Introduction into complexity measures

The ability of a robot to move in different environments is affected by the complexity of the environment, as mentioned in the state of the art section. This section is therefore dedicated to finding metrics that we can use to numerically analyze these complexities. For assessing the complexity of the world and the environment of robots, we considered a variety of factors. Table below shows the metrics we used to examine the complexity of the environment.

metrics	***reliability [0-10]***
Number of obstacles	8
Occupancy ratio	9
Entropy Entropy.Max	7
angle.mean	7
Distance Distance.Norm Distance.Variance	8

The following is an explanation of each of these metrics.
Number of Obstacles: Number of obstacles is one of the factors that contribute to the complexity of the environment. Depending on the size of the environment and the size of the robot, this metric can have a negative effect on robot performance.

Number of Obstacles:
Advantage:
number of obstacles is an important metric and easiest way to understand how comeplex a map is. that means the more obstacles a map has, the more complex it is and it can make the movement of the robots harder.
Disadvantage:
Because opencv is used, the result is accompanied by some errors.
Marginal cases:
for maps with very large number of obstacles or very small number of obstacles could have errors as it detects more edges.

Occupancy ratio:
Advantage:
A measure of how much space is taken up by obstacles compared to empty space. In relation to the size of the world and the size of the robot, this metric will affect the robot's performance.
Disadvantage: -

Marginal cases: -

Entropy:

Advantage:

By this metric, you can determine how well obstacles were distributed throughout the environment. Near the maximum, this number indicates a high degree of dispersion, which can negatively affect a robot's performance.

Disadvantage:

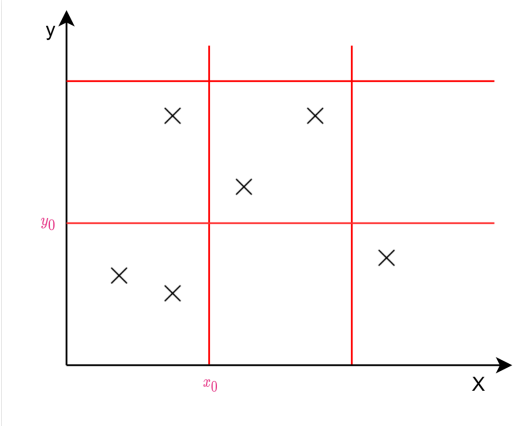
At this moment all maps are converted to the same size and then entropy is calculated with the size 2*2 mask. We can change the size of the mask, which can affect the result, and which size of the mask is more suitable depends on the size of the obstacles that we do not measure.

Marginal cases: -

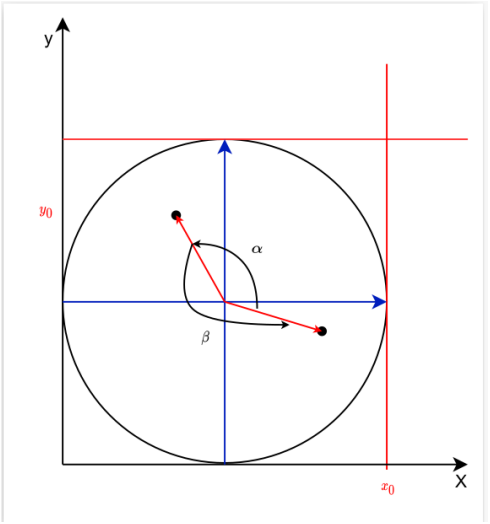
Angle:

Advantage: This metric determines the angle between obstacles in an environment. The larger the angle, the larger the space, resulting in better mobility for the robot. With a larger angle, there is an increase in space, so the robot is more mobile.

For each obstacle, we first calculated its coordinates and denote each obstacle's coordinates as [x, y]. As a result of considering the interval, we identified the obstacles that are placed within it. Figure below illustrates the obstacles and the interval.



To find the angle between two points, the center of each window is calculated and from there it is calculated what the angle is with the other points.



As shown in Figure above, the angle between the obstacles is calculated in each window in order to determine the largest and smallest angle between them. Figure shows that $\beta > \alpha$ is. Thus, the robot's best angle of motion is β. Using this method, we can calculate how many obstacles are in each window and how close they are to each other, and finally determine the degree of complexity of the environment by looking at the number of obstacles in each window and the angle between them.
Disadvantage: We measure the angles from the center of each window, not from the location of the robot. This means that in one window the robot may be at a point where there is no obstacle at all, or the angles may be different from the center of the robot.
Marginal cases: -

Distance.:
Advantage: The distance between obstacles in the whole environment is measured by this metric. With this metric, we can understand whether the distance between the obstacles in a map is large or small, and according to the size of the robot, whether it may cause problems for the movement of the robot or not.
Disadvantage: Because opencv is used, the result is accompanied by some errors.
Marginal cases: -