50 **Exercise 7: Monte Carlo Resampling**

Monte Carlo Localization (MCL) (or one of its derivates) is a popular method for mobile robot localisation. We consider the 2D case here, i.e. the robot uses a 2D map. Its position estimate, or briefly pose, within the map is a 3D vector (x, y, ϕ). In MCL, the pose is probabilistic and represented using sample sets. A sample set S is a set of pairs of poses and associated weights:

$$S = \{(p_i, w_i) \mid p_i = (x_i, y_i, \phi_i) \wedge w_i \in [0, 1]\}$$

where

$$x_i \in [-200.000, 200.000] \wedge y_i \in [-200.000, 200.000] \wedge \phi_i \in [0.0, 360.0[$$

1. Build classes for representing samples and sample sets.
2. Build a program that creates randomised sample sets with k samples with all equal weights. Test each time with $k = 100, 1000, 10000, and 100000$ samples, using the following methods for the randomised generation of samples:
   - In the first method, samples are uniformly distributed in the map space such that $-200.000 \leq x_i + y_i \leq 200.000$.
   - In the second method, samples are taken from the overlay of five Gaussian distributions with the following charcteristics: $\mu_1 = (x = -140, y = 20, \phi = 125)$, $\mu_2 = (x = -60, y = 120, \phi = 270)$ $\mu_3 = (x = 20, y = 120, \phi = 0)$ $\mu_4 = (x = 80, y = 0, \phi = 225)$ $\mu_5 = (x = 100, y = -100, \phi = 125)$ and $\sigma_x, \sigma_y = 20$ and $\sigma_\phi = 10$ are the same for all five distributions.
3. Extend your program by the capability to compute sample weights. Generate an additional sample using the second method from above and use this as the "real" pose. Using a Gaussian distribution around this pose, compute the weight of the samples as the value of the Gaussian at that pose.
4. Record and visualise the results, either by building a nice GUI and taking screenshots or by saving all sample data in a file and using some external visualisation tool.

An important step in the MCL procedure is resampling. If we have a sample set S with weighted poses, we generate a new set S' where the new distribution of the poses reflects the weights of the poses in sample set S. (Details of the procedure have been presented in class).
Implement the resampling procedure for MCL by performing the following steps

- Implement the resampling step, i.e. write a method that produces a new sample set where the samples are distributed according to the weight distribution of the original set.
- Extend you visualisation appropriately.

50 **Exercise 8: Monte Carlo Resampling in 3D**

Repeat the previous exercise and extend the framework to 3D, i.e. allow for processing position estimates in 6D:

$$S = \{(p_i, w_i) \mid p_i = (x_i, y_i, z_i, \alpha_i, \beta_i, \gamma_i) \wedge w_i \in [0, 1]\}$$

where

$$x_i, y_i \in [-200.000, 200.000] \wedge z_i \in [0.000, 20.000] \wedge \alpha_i, \beta_i, \gamma_i \in [0.0, 360.0[$$