A dual Ackerman drive would steer both front and rear wheels using an Ackerman steering approach. What would the pros and cons for this system compared to a single Ackerman drive?

Pros:
-can still be used easily and intuitively with a conventional steering wheel
-gives steering over all 4 wheels
-allows for tighter turns about some pivot point not centered on the vehicle
-drive simillar to most newer lawn tractors

Cons:
-increased complexity means higher liklihood of failure

Real motion and measurement involves error and this problem will introduce the concepts. Assume that you have a differential drive robot with wheels that are 20cm in radius and L is 12cm. Using the differential drive code (forward kinematics) from the text, develop code to simulate the robot motion when the wheel velocities are $\dot{\phi}_1=0.25t^2$, $\dot{\phi}_2=0.5t$. The starting location is [0,0] with $\theta=0$

1. Plot the path of the robot on $0\le t\le 5$. It should end up somewhere near [50,60].
2. Assume that you have Gaussian noise added to the omegas each time you evaluate the velocity (each time step). Test with $\mu=0$ and $\sigma=0.3$. Write the final location (x,y) to a file and repeat for 100 simulations. Hint:

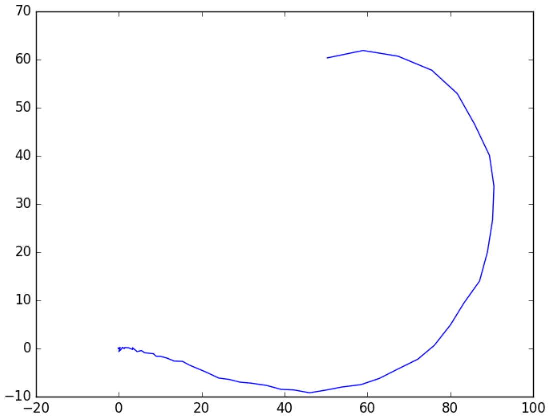
```
mu, sigma = 0.0, 0.3
xerr = np.random.normal(mu,sigma, NumP)
yerr = np.random.normal(mu,sigma, NumP)
```

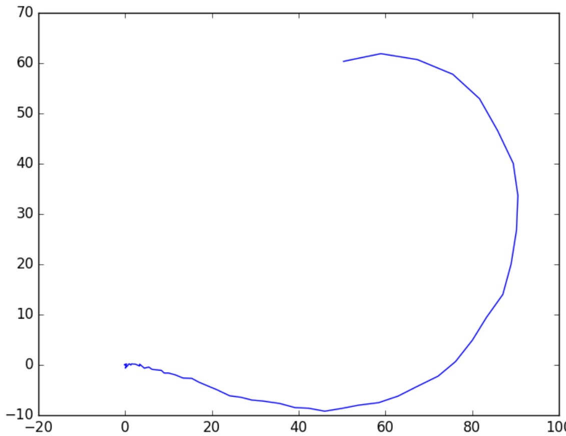
3. Generate a plot that includes the noise free robot path and the final locations for the simulations with noise. Hint:

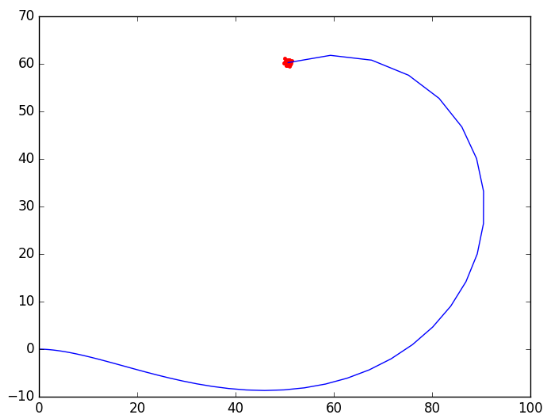
```
import numpy as np
import pylab as plt
...
plt.plot(xpath,ypath, 'b-', x,y, 'r.')
plt.xlim(-10, 90)
plt.ylim(-20, 80)
plt.show()
```

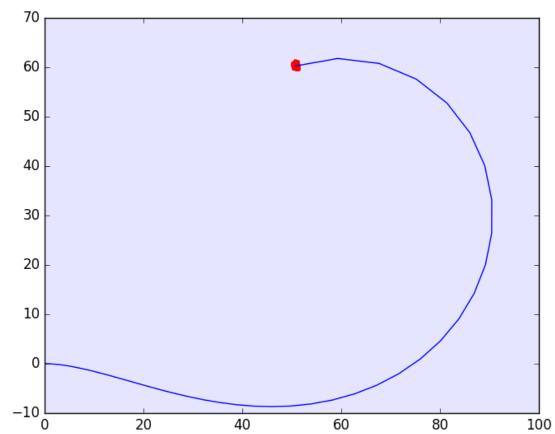
4. Find the location means and 2x2 covariance matrix for this data set, and compute the eigenvalues and eigenvectors of the matrix. Find the ellipse that these generate. [The major and minor axes directions are given by the eigenvectors. Show the point cloud of final locations and the ellipse in a graphic (plot the data and the ellipse). Hint:

```
from scipy import linalg
from matplotlib.patches import Ellipse
#  assume final locations are in x & y
mat = np.array([x,y])
#  find covariance matrix
cmat = np.cov(mat)
# compute eigenvals and eigenvects of covariance
eval, evec = linalg.eigh(cmat)
#  find ellipse rotation angle
angle = 180*atan2(evec[0,1],evec[0,0])/np.pi
# create ellipse
ell = Ellipse((np.mean(x),np.mean(y)),
                     eval[0],eval[1],angle)
#  make the ellipse subplot
a = plt.subplot(111, aspect='equal')
ell.set_alpha(0.1)    #  make the ellipse lighter
a.add_artist(ell)   #  add this to the plot
```









Top Left: 6.5.a
Top Right: 6.5.b
Bottom Left: 6.5.c
Bottom Right: 6.5.d

Code Base for problem 6.5:

a.)

```
            import pylab as plt
import numpy as np
from math import *
N=52
x = np.zeros(N)
y = np.zeros(N)
q = np.zeros(N)
x[0] = 0; y[0] = 0; q[0]  = 0.0
t = 0;  dt = 0.1

def ddstep(xc, yc, qc,r,l,dt,w1,w2):
   xn = xc + (r*dt/2.0)*(w1+w2)*cos(qc)
   yn = yc + (r*dt/2.0)*(w1+w2)*sin(qc)
   qn = qc + (r*dt/(2.0*l))*(w1-w2)
   return (xn,yn,qn)


for i in range(N-1):
   w1 = 0.25*t*t
   w2 = 0.5*t
   x[i+1], y[i+1], q[i+1] = ddstep(x[i], y[i], q[i],20,12.0,dt,w1,w2)
   t = t + dt
   print(t)

plt.plot(x,y,'b')
plt.show()
```

b.)

```
import pylab as plt
import numpy as np
from math import *
N=52
mu, sigma = 0.0, 0.3

filename = "output.txt"
file = open(filename, "w")

for k in range(100):
    x = np.zeros(N)
    y = np.zeros(N)
    x_with_error = np.zeros(N)
    y_with_error = np.zeros(N)
    q = np.zeros(N)
    xerr = np.random.normal(mu,sigma, 100)
    yerr = np.random.normal(mu,sigma, 100)
    x[0] = 0; y[0] = 0; q[0]  = 0.0
    t = 0;  dt = 0.1

    def ddstep(xc, yc, qc,r,l,dt,w1,w2):
        xn = xc + (r*dt/2.0)*(w1+w2)*cos(qc)
        yn = yc + (r*dt/2.0)*(w1+w2)*sin(qc)
        qn = qc + (r*dt/(2.0*l))*(w1-w2)
```

```
        return (xn,yn,qn)


    for i in range(N-1):
        w1 = 0.25*t*t
        w2 = 0.5*t

        x_with_error[i] = xerr[i] + x[i]
        y_with_error[i] = yerr[i] + y[i]
        x[i+1], y[i+1], q[i+1] = ddstep(x[i], y[i], q[i],20,12.0,dt,w1,w2)
        x_with_error[i+1], y_with_error[i+1], q[i+1] = ddstep(x_with_error[i], y_with_error[i], q[i],20,12.0,dt,w1,w2)
        t = t + dt
        print(t)
    file.write('{0} {1}\n'.format(x[51], y[51]))
    k+=1

file.close()

plt.plot(x_with_error,y_with_error,'b')
plt.show()
```

c.)

```
import pylab as plt
import numpy as np
from math import *
N=52
mu, sigma = 0.0, 0.3

filename = "output.txt"
file = open(filename, "w")


for k in range(100):
    x = np.zeros(N)
    y = np.zeros(N)
    x_with_error = np.zeros(N)
    y_with_error = np.zeros(N)
    q = np.zeros(N)
    xerr = np.random.normal(mu,sigma, 100)
    yerr = np.random.normal(mu,sigma, 100)
    x[0] = 0; y[0] = 0; q[0]  = 0.0
    t = 0;  dt = 0.1

    def ddstep(xc, yc, qc,r,l,dt,w1,w2):
        xn = xc + (r*dt/2.0)*(w1+w2)*cos(qc)
        yn = yc + (r*dt/2.0)*(w1+w2)*sin(qc)
        qn = qc + (r*dt/(2.0*l))*(w1-w2)
        return (xn,yn,qn)


    for i in range(N-1):
        w1 = 0.25*t*t
        w2 = 0.5*t

        x_with_error[i] = xerr[i] + x[i]
```

```
        y_with_error[i] = yerr[i] + y[i]
        x[i+1], y[i+1], q[i+1] = ddstep(x[i], y[i], q[i],20,12.0,dt,w1,w2)
        x_with_error[i+1], y_with_error[i+1], q[i+1] = ddstep(x_with_error[i], y_with_error[i], q[i],20,12.0,dt,w1,w2)
        t = t + dt

    plt.plot(x_with_error[51],y_with_error[51],'r.')

    k+=1


plt.plot(x,y,'b-')
plt.show()
```

d.)

```
import pylab as plt
import numpy as np
from scipy import linalg
from matplotlib.patches import Ellipse
from math import *
N=52
mu, sigma = 0.0, 0.3

filename = "output.txt"
file = open(filename, "w")

x_final = np.zeros(100)
y_final = np.zeros(100)

for k in range(100):
        x = np.zeros(N)
        y = np.zeros(N)
        x_with_error = np.zeros(N)
        y_with_error = np.zeros(N)
        q = np.zeros(N)
        xerr = np.random.normal(mu,sigma, 100)
        yerr = np.random.normal(mu,sigma, 100)
        x_mean = 0
        y_mean = 0
        xerr_mean =0
        yerr_mean =0
        x[0] = 0; y[0] = 0; q[0]  = 0.0
        t = 0;  dt = 0.1

        def ddstep(xc, yc, qc,r,l,dt,w1,w2):
                xn = xc + (r*dt/2.0)*(w1+w2)*cos(qc)
                yn = yc + (r*dt/2.0)*(w1+w2)*sin(qc)
                qn = qc + (r*dt/(2.0*l))*(w1-w2)
                return (xn,yn,qn)


        for i in range(N-1):
                w1 = 0.25*t*t
                w2 = 0.5*t

                x_with_error[i] = xerr[i] + x[i]
```

```
                y_with_error[i] = yerr[i] + y[i]
                x_mean += x[i]
                y_mean += y[i]
                xerr_mean += x_with_error[i]
                yerr_mean += y_with_error[i]

                x_with_error[i+1], y_with_error[i+1], q[i+1] = ddstep(x_with_error[i], y_with_error[i],
q[i],20,12.0,dt,w1,w2)
                x[i+1], y[i+1], q[i+1] = ddstep(x[i], y[i], q[i],20,12.0,dt,w1,w2)

                t = t + dt

        x_final[k] = x_with_error[51]
        y_final[k] = y_with_error[51]


x_mean /= N
y_mean /= N
xerr_mean /= N
yerr_mean /= N

print(x_mean)
print(y_mean)

tempx = (x_mean+xerr_mean)/2
tempy = (y_mean+yerr_mean)/2

varx= (x_mean - tempx)*(x_mean - tempx) + (xerr_mean - tempx)*(xerr_mean - tempx)
vary= (y_mean - tempy)*(y_mean - tempy) + (yerr_mean - tempy)*(yerr_mean - tempy)
covxy= (x_mean - tempx)*(y_mean - tempy) + (xerr_mean - tempx)*(yerr_mean - tempy)

#  assume final locations are in x & y
mat = np.array([x,y])
#  find covariance matrix
cmat = np.cov(mat)
# compute eigenvals and eigenvects of covariance
eval, evec = linalg.eigh(cmat)
#  find ellipse rotation angle
angle = 180*atan2(evec[0,1],evec[0,0])/np.pi
# create ellipse
ell = Ellipse((np.mean(x),np.mean(y)),
                        eval[0],eval[1],angle)

#  make the ellipse subplot
a = plt.subplot(111, aspect='equal')
ell.set_alpha(0.1)    #  make the ellipse lighter
a.add_artist(ell)   #  add this to the plot

print(eval)

for j in range(100):
        plt.plot(x_final[j], y_final[j],'r.')


plt.plot(x,y,'b-')
plt.show()
```