Introduction to Unmanned Ground Vehicles
Instructor: Micho Radovnikovich
Email: mtradovn@oakland.edu
ECE 4900/5900 – Winter 2018
Take-Home Exam
Due: Wednesday, March 28 th
The purpose of this assignment is to ensure that the student thoroughly understands the concepts discussed so far in the course before moving on to more advanced topics. Complete the exam on the following pages, putting your answers in a separate document. Use whichever tools you want (Word, L A TEX, pencil, etc.). You can submit your answers via email (mtradovn@oakland.edu) or by adding the document to your repository and pushing it.
http://xkcd.com/135/1. Short answer problems
(a) [5 points] Which two files are present in every ROS package?

CMakeLists.txt, package.xml

(b) [5 points] Cite an example where a private node handle could be used.

A private node handle is inside the node namespace. Maybe if the private node handle is the same name with one globle node handle, and we only need this private node handle use in the node, at this situation, we can use the private instead of globle node handle.

(c) [5 points] A complete representation of a coordinate frame transformation consists of what?

First, coordinate transformation need a translation and an orientation component. Translations are represented by vectors that are added to produce an offset. Orientation are need rotation matrices or quaternions to present.

(d) [5 points] What is a YAML file used for?

YAML file can privide parameters data to ros and can load by launch file.

(e) [5 points] The determinant of a rotation matrix must be equal to +1 in order to correctly rotate points from one frame to another. Why is this?

Matrix equal to +1 that's means vectors are unit vectors, and rotation matrices are orthogonal.
So, we can get $R^{-1} = R^T$.
If not equal to +1, then the multiplication would end up changing the vector's magnitude.

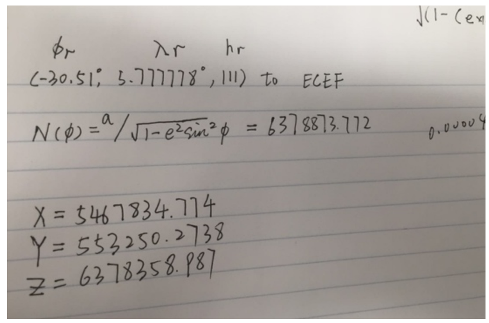
2. Given the GPS coordinates (30 ◦ 30 0 36.00 00 S, 5 ◦ 40 0 40.00 00 E):
(a) [5 points] Convert the coordinates into decimal degrees.

South: -(30+30/60+36/3600) = -30.51 degree
East: 5+40/60+40/360 = 5.7777778 degree

(b) [5 points] Assuming an altitude of 111 meters, convert the coordinates into ECEF.

(-30.51, 5.777778, 111) to ECEF:

$X = [N(\varphi_r) + h_r] \cos\varphi_r \cos\lambda_r =$ m
$Y = [N(\varphi_r) + h_r] \cos\varphi_r \sin\lambda_r =$ m
$Z = N(\varphi_r)(1 - e^2) + h_r \sin\varphi_r =$ m



$\sqrt{(1-(e\times$

ϕ_r λ_r h_r
(-30.51°, 5.777778°, 111) to ECEF

$N(\phi) = a/\sqrt{1-e^2\sin^2\phi} = 6378873.772$ 0.00004

X = 5467834.774
Y = 553250.2738
Z = 6378358.987

3. Consider two frames A and B, where the orientation from A to B is described by a pitch angle of 90 degrees, and a yaw angle of 135 degrees.

(a) [5 points] Compute the rotation matrix that would be used to transform points represented in B frame into their equivalent coordinates in A frame.

$$\begin{bmatrix} x_b \\ y_b \\ z_b \end{bmatrix} = R_z R_y R_x \begin{bmatrix} x_a \\ y_a \\ z_a \end{bmatrix} = \begin{bmatrix} \cos 90 & 0 & \sin 90 \\ 0 & 1 & 0 \\ -\sin 90 & 0 & \cos 90 \end{bmatrix} \begin{bmatrix} \cos 135 & -\sin 135 & 0 \\ \sin 135 & \cos 135 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_a \\ y_a \\ z_a \end{bmatrix}$$

$$= \begin{bmatrix} 0 & 0 & 1 \\ \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & 0 \\ \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & 0 \end{bmatrix} \begin{bmatrix} x_a \\ y_a \\ z_a \end{bmatrix}$$

(b) [5 points] What would be the x component of the quaternion representation of this rotation?
Imaginary x axes component

4. Consider a mobile robot navigating to a GPS waypoint, as illustrated below:
The vehicle's coordinates are (10, 10) in the global reference frame G, and the waypoint's coordinates are (10, 20) in G.

(a) [5 points] Compute the rotation matrix and translation vector from global frame G to vehicle frame V .

Assume heading is degree is Θ

$$T_G^V = \begin{bmatrix} 10 \\ 10 \\ 0 \end{bmatrix}$$

$$R_G^V = \begin{bmatrix} \cos\Theta & -\sin\Theta & 0 \\ \sin\Theta & \cos\Theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

(b) [10 points] Compute the coordinates of the waypoint relative to vehicle frame V .

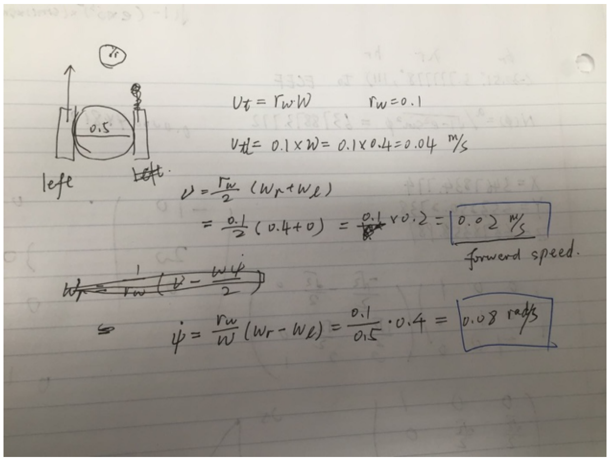
$$P_G = R_G^V P_V + T_G^V = \begin{bmatrix} \cos\Theta & -\sin\Theta & 0 \\ \sin\Theta & \cos\Theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 10 \\ 20 \\ 0 \end{bmatrix} + \begin{bmatrix} 10 \\ 10 \\ 0 \end{bmatrix}$$

(c) [5 points] What is the equivalent quaternion that represents the same rotation from G to V ?

$$\boldsymbol{P_V = q_B^A P_G (q_B^A)^{-1}}$$

5. Consider a differential drive vehicle with wheel radius 0.1 meters, and a distance of 0.5 meters between the wheels.

(a) [10 points] If the left wheel is rotating forward at 4 rad/s, and the right wheel isn't rotating at all, compute the forward speed and yaw rate of the vehicle.



(b) [5 points] Which ROS message type would you use to report this velocity? How would you populate the message?

Geometry_msgs/Twist and std_msgs Float64

Pub = mode.advertise<std_msgs::Float64>("node_name", 1);

6. [10 points] Describe and/or list the procedure for converting geodetic GPS coordinates into East-North-Up.

1. First we have geodetic GPS point.

2. Convert geodetic into ECEF.
3. First we have geodetic GPS point.

Using: X = [N (φ r) + h r] cos φ r cos λ r=
Y = [N (φ r) + h r] cos φ r sin λ r =
Z = N (φ r)(1 − e 2) + h r sin φ r =

4. Translating ECEF to ENU

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} -\sin\lambda_r & \cos\lambda_r & 0 \\ -\sin\phi_r\cos\lambda_r & -\sin\phi_r\sin\lambda_r & \cos\phi_r \\ \cos\phi_r\cos\lambda_r & \cos\phi_r\sin\lambda_r & \sin\phi_r \end{bmatrix} \begin{bmatrix} X - X_r \\ Y - Y_r \\ Z - Z_r \end{bmatrix}$$

7. [10 points] Describe and/or list the procedure for advertising a custom service in a ROS node (entire process, not just the C++ code).

1. For service we should have a request and a response.
2. So we need build a srv folder, in this folder we need a write a .srv file.
3. Then in the code we use ros::ServiceClient srv=node.serviceClient<pkgname::.srv file>
4. We also need a request and response under pkgname
5. Last part, we should know if the service works.
6. Then, we need ROS_INFO and ROS_WARN to tell us if it works