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Underground navigation and localisation using RFID tags

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I. PROBLEM STATEMENT

One of the major issues in the field of mobile robotics is localisation and navigation in an unknown environment. These tasks become even more challenging in an underground environment where no GPS signals or stationary landmark towers are available. This paper intends to tackle these challenges by using RFID tags, randomly distributed throughout the area, as landmarks. In future, the vehicle may place the tags in real-time by using an optimisation method to choose their locations. The paper will build on previous work done by Forster[8] and Vorst et al.[9] by implementing the proposed hybrid SLAM method on the mining safety platform, which will eventually be used in an underground environment.

II. NAVIGATION AND LOCALISATION SCHEME

A. Exploration and clustering

The algorithm used for exploring the RFID environment is shown in **Figure 1**.

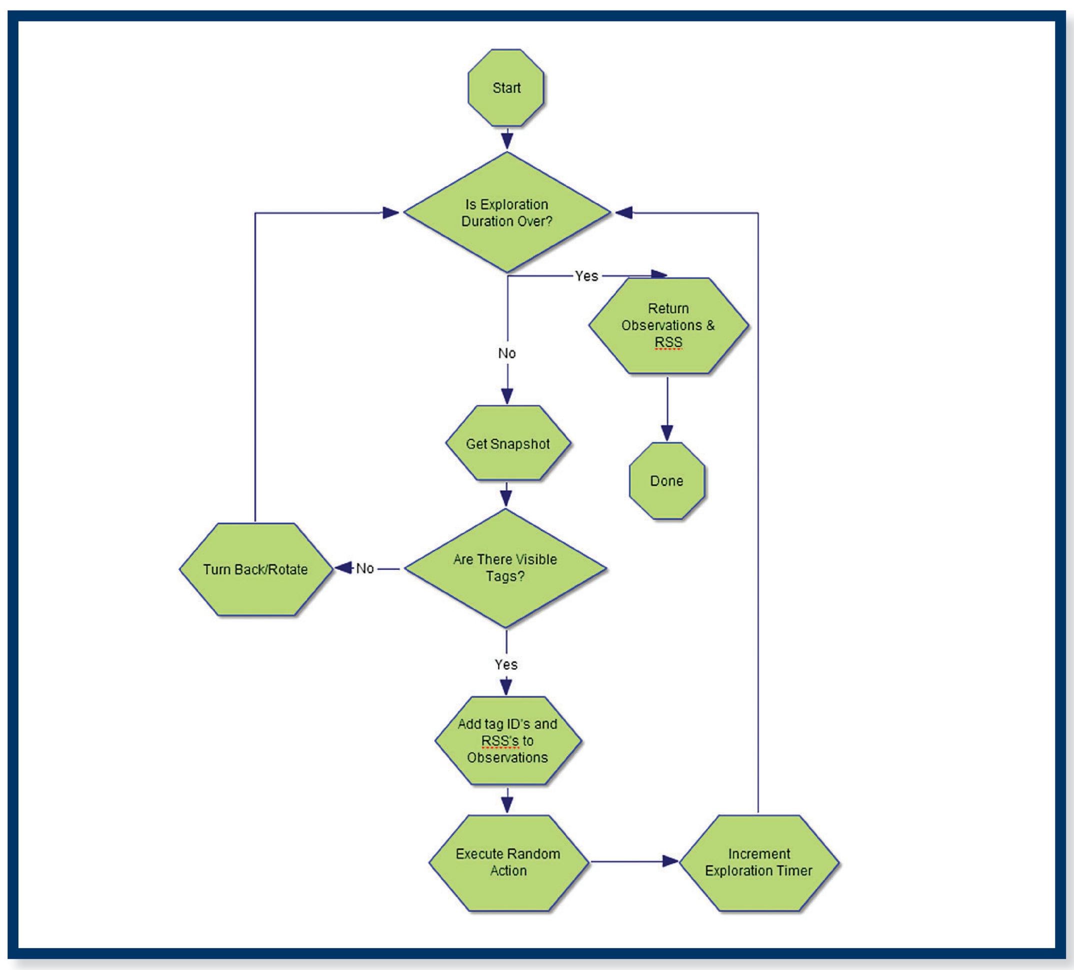


Figure 1: Algorithm used for exploring RFID environment

Given sufficient (more than 500 steps per 25 square metres) simulation time, the algorithm is able to explore the entire area multiple times.

The clustering algorithms used were k-means and k-medoids. K-means provided better results, and all further experiments were conducted using k-means. The value of k was chosen empirically assessing the best clustering to be between one half and two thirds the number of observations.

III. SIMULATION RESULTS

A. Localisation

The localisation of the vehicle averaged an error of 0.35 m over 20 trial runs. The average maximum localisation error was 0.98 m in the same simulations. A sample run of the localisation error is shown in **Figure 2**.

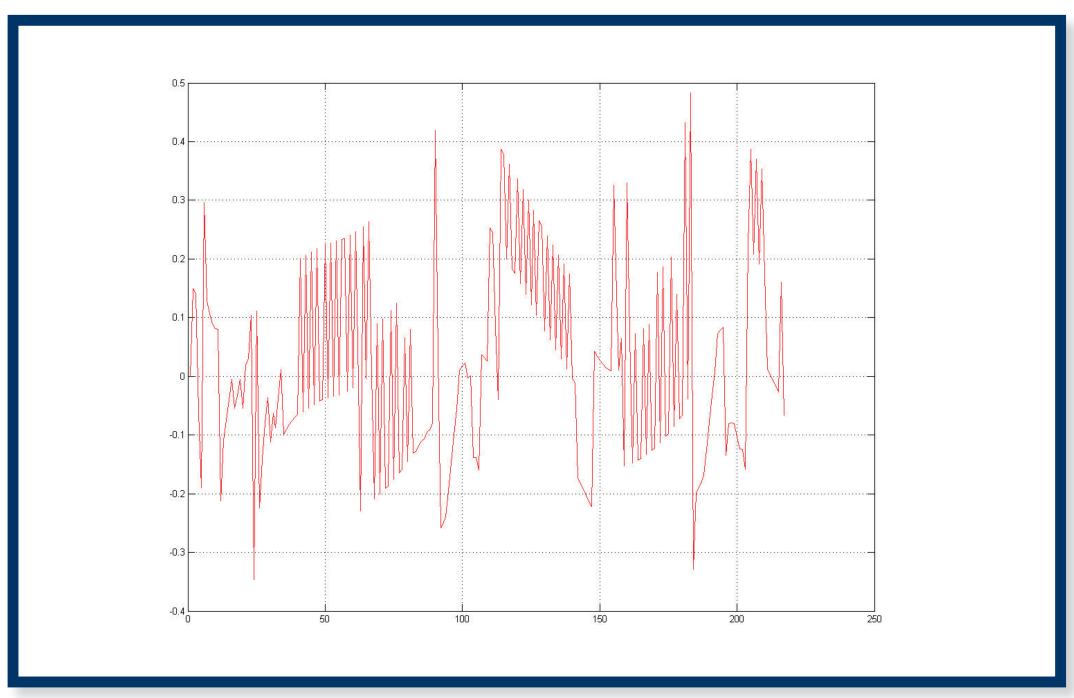


Figure 2: Localisation error

B. Navigation

A sample of the navigation results are shown in **Figure 3** below. As we can see, the displacement error decays consistently over time. Additionally, the orientation adjustment can be seen when the error may increase slightly closer to the goal.

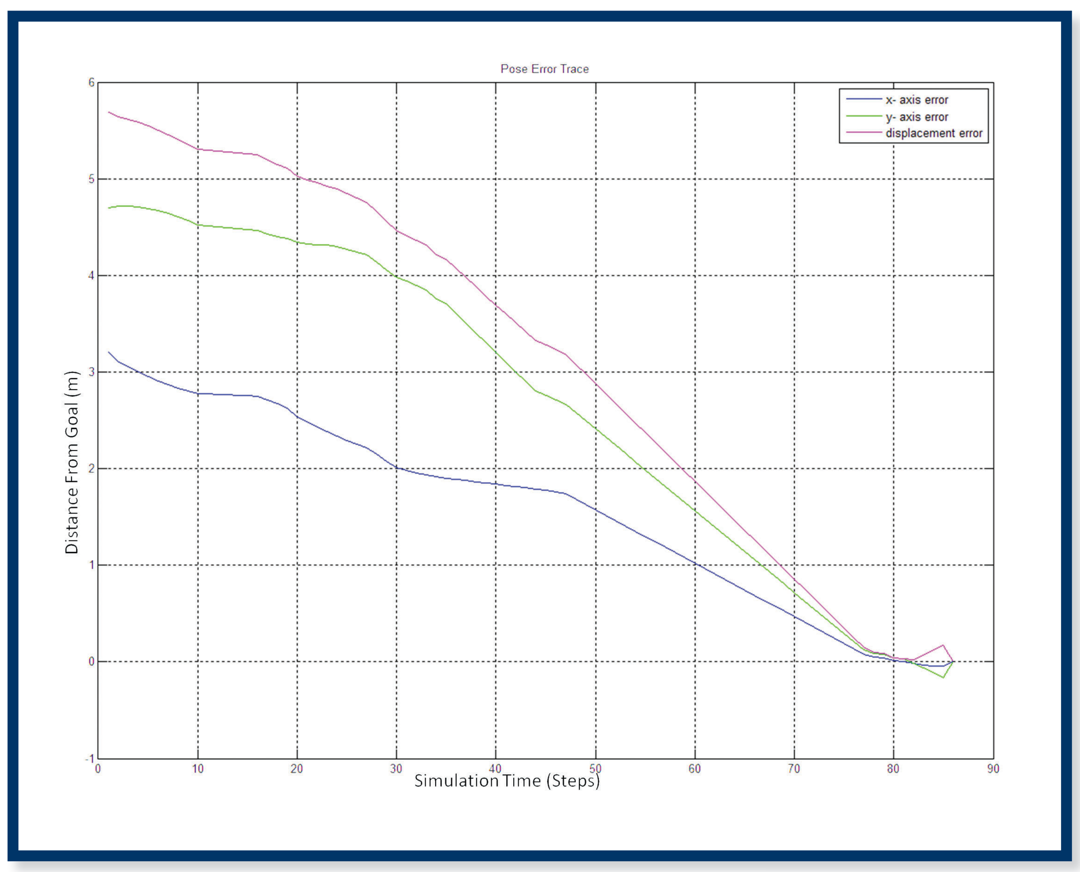


Figure 3: Sample navigation results

It is worth noting that when the vehicle is on the outskirts of the tag area (very low RSS), the poor localisation results in poor navigation results, the worst case results in the displacement error not converging. Additionally, the clustering algorithm can lead to poor clusters, depending on the starting centroids used. K-means tends to put all the observations with low RSS (usually outskirts) in the same cluster, despite the different tag identities. This leads to observations at the centre of the environment being part of the cluster with observations on the outskirts. Poor clustering can result in limit cycling and bad localisation. **Figure 4** illustrates this result. It was noted that performing the simulations under noisy velocity control eventually stops limit cycles.

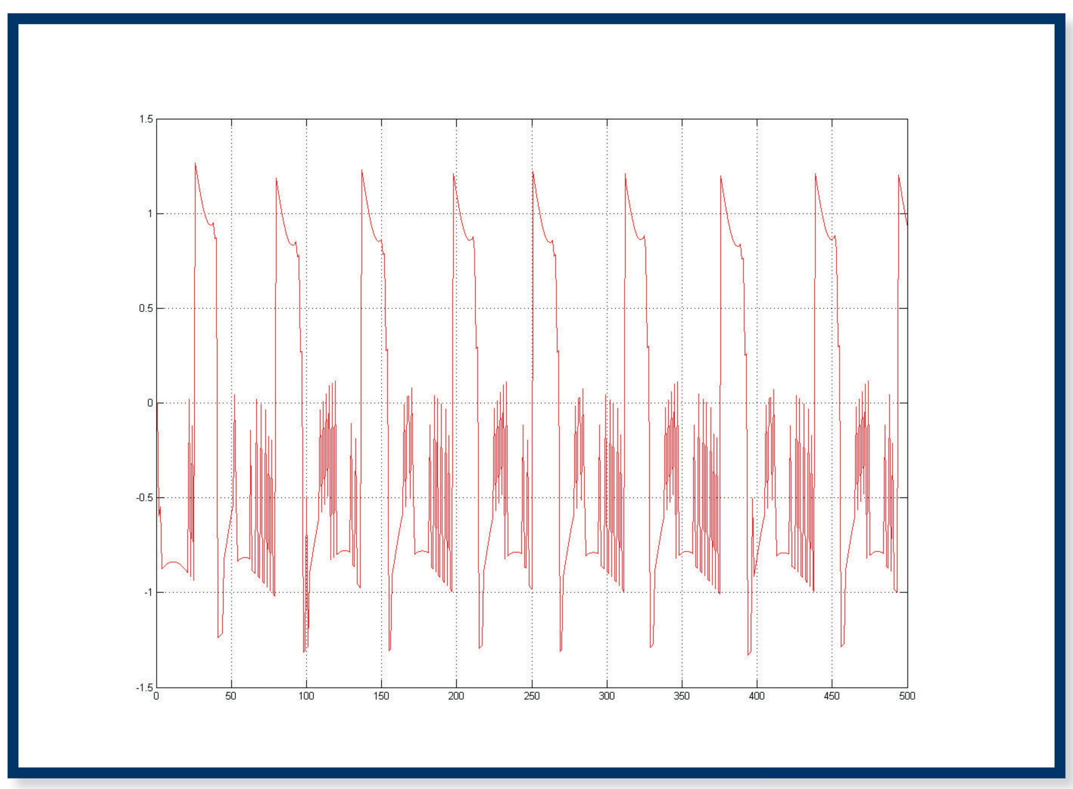
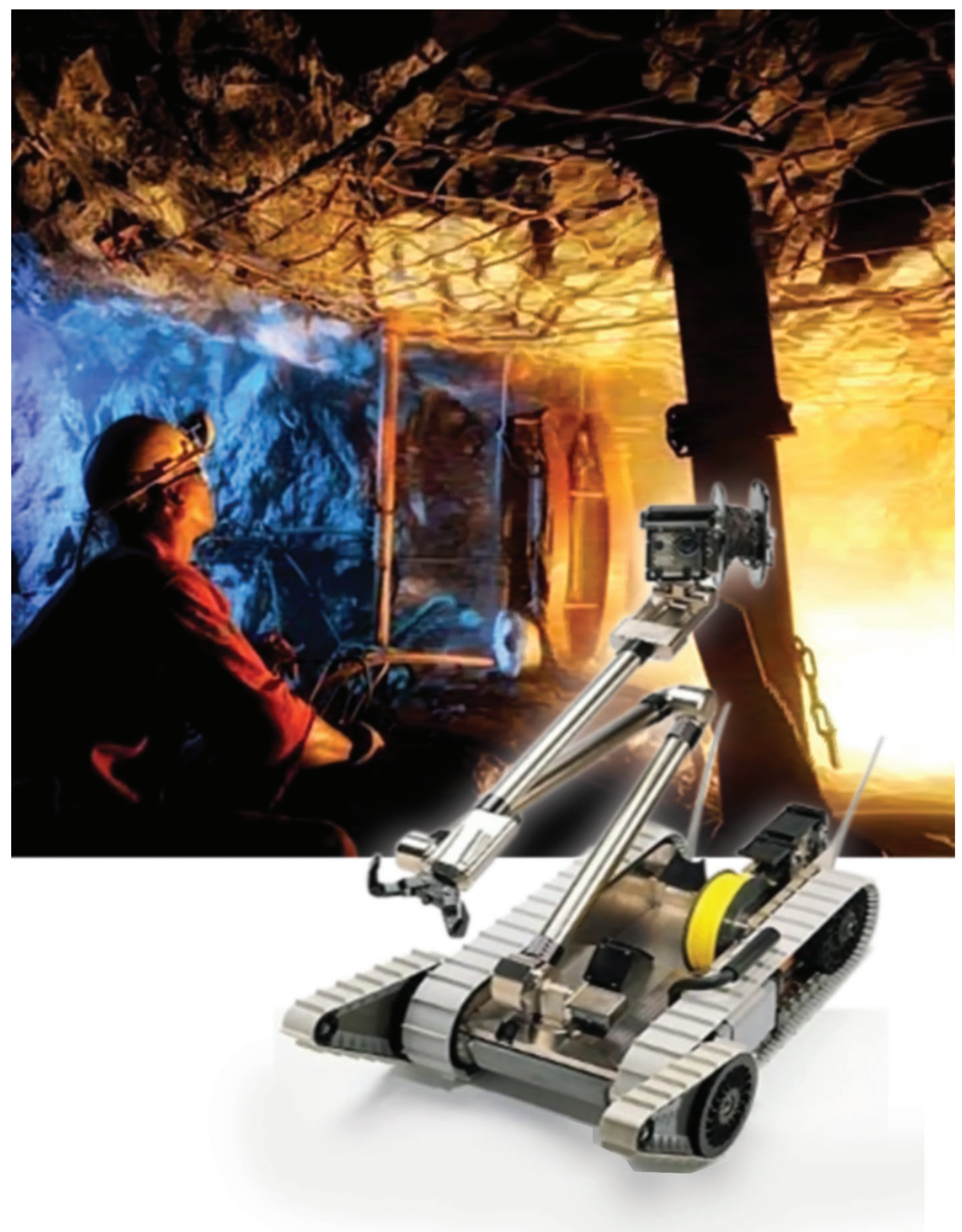


Figure 4: Limit cycling and bad localisation

IV. CONCLUSIONS

In this paper, a localisation and navigation method is developed for unmanned mobile robots in a GPS-deprived underground environment, using RFID tags. The tags are used to cluster the environment, while a value iteration method is utilised in order to plan a path and navigate from the starting point to the goal. Based on the various trial runs presented in the previous section, the clustering method is proven to be effective in localising a mobile robot. It was also observed that the quality of the clustering directly affects the accuracy of localisation and navigation. Moreover, simulation results indicate that the system is robust under noisy conditions and in some cases the presence of noise can potentially reduce the chance of a limit cycle.



Inspecting a mine after blasting is the most dangerous stage in the mining process and it is desirable to replace the human inspector with an autonomous robot.

V. FUTURE WORK

In future, a method for quantifying the confidence in different clusters can be developed in order to improve the performance of the algorithm. In addition, the clustering technique can be further improved by discarding weaker clusters and keeping the clusters with a higher confidence value.

The method presented in this paper can also be modified and improved by placing the tags in real-time using the mobile robot. Optimisation algorithms can be utilised in order to indicate the best location for new tags.

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