Talk 1

Introduction

What: Kinematics of line following
- DPRG Line Following Challenge
  - Divine path
  - Follow path
- Kinematics vs. dynamics

Why: Kinematics appear to be neglected or under estimated
- Share my experience

How: Describe my robot T2LS
- Design procedure
  - Why it is the way it is
- Lessons learned
- Speculations
  - Untested ideas
- Resources

Talk 2

Description of robot T2LS

- Designed for DPRG Tabletop Line Following
  - 1” wide white line on black
  - Approx. 6” min. radius

- Linear servo, not rule based control
  - T2LS – Type 2 Linear Servo

- Small robot, approx. 6” L, 6 1/2” W, 5” H.
  - Speed: approx. 6 inches per second
  - 1/8” plywood

- 3 wheel tricycle configuration
  - two rear wheels, free turning on nail axles
  - front wheel powered by small gear motor
    - with no encoder but
    - wheel has 25 hole pulse generation
    - homemade H bridge
  - steering by std. RC servo located behind wheel

- Power: 6 volts, five AA NIMH cells
  - Two toggle switches: drive motor, electronics.

- Brains: Atmel Atmega8 microcontroller, 16MHz, 8K bytes
  - PROTO mega8 development PWB by Dale Wheat
  - AtmanAvr C/C++ IDE
    - PonyProg parallel port programmer

Talk 2a

Line sensor: analog output voltage proportional to error

- 3"W, 1"L, 1.5"H plywood box
- 2" by ¼ " aperture in bottom
- divided into two side by side compartments
- one CdS photoresistor and 4 LED's in each compartment
- CdS in series form a voltage divider, 5volt supply
- Sensor output is output voltage of divider
- CdS resistance is proportional to % of aperture over white line
- ADC   nonlinear

Line sensor location: between rear wheels

- followed line going forward AND backward

Servo controller: Proportional Derivative

Talk 3

Design procedure – Why it is the way it is

Research prior to design:

Other DPRG robots

Cincinnati Milling Machine , Westinghouse flame cutter

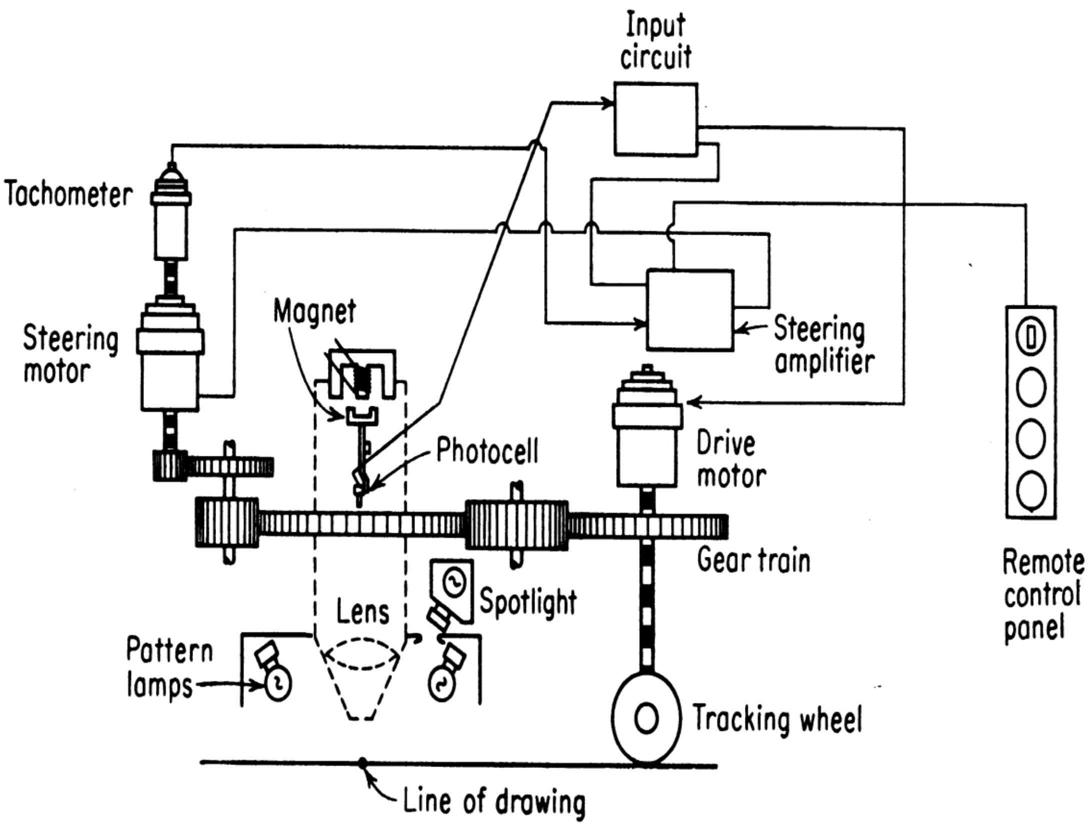

FIG. 2. A schematic drawing of a gas cutting machine tracing head, showing the control equipment.

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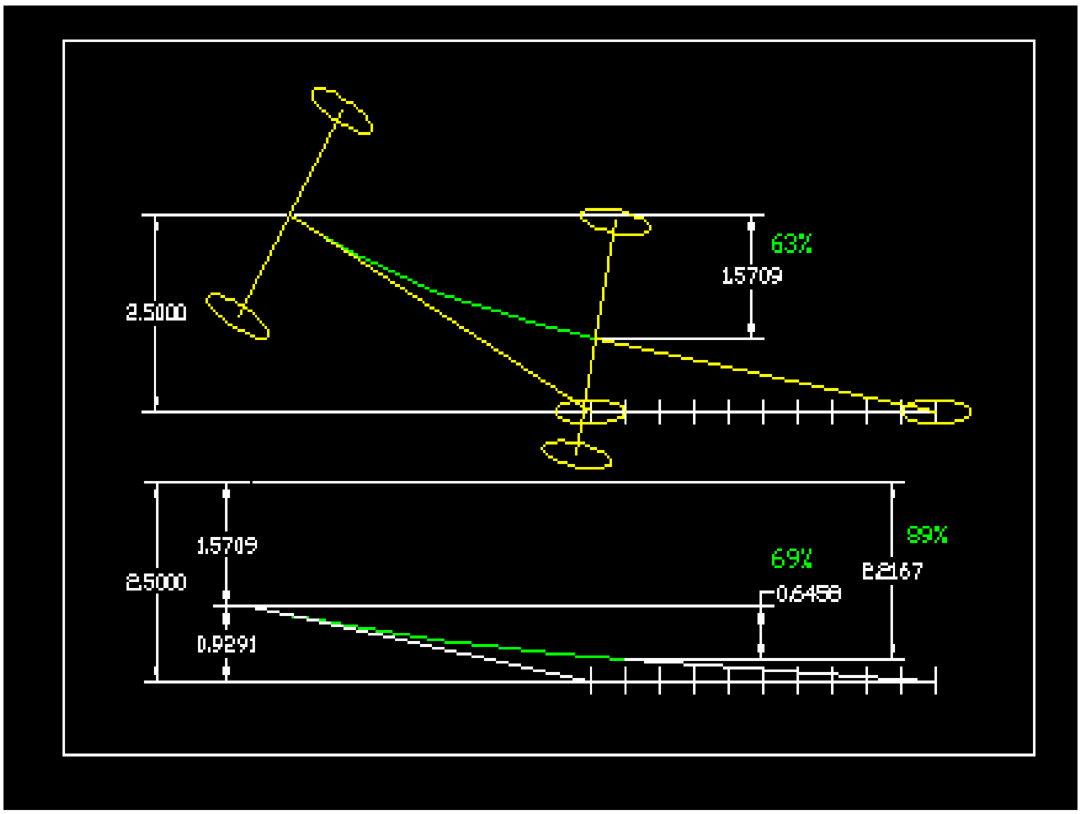
Talk 3 cont.

Review servo theory

Investigate how length of robot effects robot motion
Distance required to reach “steady state”, F2

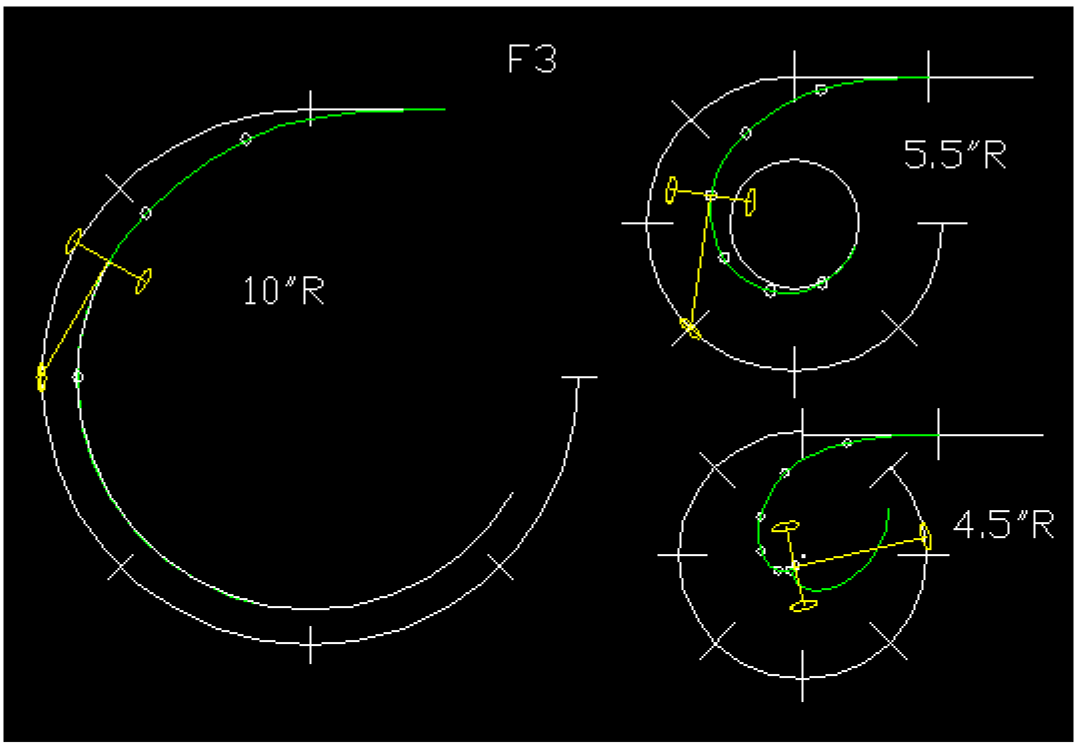


Transition from straight to circular path, F3

Intuition: Each transition from straight to curved path is a step input to the servo.

And the servo should reach steady state before the next transition.

Conclusion: Make the length of robot ½ the radius of path, That is 3 inches.



Talk 3a

Investigate stability of servo

Let steering angle be proportional to error, P only.

Graphically verified suspicion that servo is unstable.

Frequency domain analysis of servo stability:

Sine wave input → controller → plant → sine wave output

As the frequency increases the output amplitude decreases
And the phase lags.

At some high frequency lag will be 180 deg.

If at this frequency the output amplitude is greater than input, then the system will oscillate when the loop is closed.

Delays increase the phase lag.

Proportional increases amplitude.

Integral increases amplitude at low frequency.

Derivative reduces phase lag at high frequencies.

Conclusion: sensor can be located between the rear wheels
With steering ANGLE proportional to error
math model will have two integrators in series.
So requires Derivative control for stability
Is a type 2 servo so steady state error is proportional
to path curvature.
Moving the sensor forward approximates Derivative action

Talk 3b

Write simple program simulate robot following line.
Robot followed the line!
Conclusion: Actual physical robot would probably follow a line.
It is possible for a robot to follow an “internal” line.

Build the robot T2LS and try to follow a line.
It worked! -- But steering servo was a little twitchy.
Conclusion: The line sensor could be located between the rear wheels. D but not I was required.

Enter robot T2LS in contest
T2LS followed the line
but was not fast enough to win 1st place
Then discovered that just by reversing the power to the drive motor it would follow the line backward.

DPRG changed the course
Now ¾ wide black line with some sharp 90 degree turns
T2LS could no longer complete the course.
Conclusion: Robot had to be more than a linear servo, additional capability required to navigate sharp turns etc.

Talk 4

Lessons learned

Length of robot should be small relative to path radius.

For line following, sensor can be located between the rear wheels

Robot can follow an “internal” line.

DPRG Line Following course requires more than just linear servo.

Talk 5

Speculations

A physical robot can only move along a CONTINOUS path
But the Challenge course is a collection of disconnected
line segments. So how does the robot follow them? F5

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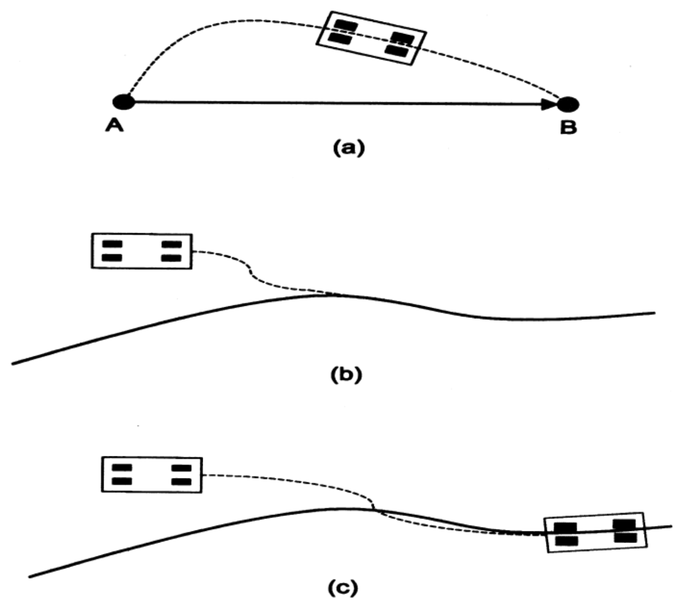

FIGURE 8.3 Three control objectives for a mobile robot: (*a*) point-to-point stabilization, (*b*) path following, (*c*) trajectory tracking.

Follow the line segments and open loop control to connect.

Expand the line segments then chose a path that avoids the non-line

What point on robot is following the line?
Is the point fixed or can it move about on (or off) the robot?

How much prior knowledge of the course should the robot have?
Implied or explicit? Landmarks.

Incorporate, use, robot state – orientation, location, odometry

Keep sensor delay out of control loop.