RoboSub Localization
Sponsor: NAVSEA
Mentor(s): Aaron Crandall, James Irwin, Edoardo Franco Vianelli, Drew Miller, Edward Kuo

Introduction
The Palouse Robosub club owns and operates a UAV (Underwater Autonomous Vehicle) sponsored by NAVSEA, a naval defense contractor, participate in the RoboNation competition. This competition brings together competitors from all over the world who showcase their creations and put the robots through their paces as they complete a series of underwater tasks. The more tasks are completed, the more points a team scores.

The RoboSub and the competition today
1. Currently the RoboSub can only complete 1 task in the competition
2. There is no way for the RoboSub to know its location and be able to navigate between tasks

The Project
Our task was to create a localization system for the RoboSub in order for it to complete more tasks and reach the finals in the competition.

The Particle Filter
This is the most important part of our final deliverable. The particle filter generates a cloud of possible states (locations) of the robot in the pool and calculates the probability of an individual point of being the actual location of the RoboSub, it does this with multiple sensors:
1. The Accelerometer: This sensor detects acceleration and we use it to allow the cloud of particles that has been generated to be shifted in the direction that the RoboSub is moving.
2. The Hydrophones and Pressure Sensor: After we have shifted the particles in the desired direction we utilize the Hydrophones and the Pressure Sensor to home in onto the right location.

To the left: this graph shows each (x, y, z) estimate of the RoboSub’s location on a 3D coordinate system, with the cloud being centered around the real location of the RoboSub.

```
def filter(self, hydr, depth):
    (x, y, z) = (self.observation[0], self.observation[1], self.observation[2])
    self.updateParticleStates() # add some random noise
    # assign the weights to the particles
    self.assignWeights(x, y, z, hydr, depth)
    # make the weights of the particles add up to 1
    self.normalize_particles()
    # pick the best particles, with replacements
    self.reweight()
    self.publish_particle(self.particleAverage())
```

The Movement Model
As the submarine moves through the pool environment, we use the most up-to-date current responses to shift our particles positions. The rough distance to move each particle is determined by the model’s integration of the data gathered from the submarine.

```
def movement(self):
    # every new accelerometer input we calculate
    # time delta
    elapsed = rospy.time.now() - self.last()
    # this is done for each x, y, and z velocity
    velocity = startPosition + (acceleration * elapsed)
    velocity = velocity * elapsed + (0.5 * acceleration * elapsed**2)
```

Testing
We needed to test the strength of the parameters we are using in the code to ensure our results are accurate enough for our goal. For our testing, we used a simulator tool built by the RoboSub team that can replicate the hardware readings that the real RoboSub can emit. We compared (x, y, z) results from the actual location versus our estimated location of the RoboSub.

Among the tests we ran are:
- Move Forward and Backwards
- Dive the submarine to a specific depth
- Strafe the Submarine to the left and to the Right
- Roll the Submarine and strafe
- Move in a square pattern

Future Work
1. Adding a Kalman Filter to reduce accelerometer noise in the movement model
   a. Improve the (x, y, z) shifts for the particles
   b. Improve the final (x, y, z) velocity estimations in the particle filter
2. Accounting for orientation in determining shifts from the Movement Model
3. Conversion of the project into the C++ Programming Language in order to achieve faster processing

Glossary
Robosub Club of the Palouse: The WSU club in charge of engineering and maintaining the WSU RoboSub
Hydrophones: A device that receives a ping and uses geometry to find the (x,y) location of the RoboSub
Pressure Sensor: A device that is used to determine the depth in the pool
Accelerometer: A device that measure acceleration

Acknowledgements
Special thanks to Aaron Crandall, James Irwin, Dustin Crossman and the entire Palouse Robosub club

Team Sedna