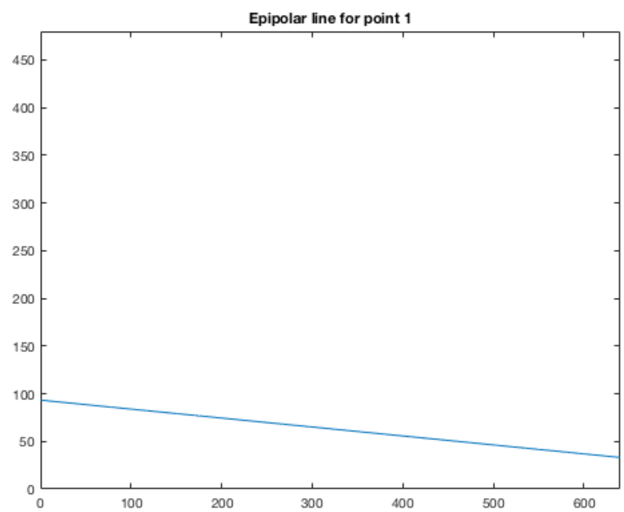
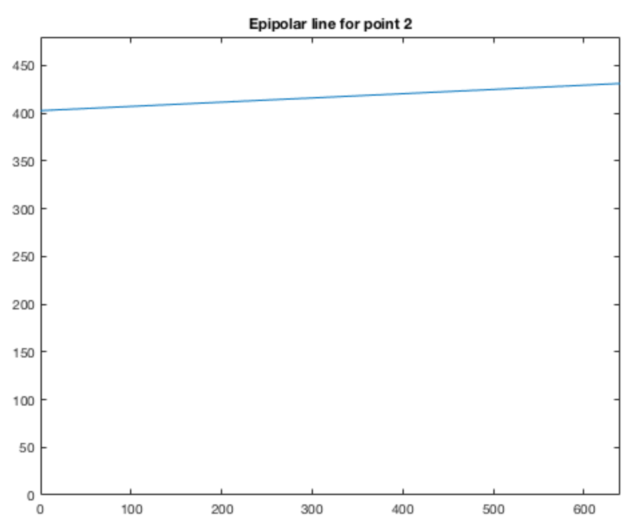
```matlab
%=========================
%  Name:                hw6_1.m
%
%  Author:              Kairi Kozuma
%=========================

% Declare given matrices
psi = [400,0,320;0,-400,240;0,0,1];
R_WL = [0.913545457642601,-0.063627629171822,0.401729040058774;0.287606238475951,0.799453749866612,-0.527405302792764;-0.287606238475951,0.59734849680
R_WR = [0.994521895368273,-0.016351854232753,0.103241544429788;0.073912785203567,0.808411029059454,-0.583959337863936;-0.073912785203567,0.58839121760
T_WL = [-8.659258262890683;2.169872981077807;4.830127018922193];
T_WR = [10.659258262890683;5.830127018922193;1.169872981077807];
rL = [552,589,531;85,405,212;1,1,1];
rR = [417,428;54,421;0,1];

G_WR = [R_WR, T_WR; 0,0,0,1];
G_WL = [R_WL, T_WL; 0,0,0,1];
G_LR = G_WL^(-1) * G_WR;
R_LR = G_LR(1:3,1:3);
T_LR = G_LR(1:3,4);

% Part a
fprintf('a) Essential matrix E_LR:\n');
T_LR_HAT = [0, -T_LR(3), T_LR(2); T_LR(3), 0, -T_LR(1); -T_LR(2), T_LR(1), 0];
E_LR = T_LR_HAT * R_LR;
disp(E_LR);

% Part b
fprintf('b) Fundamental matrix F_LR:\n');
F_LR = inv(psi') * E_LR * inv(psi);
disp(F_LR);

% Part c
disp('c) Line equations');
eqn1 = rL(1:3,1)' * F_LR;
eqn1mx = [-eqn1(1) / eqn1(2), -eqn1(3) / eqn1(2)];
fprintf('\nPoint 1:\n');
fprintf('%fx + %fy + %f = 0\n', eqn1(1), eqn1(2), eqn1(3));
fprintf('y = %fx + %f\n', eqn1mx(1), eqn1mx(2));

eqn2 = rL(1:3,2)' * F_LR;
eqn2mx = [-eqn2(1) / eqn2(2), -eqn2(3) / eqn2(2)];
fprintf('\nPoint 2:\n');
fprintf('%fx + %fy + %f = 0\n', eqn2(1), eqn2(2), eqn2(3));
fprintf('y = %fx + %f\n', eqn2mx(1), eqn2mx(2));

eqn3 = rL(1:3,3)' * F_LR;
eqn3mx = [-eqn3(1) / eqn3(2), -eqn3(3) / eqn3(2)];
fprintf('\nPoint 3:\n');
fprintf('%fx + %fy + %f = 0\n', eqn3(1), eqn3(2), eqn3(3));
fprintf('y = %fx + %f\n', eqn3mx(1), eqn3mx(2));

% Part d
fprintf('\nd) Plot of epipolar lines\n');
x_val = [0:.25:640]; % Image coordinates
y_val_p1 = x_val .* eqn1mx(1) + eqn1mx(2);
y_val_p2 = x_val .* eqn2mx(1) + eqn2mx(2);
y_val_p3 = x_val .* eqn3mx(1) + eqn3mx(2);

figure(1);
plot(x_val, y_val_p1);
axis([0,640,0,480]);
title('Epipolar line for point 1');

figure(2);
plot(x_val, y_val_p2);
axis([0,640,0,480]);
title('Epipolar line for point 2');

figure(3);
plot(x_val, y_val_p3);
axis([0,640,0,480]);
title('Epipolar line for point 3');

% TODO: plot and tell which ones are in right image plane

% Part e
disp('e) Plot of points and epipolar lines in one graph')
figure(4);
hold on
plot(x_val, y_val_p1, '-','DisplayName','Epipolar Line 1');
plot(x_val, y_val_p2, '-','DisplayName','Epipolar Line 2');
plot(x_val, y_val_p3, '-','DisplayName','Epipolar Line 3');
plot([417],[54],'+','DisplayName','Point1');
plot([428],[421],'*','DisplayName','Point2');
axis([0,640,0,480]);
legend('show');
title('Points from right camera frame and epipolar lines');
hold off
```

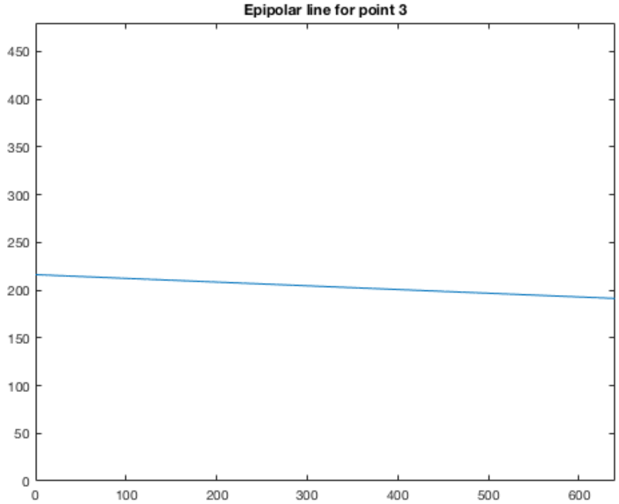
```
fprintf('Point %d in the left camera corresponds to point %d in right camera\n',1,1);
fprintf('Point %d in the left camera corresponds to point %d in right camera\n',2,2);
fprintf('Point %d in the left camera has no corresponding point in right camera\n',3);
```

```
a) Essential matrix E_LR:
   -0.0000   -3.0902   -0.4894
   -3.0902   -0.0000  -19.7538
   -0.4894   19.7538   -0.0000

b) Fundamental matrix F_LR:
   -0.0000    0.0000   -0.0059
    0.0000   -0.0000    0.0432
   -0.0059   -0.0556    3.7497

c) Line equations

Point 1:
-0.004217x + -0.044904y + 4.187925 = 0
y = -0.093916x + 93.264640

Point 2:
0.001963x + -0.044189y + 17.796452 = 0
y = 0.044426x + 402.734266

Point 3:
-0.001764x + -0.045309y + 9.797878 = 0
y = -0.038941x + 216.244519

d) Plot of epipolar lines
e) Plot of points and epipolar lines in one graph
Point 1 in the left camera corresponds to point 1 in right camera
Point 2 in the left camera corresponds to point 2 in right camera
Point 3 in the left camera has no corresponding point in right camera
```

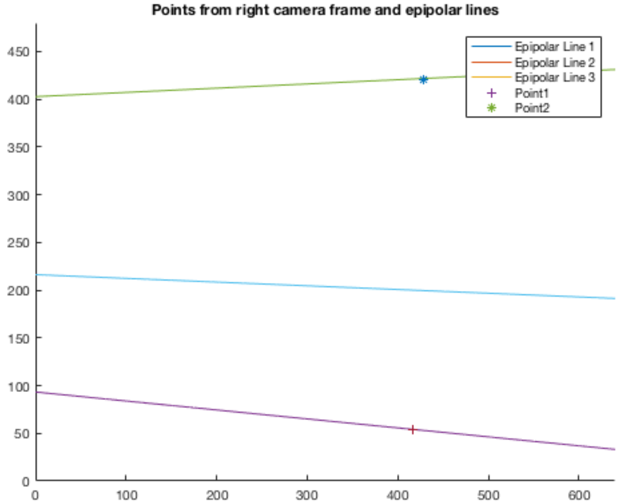




Epipolar line for point 3



Points from right camera frame and epipolar lines



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Vision-Based Autonomous Vehicle Navigation of a Robot: Week 3

Members: Xiaoyi Jeremy Cai, Kairi Kozuma

TurtleBot: TB-02

Procedure

- SSH into the turtlebot
- Copy the kobuki_button.py from the online GitHub repository
  - Modify the code, replacing “Button” with “Bumper” to subscribe to the bumper events.
  - Use the message format for BumperEvent and replace the constants related to ButtonEvent
  - See attached code: kobuki_bumper.py
- Modify the MoveForward.py code to include different states
  - 1) Move forward
  - 2) Stop when bumper hit
  - 3) Go back after stopping
  - 4) Turn 90 degrees to the left

Investigation

- What are the ROS topics that must be subscribed to in order to get these sensor measurements? To find out these things quickly, bringup the turtlebot, then use the `rostopic` command with the `list` option to query the different published topics. Using the `type` and `echo` options will let you know what the data type of the message is and what the different fields are of the message.

  The ROS topics that must be subscribed to include the /mobile_base/eventsbumper, /mobile_base/events/cliff, and /mobile_base/wheel_drop.

- Bumper: /mobile_base/events/bumper

  bumper: 2
  state: 1
  ---
  bumper: 2
  state: 0

- Cliff: /mobile_base/events/cliff

  sensor: 2
  state: 1

bottom: 1486
---
sensor: 2
state: 0
bottom: 1393
---
sensor: 2
state: 1
bottom: 1535

- Wheel Drop: /mobile_base/events/wheel_drop

  wheel: 0
  state: 1
  ---
  wheel: 1
  state: 1
  ---
  wheel: 0
  state: 0
  ---
  wheel: 1
  state: 0

- Of course, the message will only pop up when the publisher publishes. Some messages publish all the time. Some only when tiggered to. Which of the above publish all the time, which publish as needed?

Bumper, wheel drop, and cliff sensors are only published as needed, as they are events.
The odometry and laptop charge were published continuously. The laptop charge publishing only about once per second, while the odometry published every 20ms or so.

Adventure

1. Modify the `kobuki_buttons` code to also check for a bumper event. Call the file `kobuki_bumpers`. Display output whenever that is triggered. How many different bumpers does the kobuki have? Modify so that the message specifies which bumper was hit or “unhit.” Once you have this working, you are ready to combine with actuation. The important thing here is to learn how to modify what gets imported at

the beginning of the code, and how to setup the subscriber. To learn what the messages are like, you can access the kobuki message python code that describes what the message structures are like.

- The turtlebot has three different bumper sensors: left, center, and right.
- Please see attached *kobuki_bumerps.py*

2. Copy the goforward code to another file. Modify it so that the robot moves with a constant slow velocity. Add a condition to stop when it bumps into something or senses a wheel drop condition. It should start again 2 seconds after the condition is removed. The best way to do this involves coding a finite state machine, so that specific commands will be sent when the state changes, as well as keeping track of the overall hit state of the bumpers.

- Please see attached *Move.py*