Scientific writing test assignment Troubleshooting indoor localization systems ~~in~~ underground mines

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Contents

1 Abstract

The object localization problem ~~in~~ underground mine is ~~very~~ complex. Hard working conditions and the complexity of indoor mine space ~~is~~ the reason of many ~~mistakes~~ in the localization system installation process. This paper provides an approach to detect the mistakes in access points installation positions. This approach ~~includes~~ 3 algorithms for different type of the installation mistakes. The localization system itself is represented by graph-based Unscented FastSLAM model. The proposed algorithms ~~showed~~ high accuracy on the ~~simulation~~ of the underground mine.

2 Introduction

Indoor localization systems are used to estimate an object position when the global location systems such as GPS are not available. An underground mine is ~~such~~ place. Rock thickness does not ~~pass~~ a satellite signal. Indoor localization systems in underground mine are based on map of the mine itself and interaction with the mine infrastructure (landmark). The tracked object estimates distance to them and sends the results to a server. The object also may be equipped with IMU modules to get more information about ~~the~~ trajectory. All ~~this~~ information is sent to server to compute the object position.

Because of hard working conditions and the complexity of ~~an~~ indoor mine space many installation mistakes are made. It is very hard to prevent all of them on the installation stage or detect manually in the working system. There is the need to develop ~~the~~ automated system that ~~will~~ detect these mistakes during an exploitation. In this paper we provide an approach to detect these mistakes. Also we developed a simulator of the underground mine localization system with the installation mistakes to test our algorithms on it.

The localization system simulator is based on the Unscented FastSLAM algorithm [1]. We use the SLAM approach because we need to update landmarks positions to detect contradictions between their estimated and theoretic (initially given) positions. The mine itself is represented by the directed weakly connected weighted graph where the edges correspond to strict areas (tunnels) in mine and the vertices corresponds to connections between them. A similar model was already used in underground mine localization

~~tasks~~ in [2]. We need to use the unscented transformation because of the distance function on this graph space. This function does not allows to compute the Jacobian in the classic FastSLAM algorithm and we avoid it with the unscented transformation.

3 Underground mine simulation

Brief description of base simulation idea.

3.1 Graph-based model

Formal mathematical definition of the model: graph description, definition of distance function, definition of the object position on the graph edge. The graph edges correspond to the strict areas of underground mine such as tunnels. The vertices correspond to the connections between these areas. The object position is represented by the point on the graph edge – each edge has a weight (tunnel length) and the shift between 0 and the edge's weight determines the position on the edge.

3.2 Unscented FastSLAM approach

This section must present the UFastSLAM approach on the graph-based space and explain the reasons of the unscented transformation usage.

The need to use the unscented transformation comes from the definition of the distance function between the points on the graph edges. The unscented transformation allows to avoid the Jacobian computation used in the classic FastSLAM approach. The derivative of the distance function ~~cannot~~ be computed analytically and this is the reason of the Jacobian computation impossibility.

3.3 Simulation tests

The detailed description of the simulation experiments with different graph. This section includes the experiments with the generated graphs and the graphs of the real underground mines. It should also show work process of the localization system with the installation mistakes (wrong initial position of the landmarks).

4 Mistakes detection

This section and its subsections contain detailed and formal definition of the different types of landmark installation mistakes.

4.1 Shifted access point

Shifted access point is an access point that was placed on the right edge but ~~with~~ wrong position on this edge.

4.2 Incorrect installation order

Installation order is incorrect when the access points placed on the wrong edges – one access point replaced by another.

4.3 Defective access point

If ab access point does not provide the signal – it's defective.

5 Experimental results

This section contains detailed description of algorithms tests on simulation. It provides an algorithm accuracy on the different types of the mistakes detection on different underground mine graphs.

6 Conclusion

The approach of installation mistakes detection in underground mine localization systems was presented and tested ~~on~~ the simulation.

The proposed graph-based underground mine model represents underground mine as a directed graph where the object position is a point on the graph edge.

The location system simulation is based on the Unscented FastSLAM algorithm that allows to estimate position of the moving object without the Jacobian computation. The simulator was successfully tested on the generated and real underground mine structures.

The mistakes detection algorithms was proposed and tested on the simulation. All of them provided high accuracy of the mistakes detection on the generated and real input data for all presented types of the installation mistakes.

References

[1] C. Kim, R. Sakthivel, and W. K. Chung. "Unscented FastSLAM: A Robust and Efficient Solution to the SLAM Problem". In: *IEEE Transactions on Robotics* 24.4 (2008), pp. 808–820. DOI: `10.1109/TRO.2008.924946`.

[2] R. Voronov, A. Moschevikin, and A. Soloviev. "Algorithm for Smoothed Tracking in Underground Local Positioning System". In: (2018), pp. 1–6. DOI: `10.1109/RUSAUTOCON.2018.8501664`.