Line Sensors

Bot must stay inside the ring -

ring defined by White line on black bkgnd

1" wide

~~inside~~ outside is defined as any part of bot touching the area outside the white ring *

Only one item in kit to do this – line sensors

Mechanical Considerations:

What touches gnd? Wheels, castors
nothing else

Need to stop motion before any touch

Forward – place sensors just in front of wheels
– not necessarily at ~~eg~~ edges of bot

– how far forward? – key consideration
is how fast ~~bot~~ can stop
based on the motor characterization
can stop in < 10ms

Full speed – 6"/sec ⇒ 0.06"/10ms
rounding – spacing ≥ 0.1 inch would work

Mechanical – best case space is 3/4"
– limited by base structure
& pin extensions on sensor

Pin sensor fig

fig showing pin sensor gap to wheel arc

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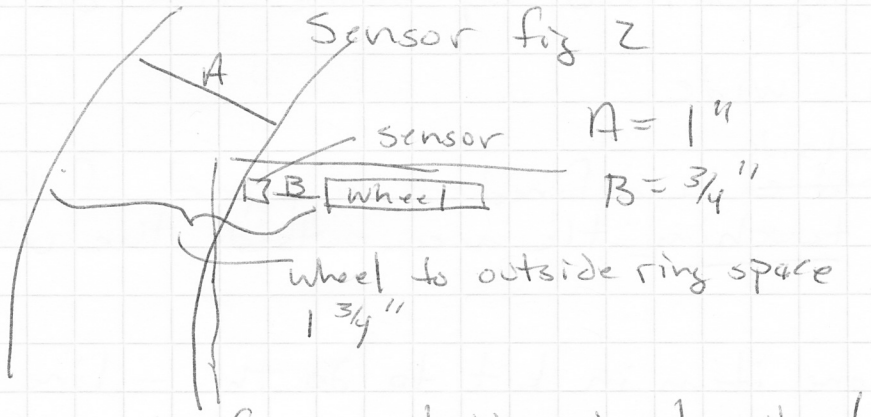
Line Sensors cont'd

Mechanical / timing check

$\frac{3}{4}$" gap + 1" ring ⇒ $1\frac{3}{4}$" distance

from sensor trigger and wheel touching outside ring



gap from outside ring to wheel

timing - $1\frac{3}{4}$ inch $\times \frac{1\,sec}{6''} = 291\,ms$

≈ 29 time reaction time ✓

Casters - put sensors just behind castors

- now up to 4 sensors (2 front, 2 back)

Are these necessary?

~~I can~~ Can I control my motion so that I will never back out of the ring

Why would I ever back up?
In pursuit - No
In search - No
In defense - No plans for this
On line sense - Yes

Event time line

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motion - forward or Arc or Spin

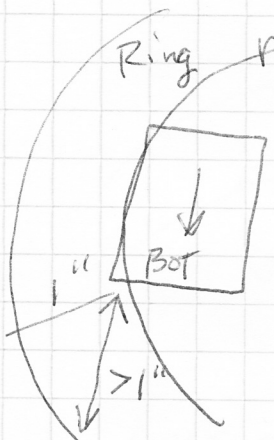
Line Sensors - cont'd

Forward motion Angles

Angle of incidence in forward motion

In all cases - stop and reverse

How far can I reverse - At least 1" based on ring width



Worst case scenario for forward motion ring detection

Motion control - STop, reverse 1", ~~rotate~~ spin

How far to spin - not critical
choose 90° to maximize time to next detection on incident detection (shallow angle)

Spin options

3 options for spin

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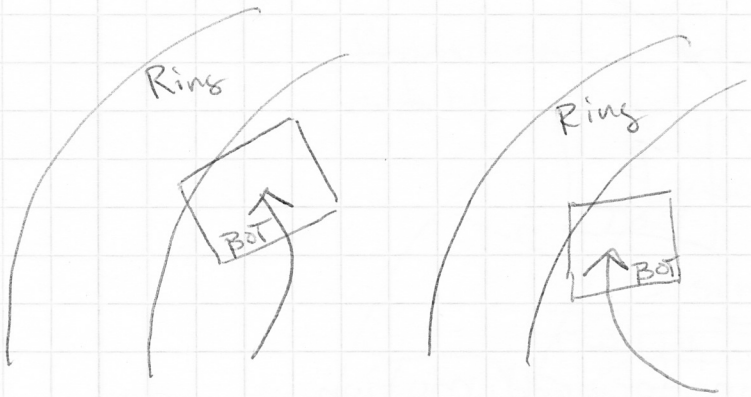
Line Sensors (cont'd)

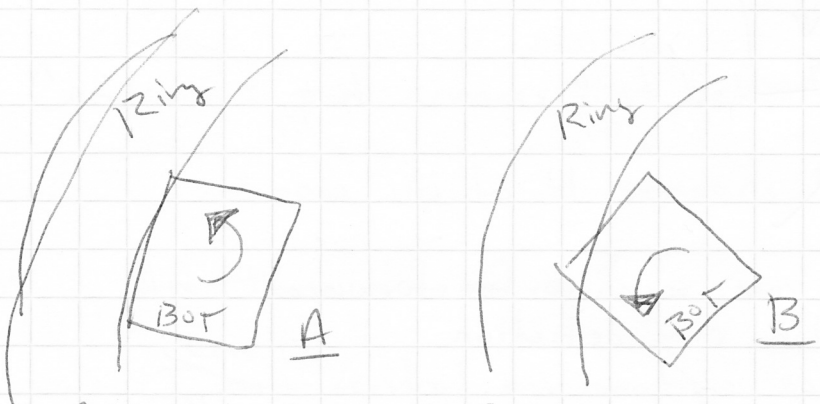
Arc Motion Angles



Angle of incidence for arc motion

Simpler that forward motion case - reverse motion does not present issues - use the same solution as forward motion

Spin Motion Angles



Angle of incidence for spin motion

I don't think A is possible, and B is also simpler than the forward motion case - use the same solution

Motion summary - 1 sensor

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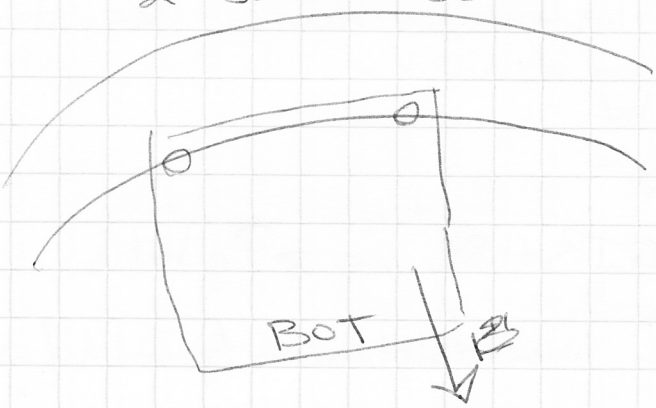
Detect, stop, reverse 1", spin 90° away from sensor that detected

Line Sensors Cont'd

Check on 2 sensors

2 sensor ~~sche~~ scenario



If both sensors detect need to reverse more than 1" → no concern for castors

reverse 3" and spin one direction (both wheels)

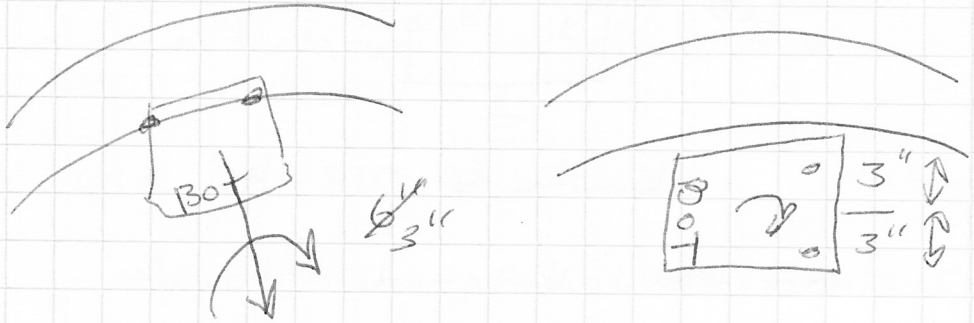


diagram of safe reverse distance

Summary

2 scenariors

1- line sensor - stop, reverse 1", spin 90° away

2- line sensors - stop, reverse ~~6~~ 3", spin 90° Right (right chosen arbitrarily)

Line sensors - continued

Actual sensor operation

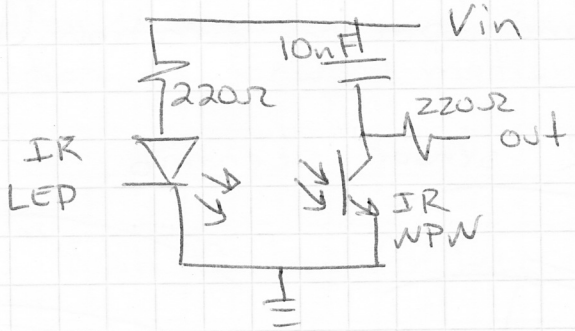
IR Reflectance sensors - 2 options

Digital -
Analog -

Digital - QTR-1RC - Pololu

spec @ www.pololu.com/product/2459

QTR-1RC



schematic for QTR-1RC

operation: Vin - tied to V+

any time V+ is supplied IR LED transmits

IR light reflects off of target (bot ring)
dark targets - minimal reflection
light targets - maximal reflection

~~more ri~~

1) Discharge the cap by pulling the output high
2) release the output
3) sensed IR light causes current flow in NPN
4) capacitor charges with NPN current

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More reflected light → more NPN current → faster charge

Line Sensor - cont'd

process - ~~characteriz~~

pull output high -
set pin to output
write "1" to pin

release output -
set pin to input
write '0' to pin to disable pull up
order is important *

sense transition on input from high to low

Characterize the sensor:

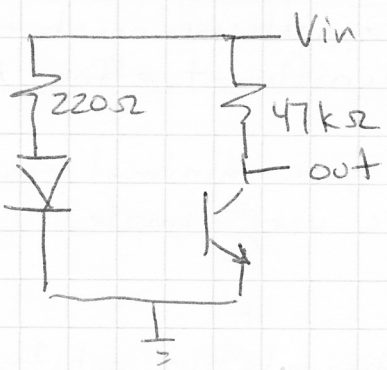
run the process on various shades of gray
plot time to input transition vs shades of gray
pick a time limit to define "white" and "black"

and various distances

Analog - QTR-1A Pololu

spec @ www.pololu.com/product/2458

QTR-1A



schematic for QTR-1A

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Line Sensors-Cont'd

operation Vin tied to V+

any time V+ applied - IR transmits

amount of reflectance causes different NPN currents

current through resistor (47kΩ) causes a voltage drop leading to various output voltages

high reflectance → high NPN current → low output vo
low reflectance → low NPN current → high output voltage

Process - no real process for the sensor
- just supply Vin @ V+

Characterization -
measure output voltage for various shades of gray
measure output voltage for various distances

2 options for measurement

A/D converter
Digital pin

A/D will give ~~m~~ significant resolution at the cost of significant effort (complexity)

Digital pin - will give minimal resolution (1 or 0) but could be very simple

Characterize the digital pin solution 1st - if good enough use it - if not good enough further ~~and~~ analyze digital vs analog w/ A/D

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Line Sensors - (cont'd)

Evaluate the Analog sensor with digital pin approach

Setup Sensor at various heights / shades of gray
Measure output voltage with analog discovery 2

spec indicates ideal height of 1/8" and worst case height at 3/8"

Bot ring - black & white

black - construction paper
white - index card

Distance spacer - quarters

Ambient light - nominal room light

5 measurements - 3 heights - round robin

heights 1/8 (2 quarters)
1/4 (4 quarters)
3/8 (6 quarters

2 shades Black -
White

Round Robin - black thru white for each height
- repeat 5x

Analog Sensor Characterization

Measurement	Height	Vout White	Vout Black
1	1/8	0.1v	3.6v
	1/4	0.1v	3.4v
	3/8	0.5v	4.4v
2	1/8	0.1v	3.5v
	1/4	0.15	3.5v
	3/8	0.45v	4.3v
3	1/8	0.15v	3.6v
	1/4	0.15v	3.7v
	3/8	0.5v	4.4v

cont'd ↓

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Line Sensors - Cont'd

Analog Sensor Characterization

Measurement	Height	Vout ~~tight~~ White	Vout black
4	1/8	.15v	~~.35~~ 3.5v
	1/4	.1v	3.2v
	3/8	.45v	4.3v
5	1/8	.1v	3.6v
	1/4	.2v	3.7v
	3/8	.5v	4.5v

Analog Sensor Averages

Averages Height	Vout White	Vout Black
1/8	0.12v	3.56v
1/4	0.14v	3.5v
3/8	0.48v	4.38v

For the Arduino -

V_{IL} = 0.3Vcc worst case
V_{IH} = 0.6Vcc worst case

@ 5v V_{IL} = ~~0~~ 1.5v
~~V_{IH}~~ V_{IH} = 3.0v

Margin Table

V_{IL} - Vout White
~~V_{IH}~~ Vout Black - V_{IH}

Height	Margin V_{IL}	Margin V_{IH}
1/8	1.38v	0.56v
1/4	1.36v	0.5v
3/8	1.05v	1.38v

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Line Sensor - Cont'd

Based on maximizing the Margin to V_{IL} and V_{IH}
choose 3/8" spacing

Implementation

Vin tied to Vtt (5v)
Gnd tied to gnd

left sensor out - dig pin ~~12~~ ~~PD7~~ PB4
Right sensor out - dig pin ~~2~~ ~~PD4~~ PB5
~~13~~

Line sensor test setup (code)

code line sensor outputs (inputs) to drive arduino outputs to drive PD0, PD1 LEDs

Light up LEDs when sensor reads a white line

Code in: test_routins/src/test_ir.c

Tests completed successfully -

next step - ~~run bot in~~
- create program for line sense and avoidance based on scenarios from pages 57-61

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