Sensors and Data in Mobile Robotics for Localisation

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INTRODUCTION

Robot navigation is challenging. Leonard and Durrant-Whyte (2012) define it by three questions:

- ”where am I?”,
- ”where am I going?”, and
- ”how should I get there?”

The first question is localisation: establishing the exact position and orientation of the robot within the frame of reference in its environment, and is the focus here. The robot may be navigating in static or dynamic environments, in indoor or outdoor environments and using static (pre-defined) path determination or dynamic path determination. Each of these variants requires different considerations. Gul, Rahiman, & Nazli Alhady (2019) provide a survey of the algorithms used for robot navigation. Effective navigation requires success in the four building blocks of navigation (Siegwart, Nourbakhsh, & Scaramuzza, 2011):

1. perception - the robot must be able to analyse its sensors data to extract meaningful knowledge;
2. localization - the robot must be able to calculate its position in the environment;
3. cognition - the robot must be able to determine how to navigate to its goals using the information from 1 and 2;
4. motion control - the robot must be able to modulate its movement to achieve the desired trajectory.

This survey focuses on 1 and 2 but also considers 3. It focuses on the sensor data used, how and where they are used and their respective advantages and disadvantages. The **Background** section outlines the different types of mobile robots and identifies the focus for this survey, and **Sensors for Robotics** describes robotics sensors, their use in robot navigation and where the main challenges lie for localisation, **Solutions and Recommendations** examines the literature on localisation for local and global localisation and indoor and outdoor robotics. **Future Research Directions** considers the most likely developments in localisation and the **Conclusion** provides an overview of the article.

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BACKGROUND

A key task for any autonomous system is acquiring knowledge about its environment. For mobile robot navigation, this is done by taking measurements using various sensors and then eliciting meaningful information from those measurements. Jones, Seiger, & Flynn, (1998) surveyed mobile robotics sensors. Many of these sensors are still used today (in enhanced forms) but new sensors and data have been introduced. The aim of this survey is not to merely catalogue all publications on robot localisation. Rather, it surveys a broad cross-section of contributions that provide the reader with good coverage and insight into the subject. It focuses on interesting and varied contributions from the last decade that use affordable, consumer-grade sensors which have progressed significantly.

Mobile robots can be classified into five different types according to their mode of operation: autonomous ground vehicles (AGVs), autonomous aerial vehicles (AAVs), autonomous surface vehicles, autonomous underwater vehicles, and autonomous spacecraft. This survey considers the first two types. AGVs are used in a broad range of applications for sensing, monitoring, data collection and surveillance, from agriculture to manufacturing logistics, surveillance to transportation, last-mile delivery to mining, defence to construction, environmental (ecological) monitoring to wildlife monitoring, warehouses to distribution centres, search and rescue to disaster analysis and utilities (oil, electricity and gas) and other environments (particularly in logistics, in hospitals or retail). There are also developmental robots and prototypes for domestic use. AAVs can be used in many applications due to their ease of deployment, low maintenance cost, high-mobility and ability to hover. They are used for remote sensing, real-time monitoring and management of road traffic, providing wireless coverage, heat source location, damage assessment, search and rescue operations, delivery of goods, security and surveillance, agriculture, construction and civil infrastructure inspection, environment monitoring, hazard monitoring and weather monitoring, specifically atmospheric forecast and wind.

SENSORS FOR ROBOTICS

Sensors used in robot navigation subdivide into proprioceptive and exteroceptive sensors. Proprioceptive sensors measure the robot itself using data from accelerometers, gyroscopes, magnetometers and compasses, wheel encoders and temperature sensors. Some of these are useful for robot localisation, for example pose estimations or establishing distance travelled during navigation. Exteroceptive sensors measure the external world and acquire information about the robot's environment. Localisation algorithms often need to combine measurements from proprioceptive sensors with information collected by exteroceptive sensors to obtain an overall view of the position, motion and surroundings of the robot within its environment. The various sensors have different operating characteristics and Kelly and Sukhatme (2014) investigate a framework to harmonise the measurement data generation from a cross-section of these sensors to allow a robot to generate information about its environment.

Navigation systems

A typical robot navigation system comprises the five layer architecture shown in Figure 1.

Sensor data are transmitted either as a time-series where data are produced continuously / periodically or, a sequence of readings where data is generated ad hoc, for example generated every time the robot moves. The various data analytics for robot navigation can be performed continuously, periodi-