

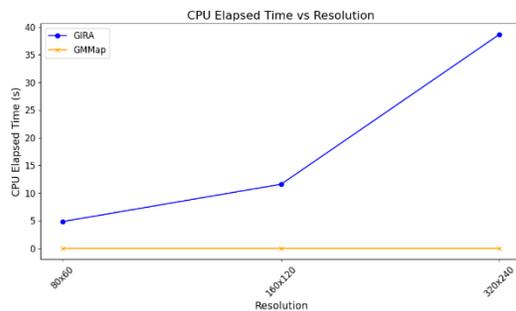
Alternatives to the Expectation-Maximization Algorithm for Gaussian Mixture Model Optimization

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In the following project different ways to generate Gaussian Mixture Models (GMM) were evaluated. Gaussian Mixture Models provide a scalable method for mapping an environment. A problem with that approach is that the algorithms to produce GMMs rely on the Expectation Maximization algorithm. This is an iterative algorithm that takes a long time to complete. Another problem with the classical approach is that you need to know beforehand how many Gaussian ellipsoids you want to fit on the map. Both of those problems are not optimal for a scenario where a drone is exploring a new environment as the execution time is critical and the environment changes dynamically as the drone moves.

GIRA is a method that tries to eliminate one of these issues. While it still relies on the Expectation Maximization algorithm, it dynamically adjusts the number of Gaussians that are fit during execution.



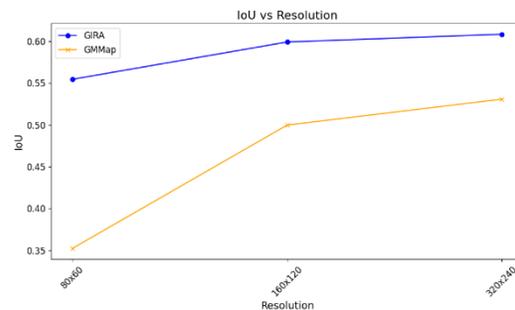
GMMMap clusters Gaussians in a fraction of the time that GIRA takes

GMMMap on the other hand relies on a completely different approach. It scans a depth image and separates it into different planes. It then fits Gaussians directly to these planes.

For the comparison, matching input data was generated using the Webots simulator. In addition to comparing the two approaches, the goal was also to compare and characterize different parameters of the models.

For that reason, the input data was captured at three different resolutions. Once the data was generated, both models were run with the exact same input data and different combinations of parameters.

The metrics on which the models were evaluated were the execution time as well as the Intersection over Union value, that estimates the quality of the map.



Intersection over Union, the map quality metric, of GMMMap and GIRA

Analyzing the results, we notice that GMMMap is up to 10000 times faster than GIRA depending on the resolution. In return GIRA does produce maps of higher quality than GMMMap when comparing the Intersection over Union value. When observing the trend of the Intersection over Union value with respect to resolution, we notice a clear pattern. For resolutions higher than those used in this experiment, GMMMap may produce higher-quality maps than GIRA. At the same time, the execution time trend suggests that GMMMap would remain multiple times faster than GIRA.

Observing how the choice of parameter influences both metrics, we notice that the resolution contributes to more than 99% of the variance in the results. Therefore, any choice of parameter for the models has a minor impact on the result for both approaches.