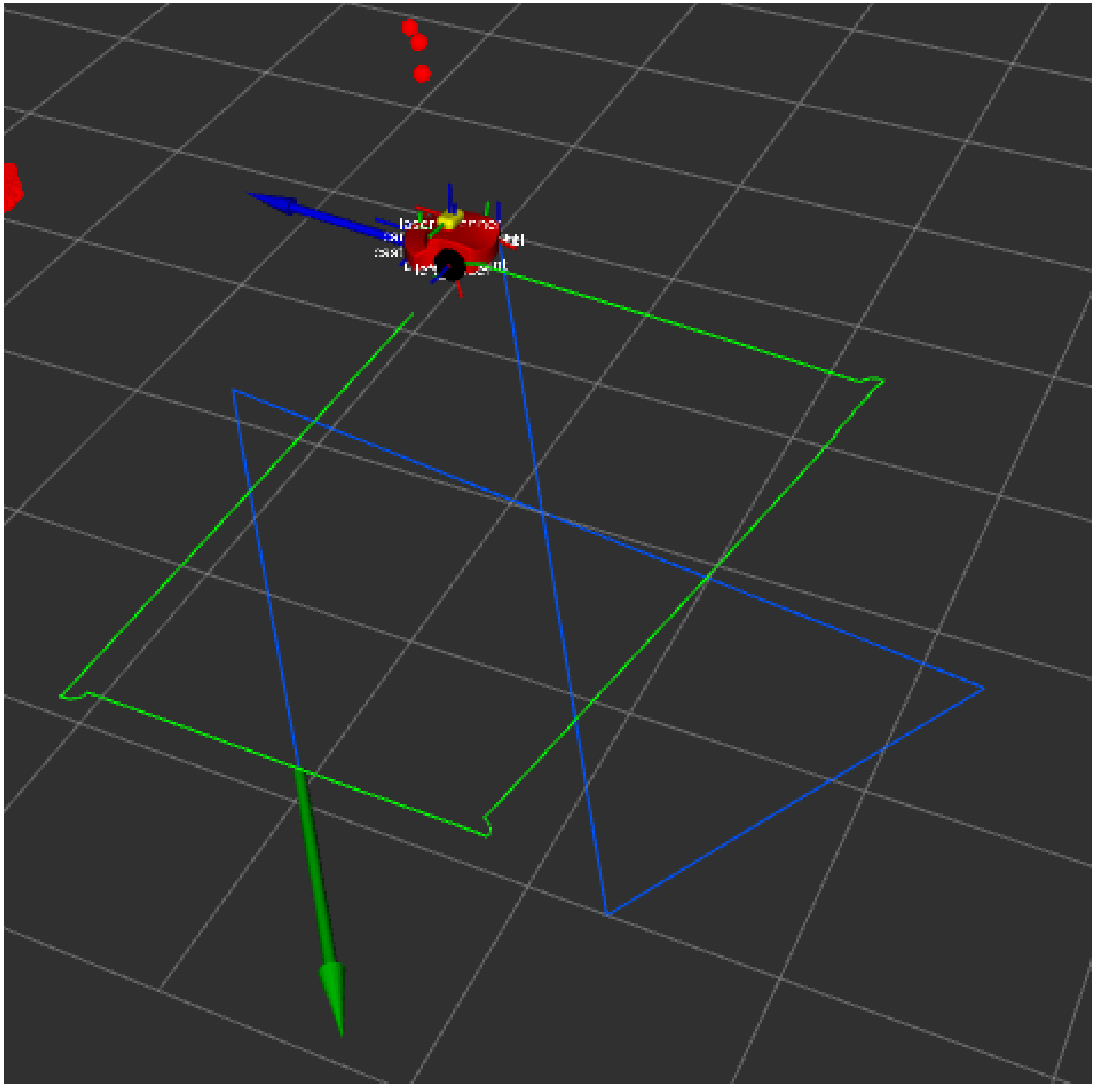
CATBot Localization
Part 2
UMBmark: Systematic Errors

Mahmoud Abdul Galil

Tutorial-8, Wednesday November 9, 2016

Ground-Truth vs Encoder

- Blue line is Encoder
- Green line is ground-truth
- Huge difference due to huge model errors



Systematic Errors

Systematic errors are caused by:

- Unequal wheel diameters
- Average of both wheel diameters differs from nominal diameter
- Misalignment of wheels
- Uncertainty about the effective wheelbase (due to non-point wheel contact with the floor)
- Limited encoder resolution
- Limited encoder sampling rate

Systematic Error Correction

- Scaling Error:
  - Simple
  - Easily compensated for
  - Measuring tape is the only requirement
- Effective Wheel-base error
- Unequal Wheel-Diameter error
-

Uni-directional Square Benchmark

- Program vehicle to follow a square path
- Use a reference wall to calculate absolute position
- Begin by calculating start point co-ordinates
- Let the vehicle follow the path clock-wise
- When it finishes, calculate absolute position and orientation of end point

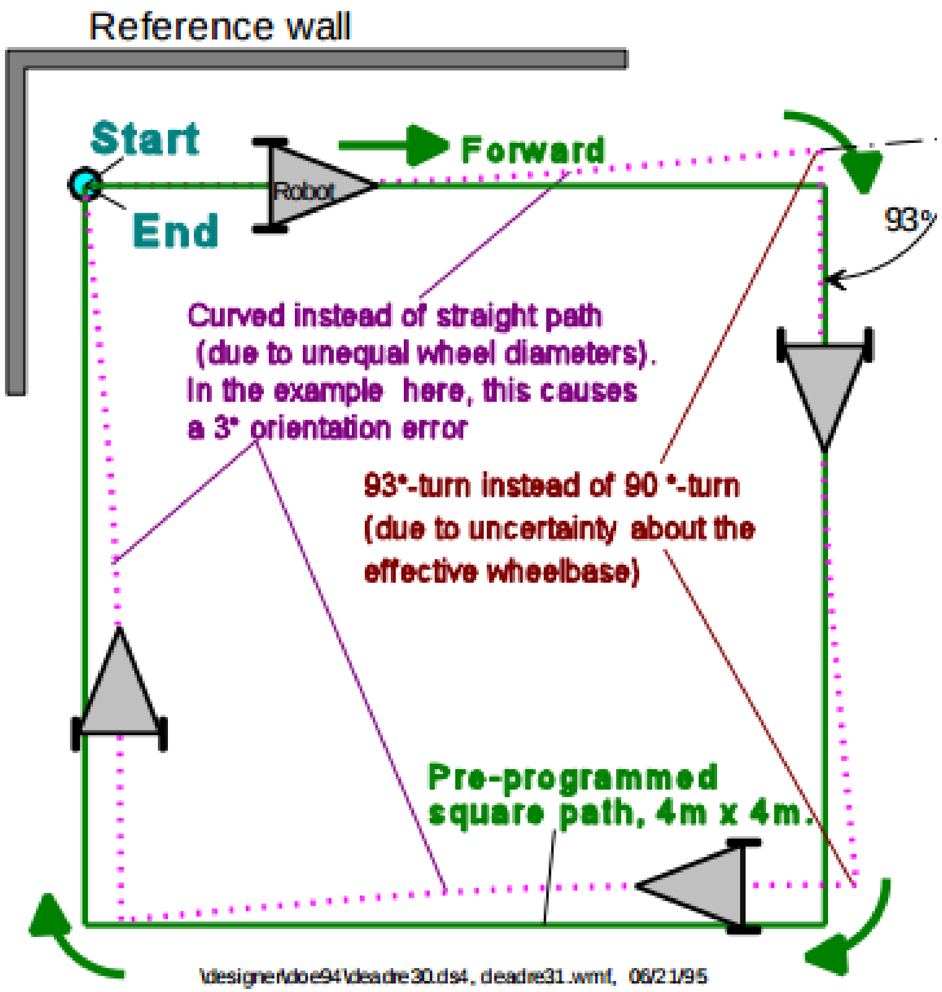


Figure 2: The effect of the two dominant systematic odometry errors E_b and E_d . Note how both errors may cancel each other out when the test is performed in only one direction.

Uni-directional Square Benchmark

$$\begin{aligned} \in x &= x_{abs} - x_{calc} \\ \in y &= y_{abs} - y_{calc} \qquad (1) \\ \in \theta &= \theta_{abs} - \theta_{calc} \end{aligned}$$

where

$\in x, \in y, \in \theta$ — Position and orientation errors due to odometry.

$x_{abs}, y_{abs}, \theta_{abs}$ — Absolute position and orientation of the robot.

$x_{calc}, y_{calc}, \theta_{calc}$ — Position and orientation of the robot as computed from odometry.

Uni-directional Square Benchmark

However, this benchmark is susceptible.
Consider the case shown on the right:

In the clockwise direction, the unequal-wheel-diameter might the oppose the uncertainty in the wheel-separation, thus leading to a false conclusion regarding odometry error.

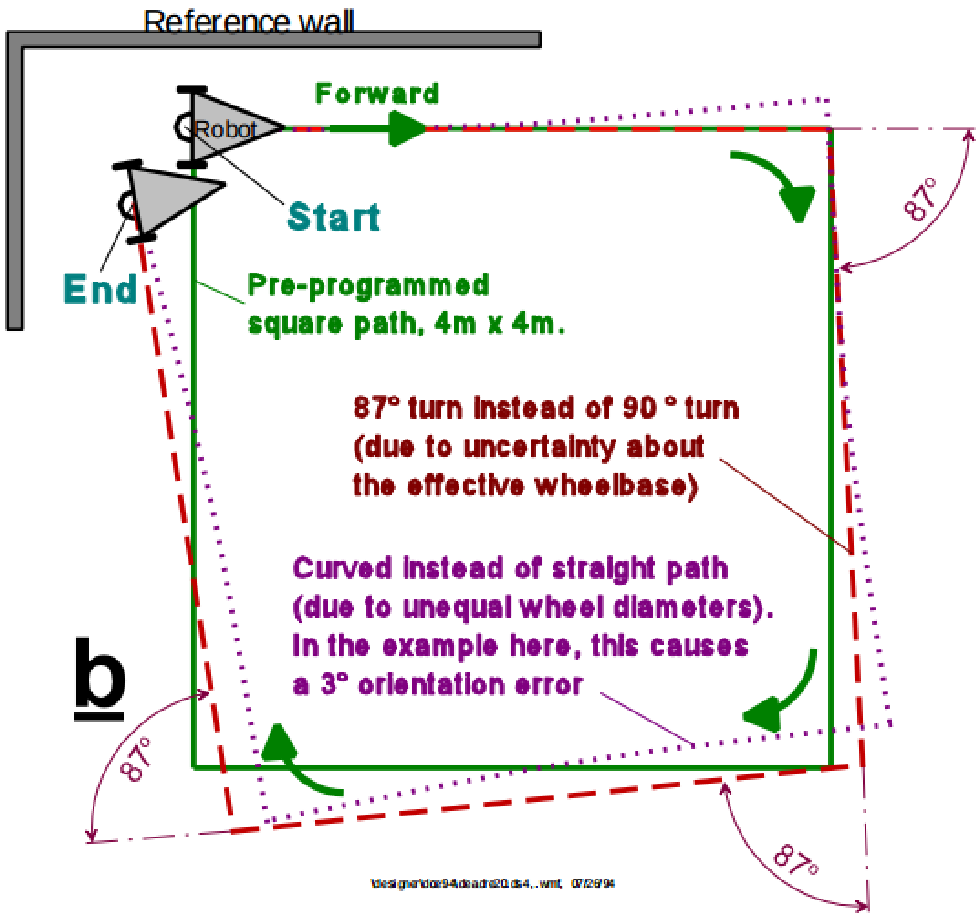


Figure 3: The unidirectional square path experiment.
a. The nominal path.
b. Either one of the two significant errors E_b or E_d can cause the same final position error.

Bi-directional Square Benchmark (UMBmark)

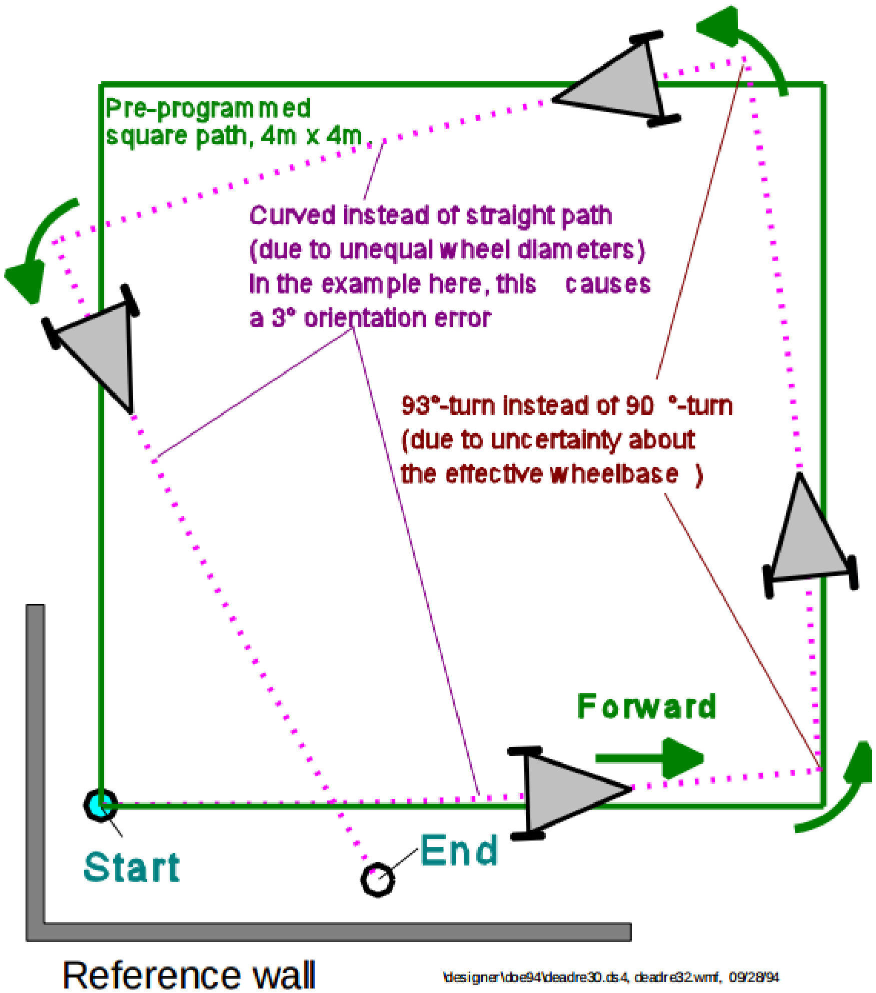


Figure 4: The effect of the two dominant systematic odometry errors E_b and E_d : When the square path is performed in the opposite direction one may find that the errors add up.

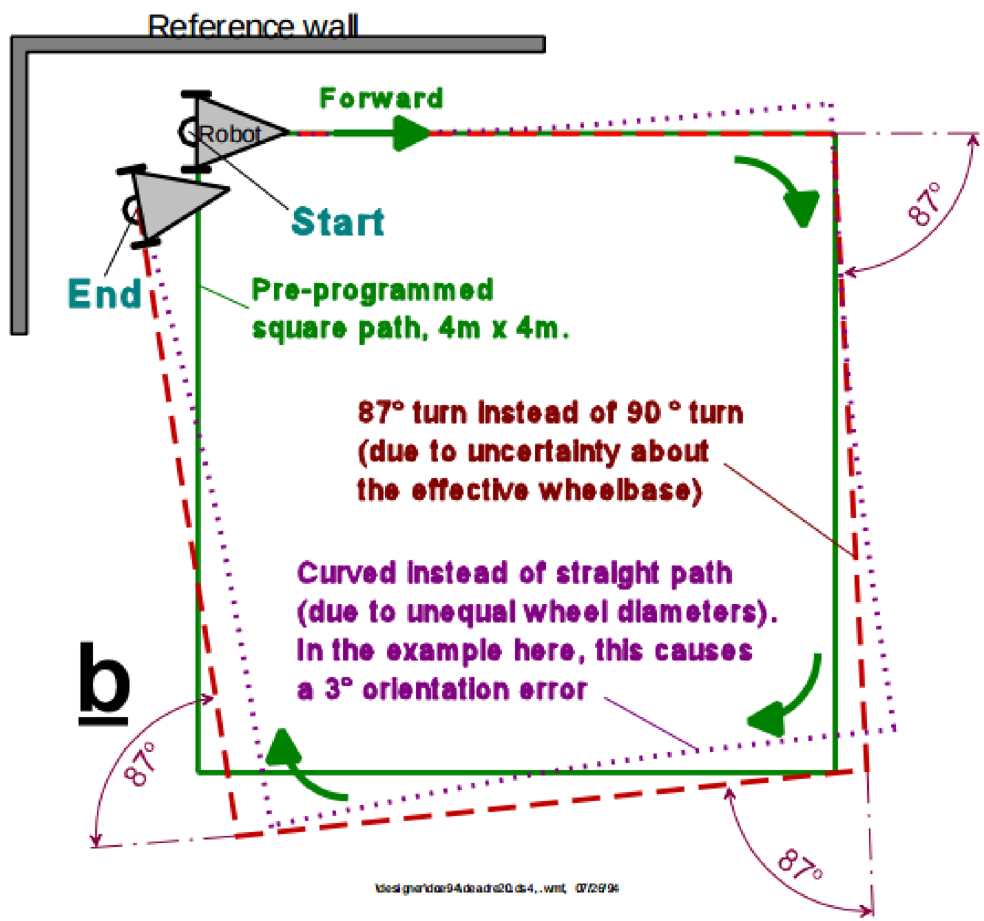


Figure 3: The unidirectional square path experiment.

a. The nominal path.

b. Either one of the two significant errors E_b or E_d can cause the same final position error.

Bi-directional Square Benchmark (UMBmark)

- At the beginning of the run, measure the absolute position (and, optionally,orientation) of the vehicle and initialize to that position the starting point of the vehicle's odometry program.
- Run the vehicle through a 4×4 m square path in cw direction, making sure to stop after each 4 m straight leg; make a total of four 90 -turns on the spot; run the vehicle slowly to avoid slippage.
- Upon return to the starting area, measure the absolute position (and, optionally, orientation) of the vehicle.
- Compare the absolute position to the robot's calculated position, based on odometry
- Repeat steps 1-4 for four more times (i.e., a total of five runs).
- Repeat steps 1-5 in ccw direction.
- Use Eqs. (2) and (3) to express the experimental results quantitatively as the measure of odometric accuracy for systematic errors

Bi-directional Square Benchmark (UMBmark)

$$x_{c.g.,cw/ccw} = \frac{1}{n}\sum_{i=1}^{n} \in x_{i,cw/ccw}$$

$$y_{c.g.,cw/ccw} = \frac{1}{n}\sum_{i=1}^{n} \in y_{i,cw/ccw} \qquad (2)$$

$$r_{c.g.,cw} = \sqrt{(x_{c.g.,cw})^2 + (y_{c.g.,cw})^2}$$

and

$$r_{c.g.,ccw} = \sqrt{(x_{c.g.,ccw})^2 + (y_{c.g.,ccw})^2}$$

Table I: Summary of properties and UMBmark results for the six different vehicles tested

Name of vehicle or configuration	Tested Platform			Result in [mm]	
	Platform Name	Modification	Calibration	$E_{max,syst}$	σ
1. TRC-nomod/nocal	TRC LabMate	none	none (b=340.0, D_R/D_L=1)	310	50
2. TRC-3loop/nocal	TRC LabMate	3 loops of masking tape on right wheel	none (b=340.0, D_R/D_L=1)	423	31
3. TRC-nomod/docal	TRC LabMate	none	yes (b=337.2, D_R/D_L=1.00121)	26	32
4. TRC 3loop/docal	TRC LabMate	3 loops of masking tape on right wheel	yes (b=337.1, D_R/D_L=1.00203)	20	49
5. CLAPPER	University of Michigan CLAPPER	4-DOF vehicle, made from 2 TRCs with compliant link	yes	22	11
6.Cybermotion	Cybermotion K2A	Slightly worn-out, in service since 1987	Original, from manufacturer	63	60

Table I: Summary of properties and UMBmark results for the six different vehicles tested

Name of vehicle or configuration	Tested Platform			Result in [mm]	
	Platform Name	Modification	Calibration	$E_{max,syst}$	σ
1. TRC-nomod/nocal	TRC LabMate	none	none (b=340.0, D_R/D_L=1)	310	50
2. TRC-3loop/nocal	TRC LabMate	3 loops of masking tape on right wheel	none (b=340.0, D_R/D_L=1)	423	31
3. TRC-nomod/docal	TRC LabMate	none	yes (b=337.2, D_R/D_L=1.00121)	26	32
4. TRC 3loop/docal	TRC LabMate	3 loops of masking tape on right wheel	yes (b=337.1, D_R/D_L=1.00203)	20	49
5. CLAPPER	University of Michigan CLAPPER	4-DOF vehicle, made from 2 TRCs with compliant link	yes	22	11
6.Cybermotion	Cybermotion K2A	Slightly worn-out, in service since 1987	Original, from manufacturer	63	60

References

1) UMBmark: A Benchmark Test for Measuring Odometry Errors in Mobile Robots: http://www.johnloomis.org/ece445/topics/odometry/borenstein/paper60.pdf