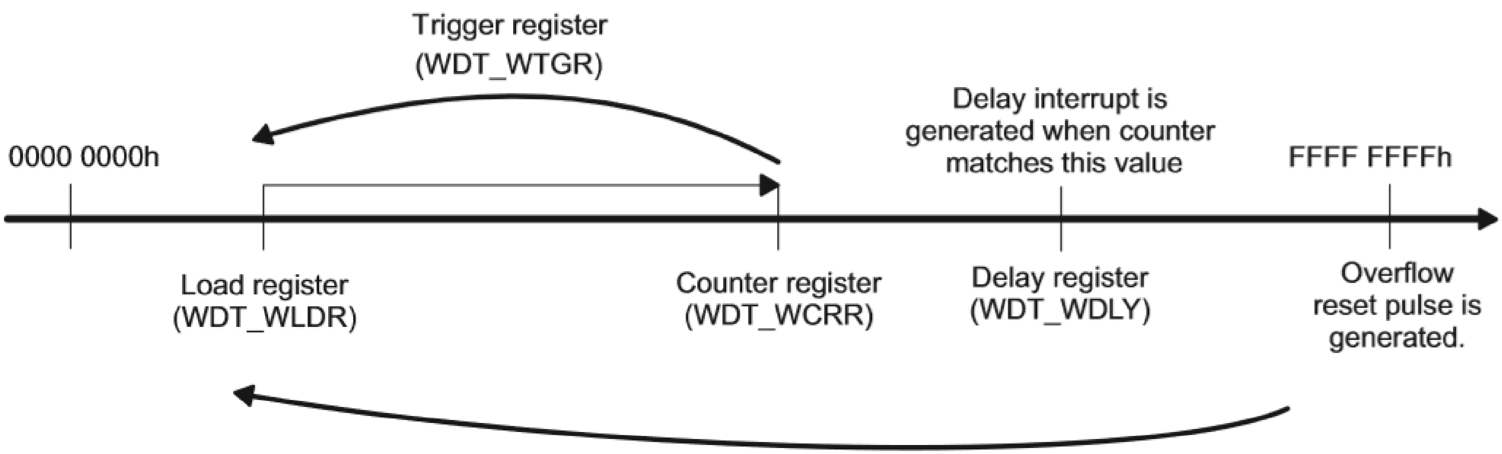
### 20.4.3.5 Overflow/Reset Generation

When the watchdog timer counter register (WDT_WCRR) overflows, an active-low reset pulse is generated to the PRCM module. This RESET pulse causes the PRCM module to generate global WARM reset of the device, which causes the nRESETIN_OUT pin to be driven out of the device. This pulse is one prescaled timer clock cycle wide and occurs at the same time as the timer counter overflow.

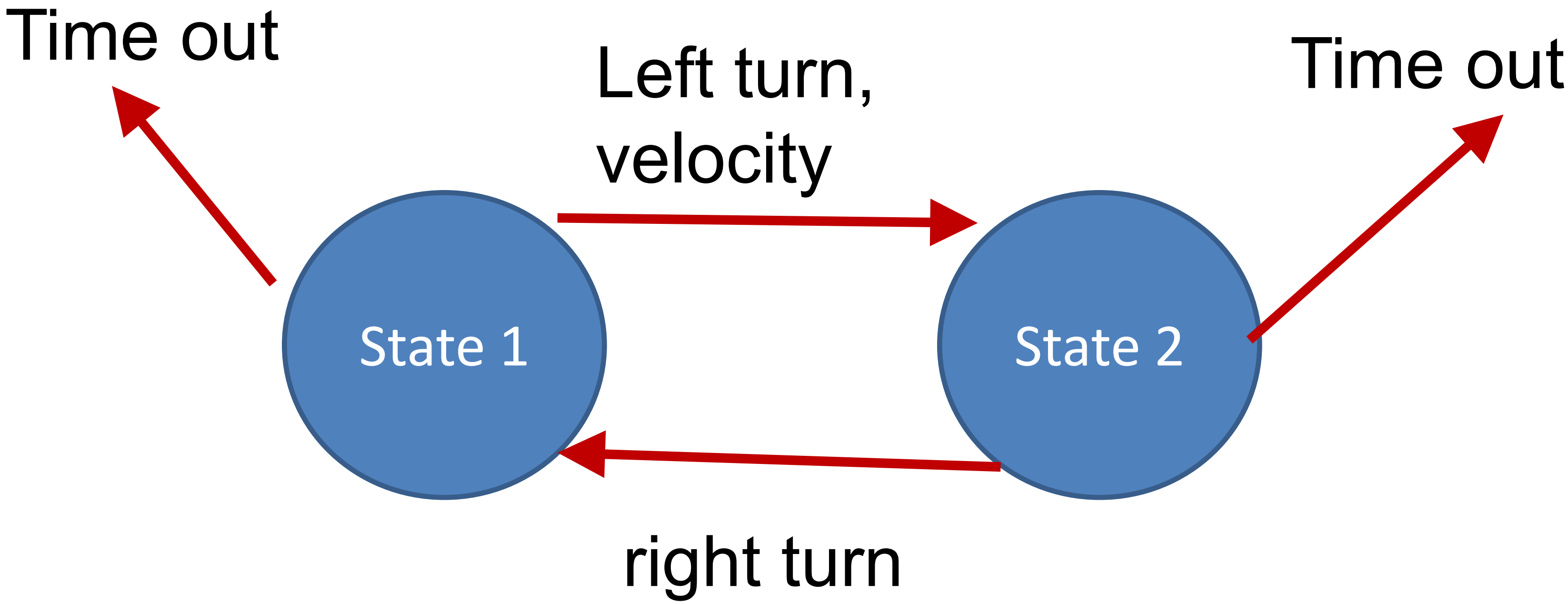
After reset generation, the counter is automatically reloaded with the value stored in the watchdog load register (WDT_WLDR) and the prescaler is reset (the prescaler ratio remains unchanged). When the reset pulse output is generated, the timer counter begins incrementing again.

Figure 20-95 shows a general functional view of the watchdog timers.

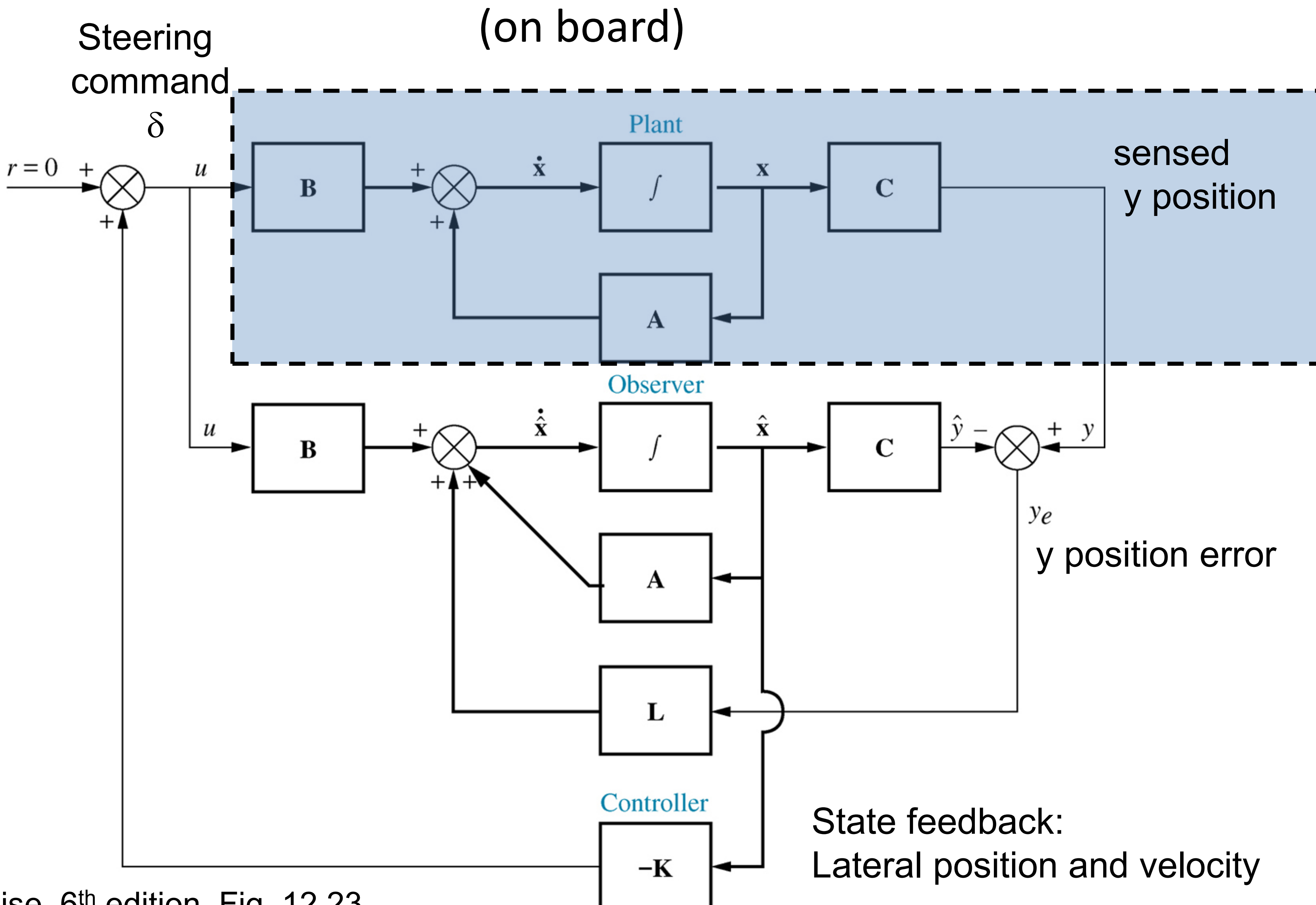
**Figure 20-95. Watchdog Timers General Functional View**



# FSM Recognizer (generalized WDT)



# Software Robustness: Observer




N. Nise, 6th edition, Fig. 12.23

# General Caution

Freescale Semiconductor products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which failure of the Freescale Semiconductor product could create a situation where personal injury or death may occur.

Should Buyer purchase or use Freescale Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify Freescale Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claims alleges that Freescale Semiconductor was negligent regarding the design or manufacture of the part.

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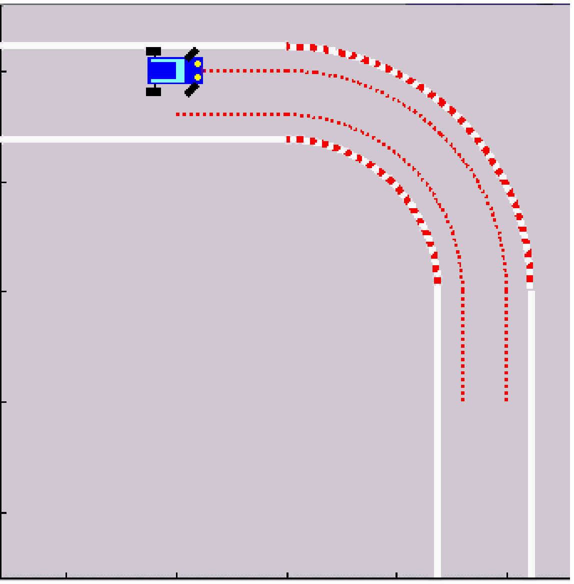
# Steering References (on web page)

- Vehicle Dynamics and Control During Abnormal Driving

http://soliton.ae.gatech.edu/people/dcsl/research-abnormal.html

Prof. Panagiotis Tsiotras, Georgia Tech



http://soliton.ae.gatech.edu/people/dcsl/movies/skidding.avi

http://soliton.ae.gatech.edu/people/dcsl/movies/TrailBraking.avi

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https://inst.eecs.berkeley.edu/~ee192/sp15/refSteer.html


- Vehicle Dynamics and Control During Abnormal Driving (Georgia Tech)
- Velenis, E., Tsiotras, P., and Lu, J., "Aggressive Maneuvers on Loose Surfaces: Data Analysis and Input Parameterization,'' 15th IEEE Mediterranean Control Conference, June 26-29, Athens, Greece.
- Velenis, E., Tsiotras, P., and Lu, J., "Modeling Aggressive Maneuvers on Loose Surfaces: The Cases of Trail-Braking and Pendulum-Turn,'' European Control Conference, Kos, Greece, July 2-5, 2007.
- Baffet, G. Charara, A. Dherbomez, G. ''An Observer of Tire Road Forces and Friction for Active Security Vehicle Systems'' Mechatronics, IEEE/ASME Transactions on Publication Date: Dec. 2007 Volume: 12, Issue: 6 On page(s): 651-661
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- T. Pilutti, G. Ulsoy, and D. Hrovat, ''Vehicle steering intervention through differential braking,'' Proc. American Control Conf. Seattle, Wash. June 1995.
- Brennan, S. Alleyne, A. ''Using a scale testbed: Controller design and evaluation'' Control Systems Magazine, IEEE Publication Date: Jun 2001 Volume: 21, Issue: 3 On page(s): 15-26
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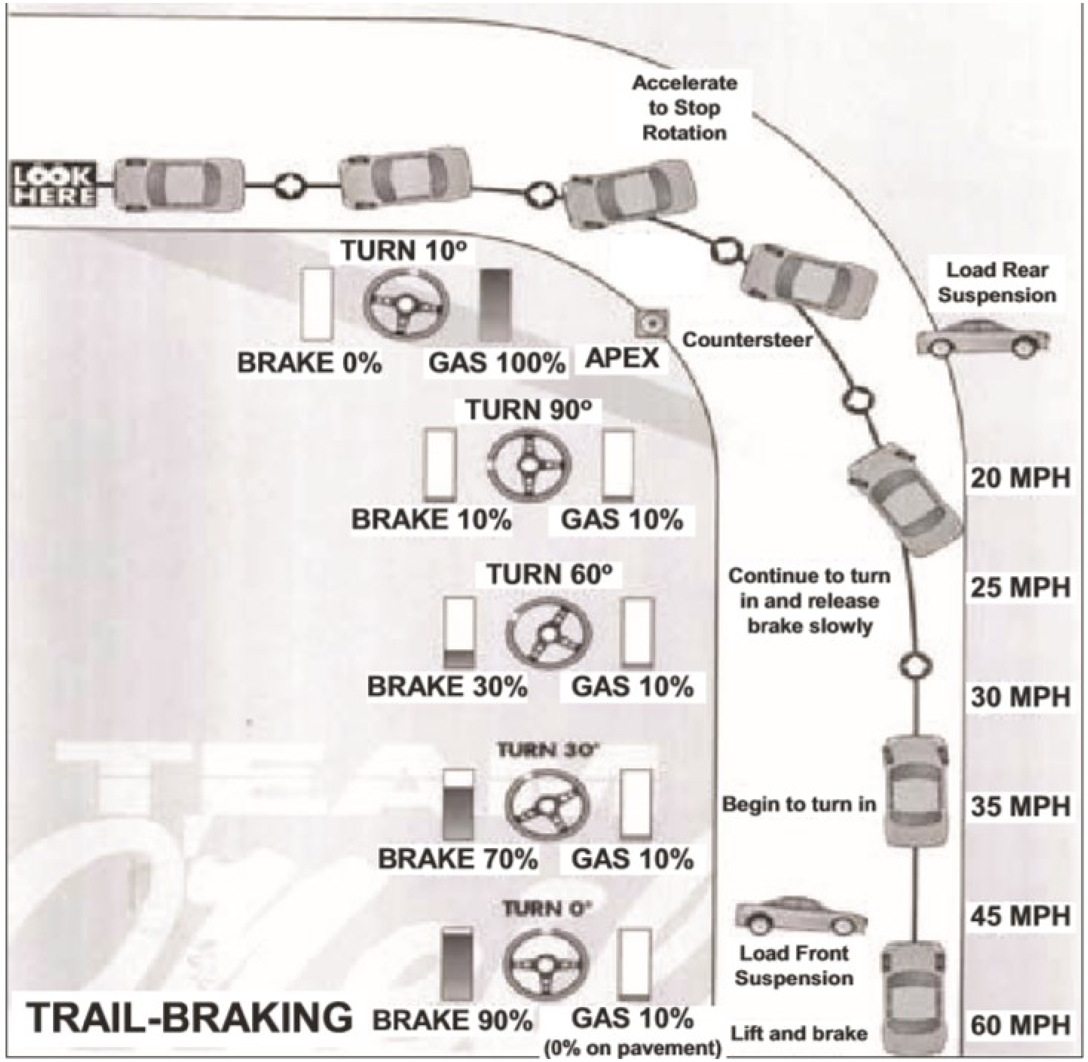
- Chankyu Lee K. Hedrick Kyongsu Yi , ''Real-time slip-based estimation of maximum tire-road friction coefficient,'' Mechatronics, IEEE/ASME Transactions on Publication Date: June 2004
- Han-Shue Tan; Guldner, J.; Patwardhan, S.; Chieh Chen; and others. Development of an automated steering vehicle based on roadway magnets-a case study of mechatronic system design. IEEE/ASME Transactions on Mechatronics, Sept. 1999, vol.4, (no.3):258-72.
- Guldner, J.; Sienel, W.; Han-Shue Tan; Ackermann, J.; and others. Robust automatic steering control for look-down reference systems with front and rear sensors. IEEE Transactions on Control Systems Technology, Jan. 1999, vol.7, (no.1):2-11.
- Patwardhan, S.; Han-Shue Tan; Guldner, J. A general framework for automatic steering control: system analysis. Proceedings of 16th American CONTROL Conference, Albuquerque, NM, USA, 4-6 June 1997). Evanston, IL, USA: American Autom. Control Council, 1997. p. 1598-602 vol.3.
- Patwardhan, S.; Han-Shue Tan; Guldner, J.; Tomizuka, M. Lane following during backward driving for front wheel steered vehicles. Proceedings of 16th American CONTROL Conference, Albuquerque, NM, USA, 4-6 June 1997). Evanston, IL, USA: American Autom. Control Council, 1997. p. 3348-53 vol.5.
- Guldner, J.; Han-Shue Tan; Patwardhan, S. Study of design directions for lateral vehicle control. Proceedings of the 36th IEEE Conference on Decision and Control, San Diego, CA, USA, 10-12 Dec. 1997). New York, NY, USA: IEEE, 1997. p. 4732-7 vol.5.
- Analysis of automatic steering control for highway vehicles with look-down lateral reference systems. Vehicle System Dynamics, Oct. 1996, vol.26, (no.4):243-69.

# Steering: Trail Braking Maneuver (Rally car)




1. Brake hard, drive straight (increased load on front wheels)
2. Increase steering command, reduce braking (oversteering)
3. Decrease steering, counter steers, apply throttle to stabilize

Velenis, E., Tsiotras, P., and Lu, J., “Modelling Aggressive Maneuvers on Loose Surfaces'' European *Control Conference*, 2007.

# Steering: Trail Braking Maneuver

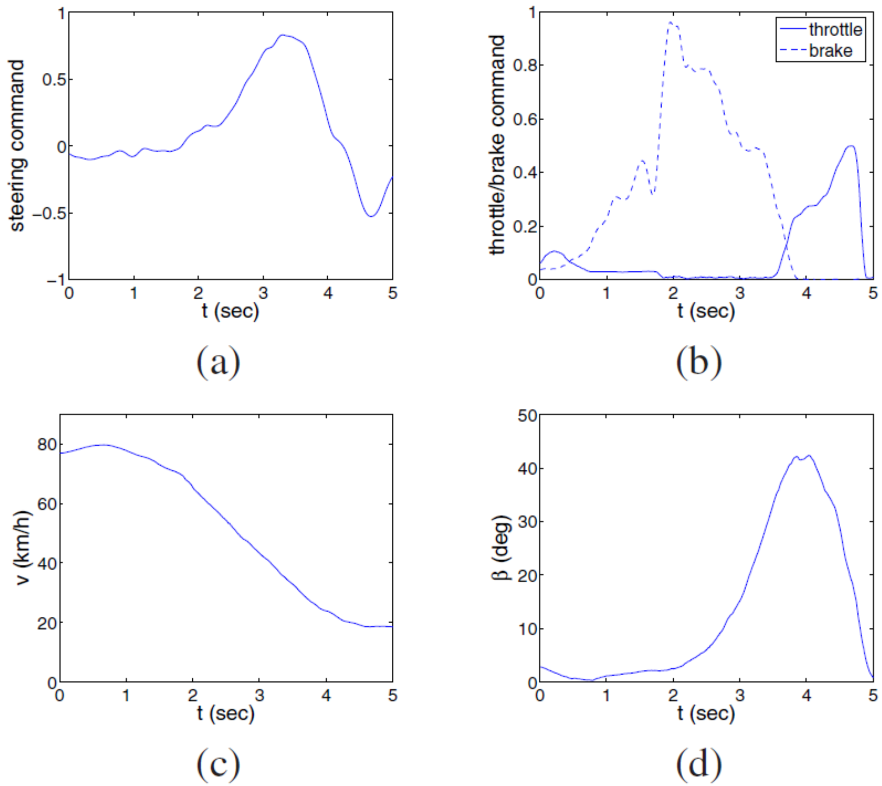
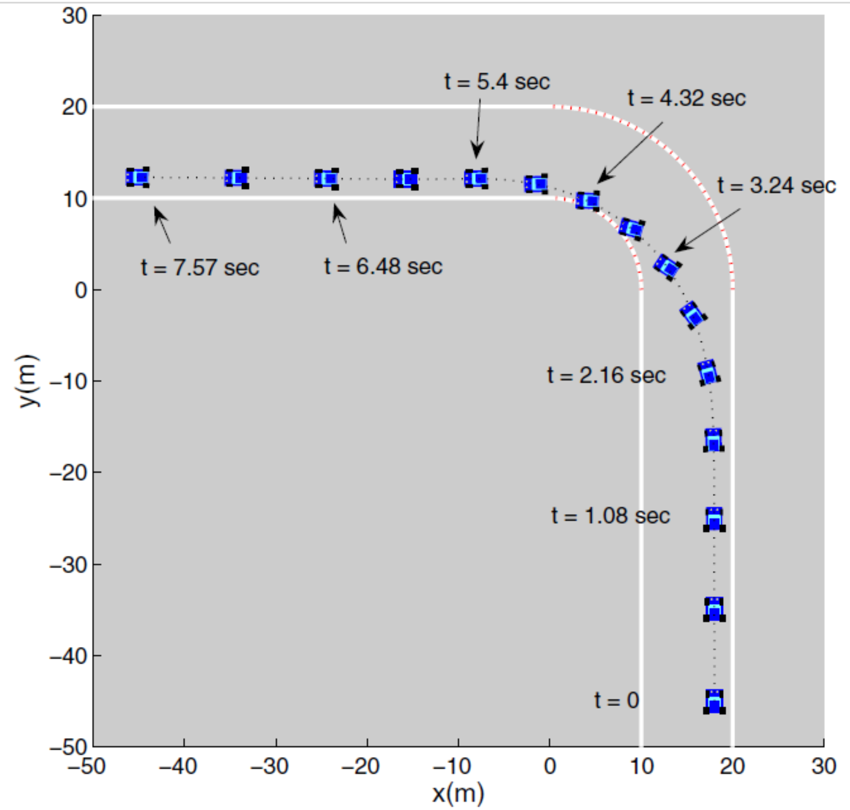



Fig. 3. Trail-Braking maneuver experimental data: (a) Normalized steering command; (b) Normalized throttle and braking commands; (c) Vehicle speed; (d) Vehicle slip angle.




1. Brake hard, drive straight (increased load on front wheels)
2. Increase steering command, reduce braking (oversteering)
3. Decrease steering, counter steer, apply throttle to stabilize

Velenis, E., Tsiotras, P., and Lu, J., "Aggressive Maneuvers on Loose Surfaces: Data Analysis and Input Parameterization," *15th IEEE Mediterranean Control Conference*, June 26-29, 2007 Athens, Greece.

# Steering: Trail Braking Maneuver

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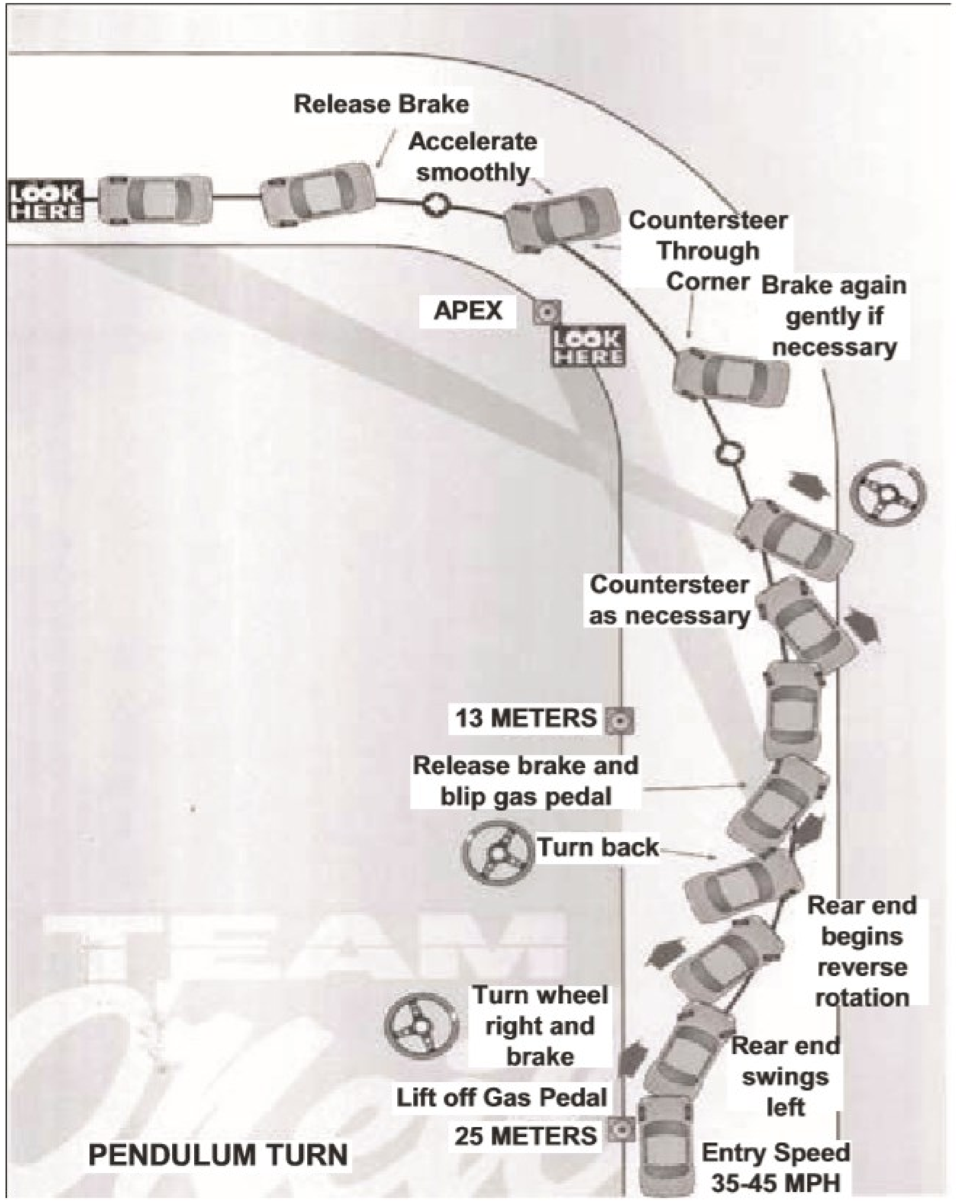
http://soliton.ae.gatech.edu/people/dcsl/research-abnormal.html

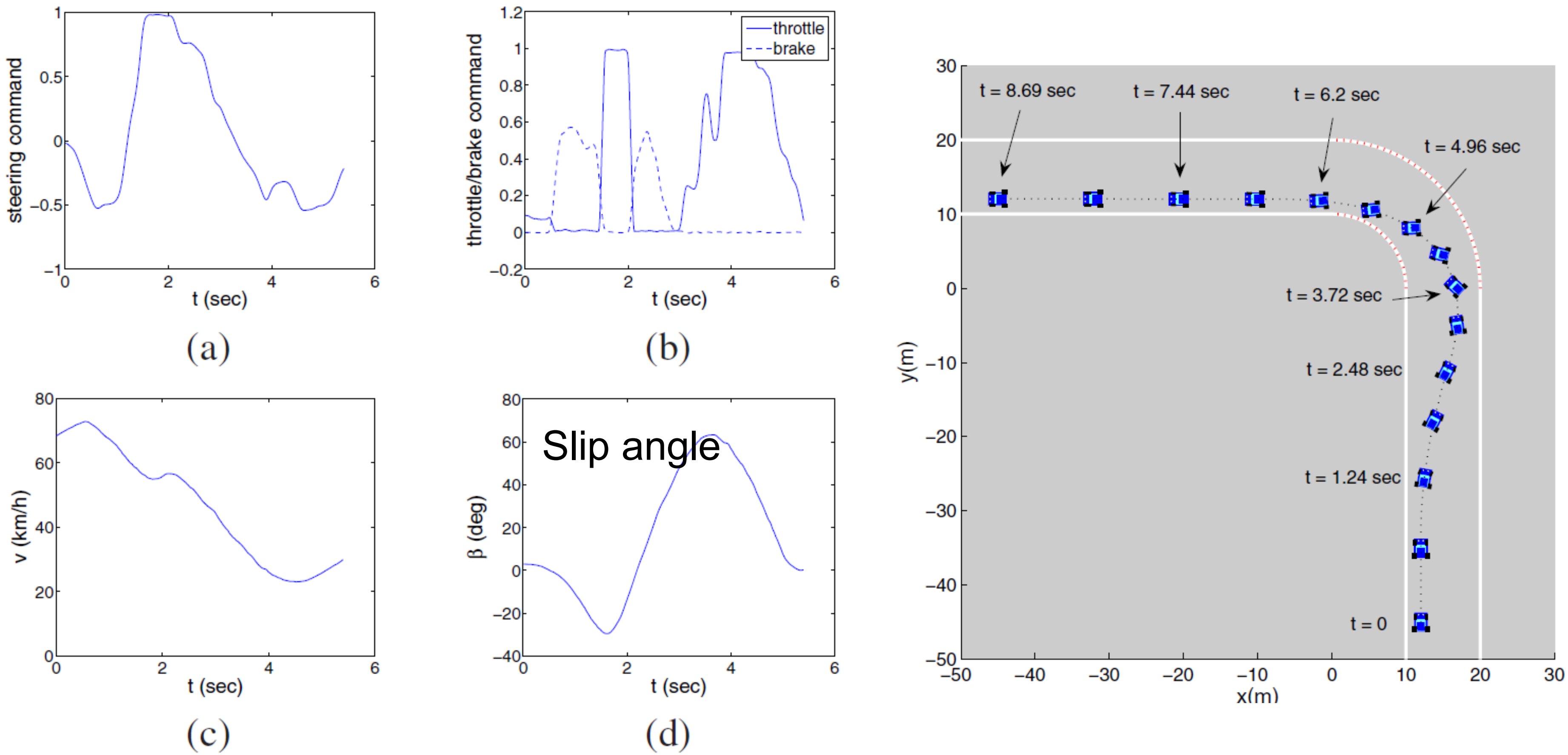
Prof. Panagiotis Tsiotras, Georgia Tech

http://soliton.ae.gatech.edu/people/dcsl/movies/TrailBraking.avi

# Steering: Pendulum Turn Maneuver (Sim)



# Steering: Pendulum Turn Maneuver (Sim)




1. Turn opposite while applying brakes (increased load on front wheels, oversteering)
2. Throttle blip to damp rotation
3. steer in direction of turn and apply brakes to rotate fast
4. Decrease steering command, counter-steers, applies throttle to stabilize


Velenis, E., Tsiotras, P., and Lu, J., "Aggressive Maneuvers on Loose Surfaces: Data Analysis and Input Parameterization," *15th IEEE Mediterranean Control Conference*, June 26-29, 2007 Athens, Greece.

http://soliton.ae.gatech.edu/people/dcsl/movies/PendulumTurn.avi

# Vehicle Stability through Differential Braking

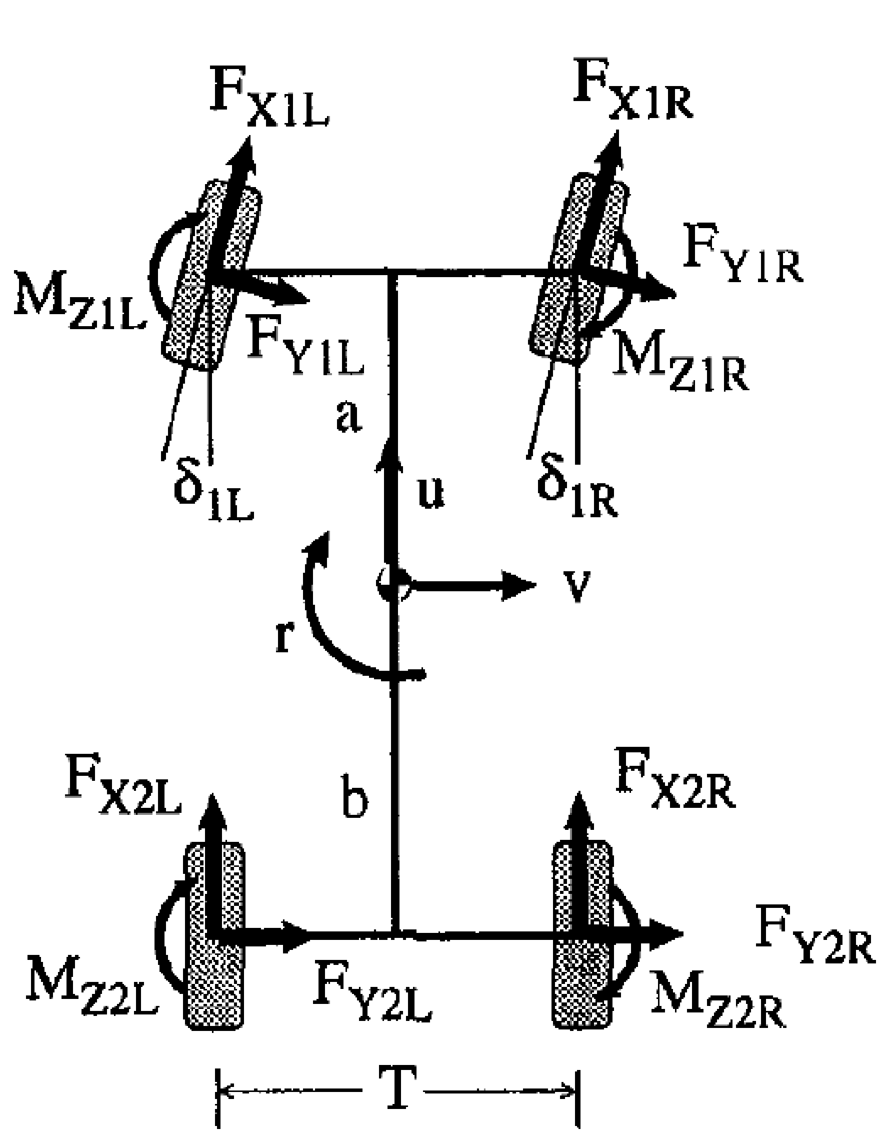



**Fig. 1 Seven DoF vehicle model**

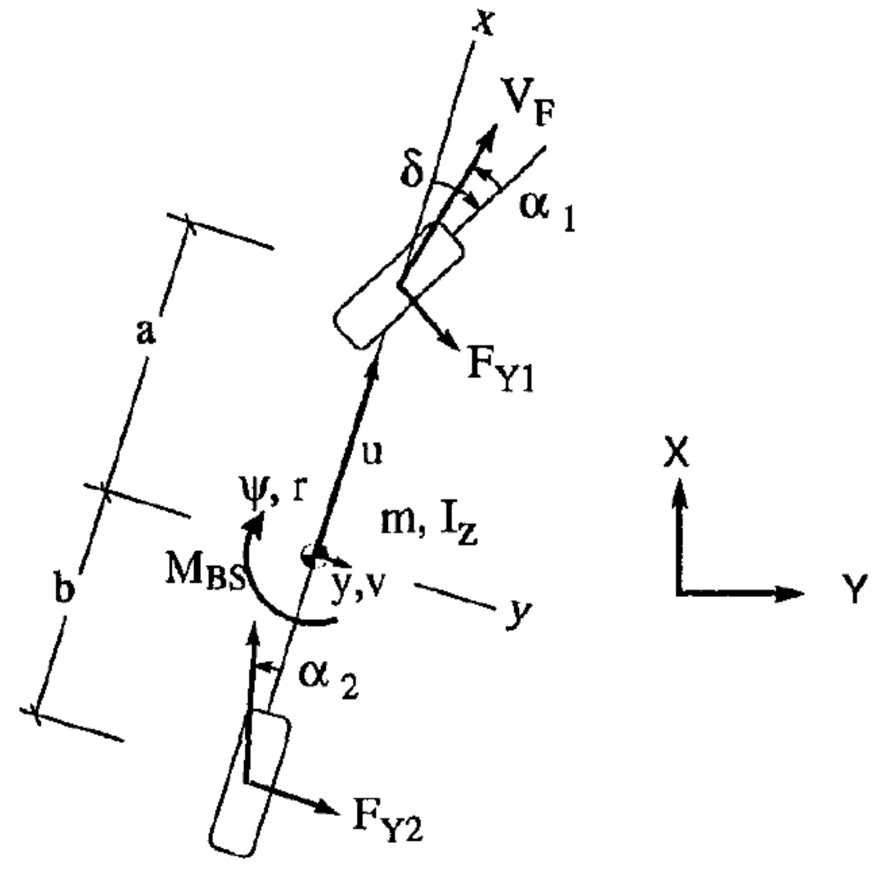
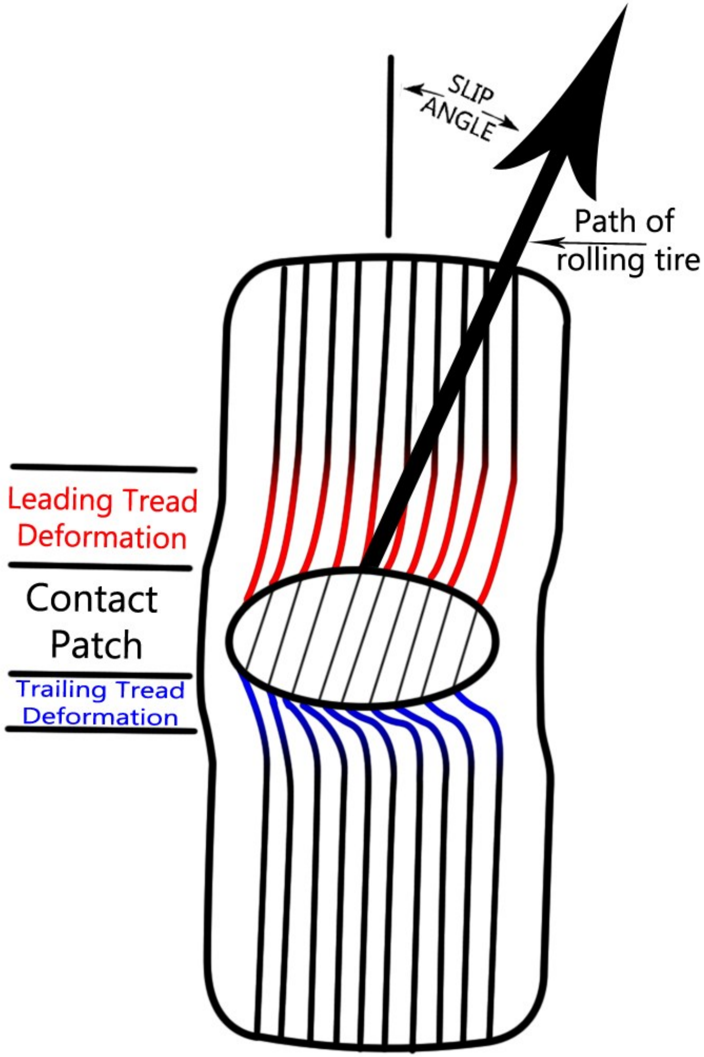



**Fig. 2 Two DoF model**

- T. Pilutti, G. Ulsoy, and D. Hrovat, "Vehicle steering intervention through differential braking," Proc. American Control Conf. Seattle, Wash. June 1995.

# Tire Slip Angle




http://technicalf1explained.blogspot.com/2012/10/f1-tirespart-2.html

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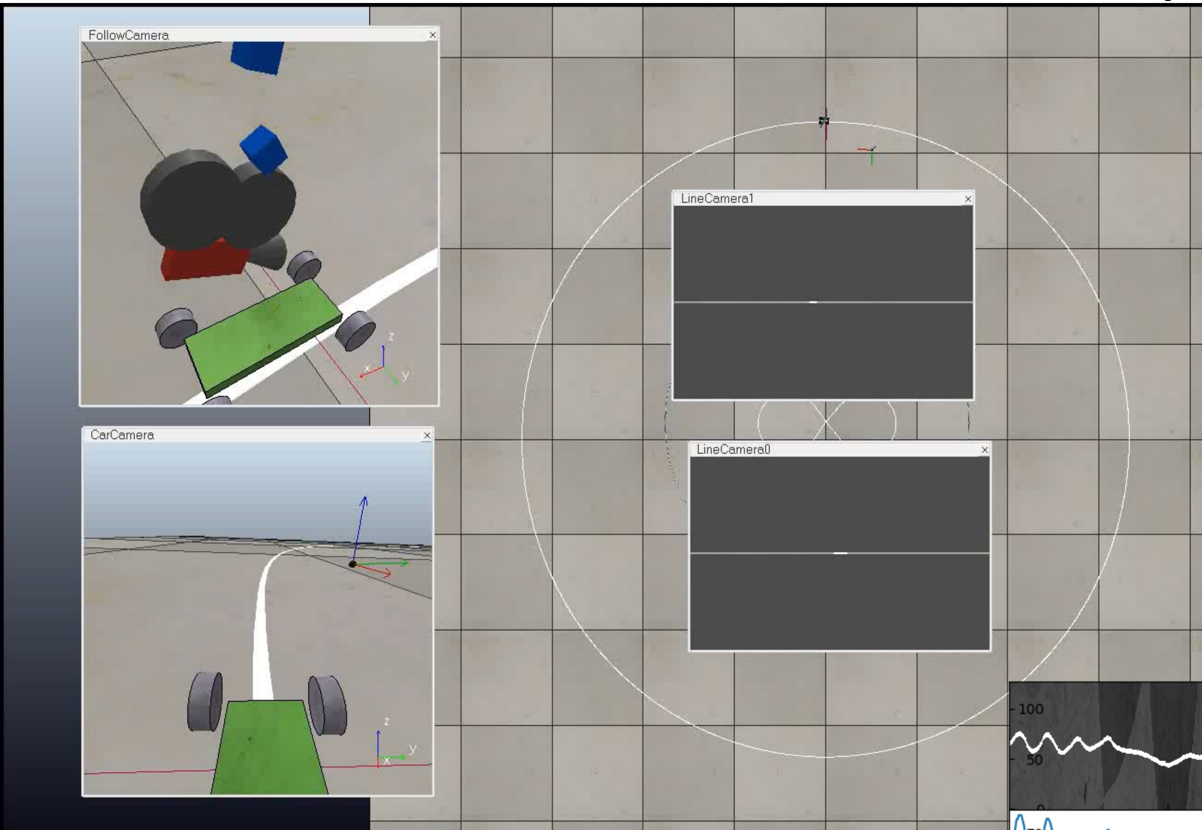
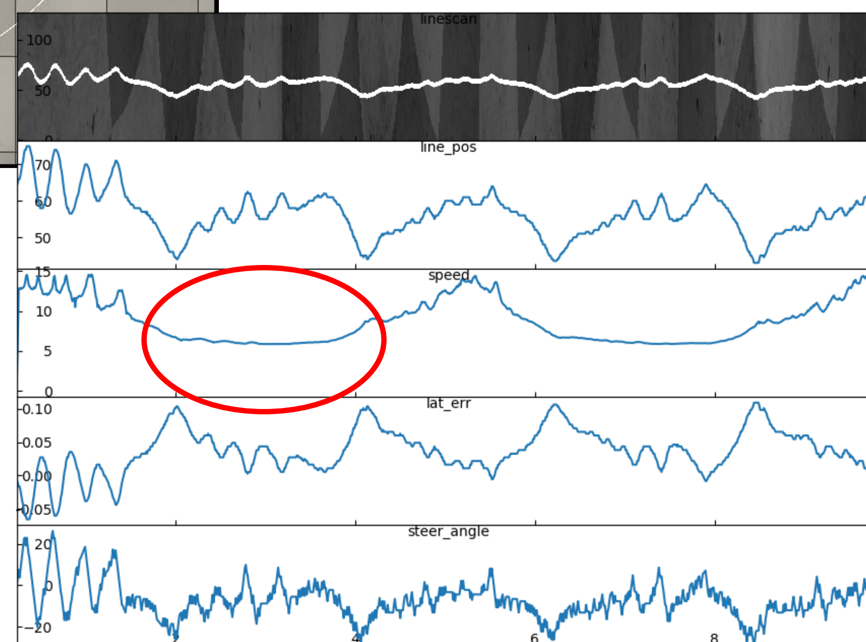
# Extra Slides

# Circle at 10 m/s




Slow down due to steering sliding