Automatic Gain Control
Automatic Gain Control
So the lighting on the 3rd floor is different than in the lab?

Solutions

- External Lights (LED, flashlights, etc.)
- Robust line detection (derivatives, LPF, cross correlation - see discussion 8)
- Automatic Gain Control!!
TSL1401 Timing - No Automatic Gain Control

- **capacitor voltages**
  - [img1 = garbage]
  - [img2 = voltages charging]
  - [img3 = voltages charging]
  - [img4 = voltages charging]
  - [img5 = voltages charging]

- **camera [128]**
  - (in software)
  - [undefined]
  - [img1 = garbage]
  - [img2]
  - [img3]
  - [img4]

- **SI**
- **CLK**

**Number of Images Taken**
Pseudocode

```c
void take_pic(){
    SI High;
    CLK High;
    SI Low;
    for(i=0 to 128){
        CLK High;
        camera[i] = read_adc();
        CLK_Low;
    }
}
```

- Each call to take_pic reads out the previous capacitor voltages
- There is currently no exposure control
- Next up → Let’s run take_pic() on a PIT!
Don’t need to read garbage frames!
▶ Don’t need to read garbage frames!
▶ Removing read_adc speed’s up code execution significantly
void take_pic(int mode){
    SI High;
    CLK High;
    SI Low;
    for(i=0 to 128){
        CLK High;
        if (mode == 1)//Read
            camera[i] = read_adc();
        CLK_Low;
    }
    if (mode == 0)//Delay
        delay(camera_delay);
    else//Read
        adjust_camera_delay();
    // How might you do this?
}

void pit_handler(){
    /* Clock out garbage data & expose new image */
    take_pic(0);
    /* Read new image and update exposure delay */
    take_pic(1);
}
int main(){
    take_pic(0);
    take_pic(1);
    find_line();
    estimate_velocity();
    calculate_new_controls();
    telemetry.do_io();
}

void pit_handler(){
    apply_servo_control();
    apply_motor_control();
}

- Pro- Interrupt executes very quickly- potentially easier to debug
- Con- Potentially updating servo/motor control on old sensor readings
int main(){
    telemetry.do_io();
}

void pit_handler(){
    take_pic(0);
    take_pic(1);
    find_line();
    estimate_velocity();
    calculate_new_controls();
    apply_servo_control();
    apply_motor_control();
}

- Pro- Updating servo/motor control on newest sensor readings
- Con- Interrupt execution time must fit within interrupt period
Mechanical Tuning
Disclaimer

- I’m not a mechanical engineer
  - I’ve tuned exactly zero cars
- Information here from various Internet sources, which hopefully is correct
  - (it passes the “smell test”)
- If it sounds wrong, it might really be...

not actually *that* bad
from knowyourmeme.com
Goals

What’s the ultimate goal here?
Goals

What’s the ultimate goal here?
  ▶ Reduce race time

How do we do that?

what you want
from Big Rigs: Over the Road Racing
a game that you should never touch
Goals

What’s the ultimate goal here?
- Reduce race time

How do we do that?
- High acceleration - speed on straights
- Fast cornering - fast through turns
- High deceleration - slowing for turns

Essentially maximizing acceleration. How?

what you want from Big Rigs: Over the Road Racing
a game that you should never touch
Goals

What’s the ultimate goal here?
- Reduce race time

How do we do that?
- High acceleration - speed on straights
- Fast cornering - fast through turns
- High deceleration - slowing for turns

Essentially maximizing acceleration. How?
- Maximize tire grip!

what you want from Big Rigs: Over the Road Racing
a game that you should never touch
Tire Grip Curves

Tire Grip vs. Load Curve

- Tire grip is nonlinear with load
- Diminishing returns with more pressure

So I have 4 tires - what’s the optimal distribution?
Tire Grip Curves

Tire Grip vs. Load Curve

- Tire grip is nonlinear with load
- Diminishing returns with more pressure

So I have 4 tires - what’s the optimal distribution?

- Completely even
- Don’t trade a loss of larger amount of grip for a gain of smaller amount of grip
Camber

Camber: angle between wheel and vertical (from front)

- Positive if tilting outwards
- Negative if tilting inwards

What’s optimal to maximize contact area?

- 0 degree, ideally
- But need to account for turning chassis roll
  - Increases camber angle during turns
  - So slightly negative camber (1° - 4°) to increase traction when cornering
Camber

Camber: angle between wheel and vertical (from front)

- Positive if tilting outwards
- Negative if tilting inwards

What’s optimal to maximize contact area?

- 0 degree, ideally

But need to account for turning chassis roll
Camber

Camber: angle between wheel and vertical (from front)

- Positive if tilting outwards
- Negative if tilting inwards

What’s optimal to maximize contact area?

- 0 degree, ideally

But need to account for turning chassis roll

- Increases camber angle during turns
- So slightly negative camber (1°-4°) to increase traction when cornering
Camber

Camber: angle between wheel and vertical (from front)
- Positive if tilting outwards
- Negative if tilting inwards

What’s optimal to maximize contact area?
- 0 degree, ideally

But need to account for turning chassis roll
- Increases camber angle during turns
- So slightly negative camber (1°-4°) to increase traction when cornering
Caster: angle between steering axis and vertical

- Positive when steering axis line intersects road ahead of contact patch

What are the stability effects of positive caster?
think shopping cart “caster” wheels
Caster: angle between steering axis and vertical

- Positive when steering axis line intersects road ahead of contact patch

What are the stability effects of positive caster?

think shopping cart “caster” wheels

- Self-centering effect
  - Contact patch “trails” steering axis
- Typically 3°-5° recommended
  - Less may increase steering at stability cost
- Overall effect is fairly small
Toe

Toe: angle between wheels, viewed from top
  ▶ Toe-in (positive): inwards towards front
  ▶ Toe-out (negative): outwards towards front

Effects of toe:
  ▶ Toe-in provides straight-line stability
  ▶ Toe-out provides better turn-in but amplifies disturbances
  ▶ Small changes produces noticeable effect
  ▶ Recommended range (front): -3°-1°

Why might toe be bad?

- Wheels rub against road - reduces tire life
Toe

Toe: angle between wheels, viewed from top
- Toe-in (positive): inwards towards front
- Toe-out (negative): outwards towards front

Effects of toe:
- Toe-in provides straight-line stability
- Toe-out provides better turn-in but amplifies disturbances
- Small changes produces noticeable effect
- Recommended range (front): -3°-1°

Why might toe be bad?
- Wheels rub against road - reduces tire life
Weight Distribution

Freescale Car setup:
- Front wheels: steering
- Rear wheels: power

What does front/back weight distribution do?
Weight Distribution

Freescale Car setup:
- Front wheels: steering
- Rear wheels: power

What does front/back weight distribution do?
- Towards front: more steering grip
- Towards back: more acceleration traction
Vehicle Dynamics
Lateral Weight Transfer

What happens to my effective weight distribution when turning?

assume stiff suspension for simplicity
analysis with springs much more involved
Lateral Weight Transfer

What happens to my effective weight distribution when turning?
assume stiff suspension for simplicity
analysis with springs much more involved

▶ Inward turning force from wheels
▶ Applies torque, rolling to outer side of turn
▶ Increases pressure on outer wheel
▶ Decreases pressure on inner wheel

So total grip reduced - how to fix?
Lateral Weight Transfer

What happens to my effective weight distribution when turning?
assume stiff suspension for simplicity
analysis with springs much more involved

- Inward turning force from wheels
- Applies torque, rolling to outer side of turn
- Increases pressure on outer wheel
- Decreases pressure on inner wheel

So total grip reduced - how to fix?

- Note lever effect of turning force
- Shorten lever to reduce torque
Longitudinal Weight Transfer

What happens to my effective weight distribution when accelerating?
Longitudinal Weight Transfer

What happens to my effective weight distribution when accelerating?

- Acceleration force produced at rear wheel
- Applies torque pitching up
- Increases traction on motor wheels
- Decreases grip on steering wheels
Tuning Ride Height

Ride height: distance between track surface to underside of chassis

We know lower center-of-gravity minimizes weight transfer. What are the limits?
Ride height: distance between track surface to underside of chassis

We know lower center-of-gravity minimizes weight transfer. What are the limits?

- Need to clear uneven surfaces
  - Like the courtyard tile gaps
  - Or the Freescale Cup hump
- Don’t drag your chassis
  - you know who you are...
You may have noticed that your wheels aren’t parallel when turning. Why?
You may have noticed that your wheels aren’t parallel when turning. Why?

- Different turn radius for inner/outer wheels
- Ackermann steering: angular difference between inner and outer wheels for different turn radius
- A result of the different lengths / angles of steering linkages
Slipping

Given the Ackermann steering geometry...

What happens if the front wheels slip?
Slipping

Given the Ackermann steering geometry...

What happens if the front wheels slip?
- Understeer: turns less than intended
- Turning radius increased

What happens if the back wheels slip?
Slipping

Given the Ackermann steering geometry...

What happens if the front wheels slip?
- Understeer: turns less than intended
- Turning radius increased

What happens if the back wheels slip?
- Oversteer: turns more than intended
- Turning radius decreased
Benchmarking

Obviously, what matters in the end is measurable performance

So, what are some ways to measure success?
Benchmarks

Obviously, what matters in the end is measurable performance

So, what are some ways to measure success?

▶ Straight-line acceleration
▶ Maximum cornering velocity
▶ Minimum cornering radius

We’ve typically had less experience with mechanical tuning

▶ Try to benchmark and measure results
▶ Have a known-good configuration
  ▶ “The better is the enemy of the good”
▶ Sensor and control algorithms important
Summary

- **Demo:** adjusting suspension parameters
- Maximize grip to maximize acceleration to reduce track times
- Tune camber (slightly negative), caster (slightly positive), toe
- Lower center of gravity: minimize weight transfer
- Measure, measure, measure

- Many topics not covered: tires, springs, shocks, sprung roll

(Possibly) one more discussion section left
- Any topics people want to see?