Automation in Construction paper review

Abstract

This is a review of the paper *Localisation of a mobile robot for bridge bearing inspection* [1] which discusses the problem of using an unmanned robot to undertake bridge bearing inspection, the likes of which could not easily be done by hand and provides an elegant solution. Here, we will discuss just how essential the findings in this paper are for robotics in the construction and maintenance use cases.

1.1: Overview – localisation

Robot localisation is the process of determining where a robot is in relation to the environment around it. Typically, the map is available to the robot and the effective ways to ascertain this the subject of experimental tests in the reviewed paper[1]. The robot must also be equipped with sensors to observe this environment, these can be cameras, like in the vison based robots dogs investigated in the linked paper paper[2], but here paper it is a 2d LIDAR, as well as odometry sensors to measure its own movement. From here, the problem becomes estimating the position and orientation of the robot within the given map according to its sensors, while also being resilient to noisy observations. Therefore, the uncertainty of the estimated position must be considered when calculating the belief for a pose.

Localisation answers the question to “where am I now?”. Ones knowledge of their surroundings is absolutely critical for day-to-day tasks. Locating your friend’s house in an unknown city is impossible without first locating yourself on a map and heading in the right direction. Now imagine, instead of travelling, you must traverse across a platform barely large enough for yourself, let alone your tools in order to identify and monitor a critical point of structural integrity on a bridge. You must be willing to take a risk to investigate the problem area due to the hight of the working environment, you must be highly skilled, not only in a knowledge of the problem at hand but in order to safely traverse the environment knowing your location and location of the goal. Perilous and thusly expensive to pay brave workers, robot localisation provides an elegant, long-term solution to taking the human out of the danger entirely, while also adding a reliable maintainer no matter the conditions.

The investigation of the paper is motivated by this concept

1.2: Choice of Sensor type and Localisation

First the authors discuss and select the most suitable sensor type for the problem: 2D-LiDAR. GPS is infeasible due to the lack of signal underneath a bridge. A visual approach cannot be applicable because poor weather will cloud the robot’s perception of the environment as well require high levels of computing power that are not available on a robot of that size. Secondly, best performing localisation algorithms for the problem at hand are selected: adaptive Monte Carlo Localisation and Hector Slam; based on the fact that the two can be easily run on a primitive CPU – allowing implementation on the Raspberry PI, a small onboard computer used in the robot; cope with drifting well and that they can both make use of the LiDAR sensor effectively.

1.3: Experimental results

After theoretically reducing the methods of localisation in 1.2, the next goal was to select the most accurate localisation result by the combination of available and applicable methods of producing the map and localisation. These are AMCL combined with Hector SLAM map output (AMCL-Hector), combined with a map created from a map produced from a point cloud using the Structure from Motion method (AMCL-SfM) and finally simply the Hector SLAM algorithm’s output.

The first experiment took place on a in lab robotics with the conclusion that in all mapping techniques there was an error of 4 cm. To set a goal for experiment two in a real bridge environment, it is said that the maximum error feasible to avoid the loss of the entire system is 10cm.

The second experiment yielded the fact that AMCL-SFM and Hector SLAM both provide uncertain results, giving a spike of 10cm and 6cm error respectively relative to the ground truth. However, a solution was devised that if you average out the readings for both methods of map creation, the average error goes down to 6cm, reducing both of the respective spikes to a combined 4cm error each. The solution further includes a redundancy check. In the event that one of the mapping methods fail, the robot can continue to work safely.

The robot is then deployed as a proof on concept to carry out geometry readings of a bearing on a bridge, by capturing the 2D images of the bearing, making use of the ZED SDK camera on the robot to calculate the 3D data and thus measuring the dimensions of the bearing.

1.4: Understanding

The results provided in this paper show that a solution to robot localisation for bridge bearings inspection are possible. However, it is also critical to the field of robotics because it unequivocally shows that this localisation problem, applicable to numerous scenarios, is possible to such a large degree of precision. New crucial long-term solutions to previously dangerous or impractical construction and locating problems are motivated by these findings.

Some of these problems concerning repeatable movement without the need for human intervention could be the search of missing people trapped in building in which humans would find it impossible to effectively traverse. The robot, without any need for human manning could easily get into the location, explore the area and once something of significance has been found it can accurately give its location for an extraction team to retrieve the robot and the missing person. The robot could also simultaneously evaluate the structural integrity of the surroundings, similar to methods shown in the reviewed report.

1.5: Conclusion and Next Steps

To conclude, automation in construction provides a safe, repeatable option for the inspection of bridge bearings, while also providing motivation for numerous untested applications for robotics in the localisation field.

The current solution is viable for an error of up to 6cm, but for the future a robot for use in much more constrained environments application will certainly prove useful. To do so localisation accuracy need to become much greater. I propose, to increase the accuracy of the localisation, an approach of adding negative information and line observations into the calculation of the location; a concept explored thoroughly in the paper [2] referenced below. The results proved that localisation accuracy dramatically increased, especially after kidnapping. A robot slipping or being displaced by outside forces such as wind is a real issue to take into account when in such delicate positions, and the kidnapping enhancements would only remedy this.

A secondary investigative direction could be to incorporate reinforcement learning into solutions. This would discourage the need for any human to be present at all and fully promote the idea of autonomy. Due to an accurate, unchanging map and precise localisation results, formulating the reinforcement learning problem as a Markov Decision process would be a valid solution. A value iteration approach is one method that should be investigated to as to the suitability of discerning the route for the worker robot.

References

[1] Automation in Construction - H. Peel, S. Luo, A.G. Cohn, R. Fuentes

[2] Negative Information and Line Observations for Monte Carlo Localization - Todd Hester and Peter Stone