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Mapping and tracking of moving objects in dynamic environments

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INTRODUCTION

Mobile robot applications have evolved from different environments such as indoor to outdoor, aerial and underwater. In order for mobile robots to perform their tasks effectively in dynamic environments, they must be able to build a reliable map of the environment to be used for localisation. Moving objects must not be included in maps as they may lead to localisation errors.[1-3]

Data association and filtering techniques allow for the detection and tracking of moving objects; thereby, improving map quality and enabling mobile robots to operate reliably in dynamic environments. **Figure 1** illustrates the difference in quality between maps with and without moving objects. Moving objects are mapped as spurious measurements and decrease map quality.[4]

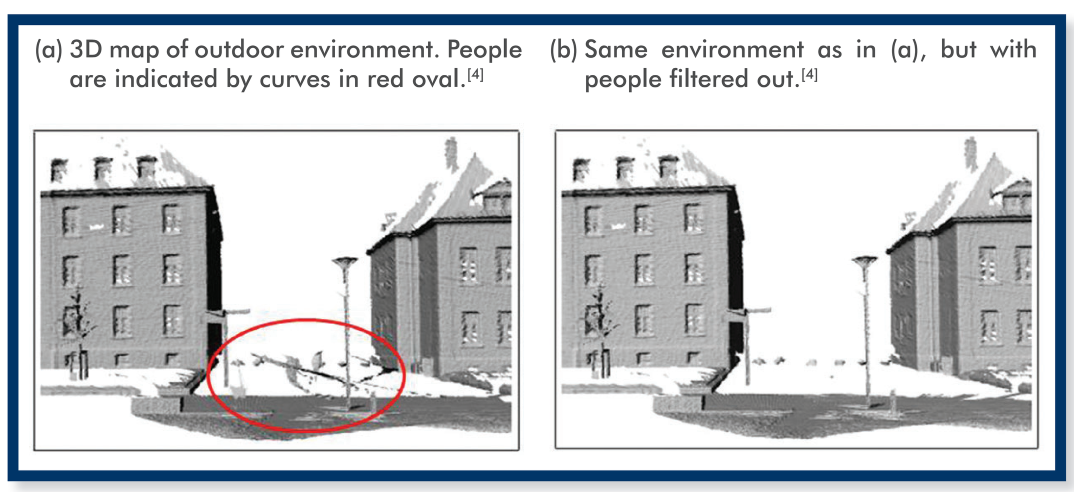

Figure 1: Difference in quality between maps with and without moving objects

MAPPING

Mapping in dynamic environments involves:

- The differentiation of static and dynamic objects, and
- The representation of static and dynamic objects.

There are three main map types: direct, feature and grid-based maps. These maps are illustrated in **Figure 2**.[5-7]

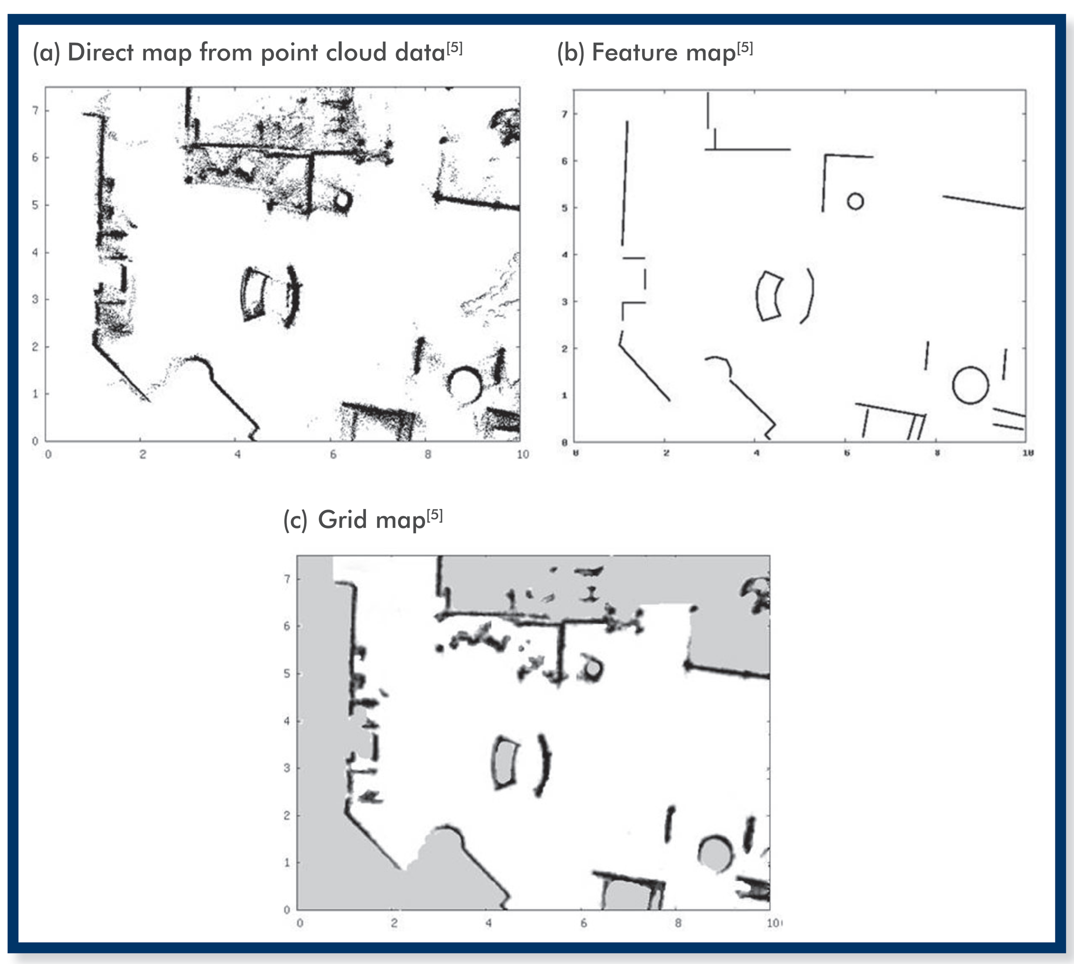

Figure 2: Different map types

Direct maps represent the environment with raw observation data. Feature maps represent the environment with geometric primitives such as points, lines, arcs, etc. Grid maps divide the environment into a grid of rectangular cells. The occupancy of each cell is represented by a binary variable which indicates whether the cell is occupied by an object or is free. Direct and grid maps are suited to any type of environment, whereas feature maps are restricted to indoor environments.[5, 6, 8]

DATA ASSOCIATION AND TRACKING

The tracking of multiple moving objects in dynamic environments involves filtering and data association. Filtering is concerned with tracking one particular object and processing the data over time to compute a state estimate for the single object. Data association deals with tracking multiple objects and determines which data belong to which object. Filtering methods then compute object state estimates with the respective data.[5, 9]

Data association

Common data association techniques are Greedy Nearest Neighbour (GNN) combined with filtering; Joint Probabilistic Data Association (JPDA) and Multiple Hypothesis Tracking (MHT).

GNN is simple to use, has low computational complexity and offers high speed. It is, however, unable to correct false associations. MHT processes multiple scans to produce multiple hypotheses and chooses the hypothesis with the maximum posterior. MHT in its pure form suffers from high computational complexity as the number of hypotheses expands exponentially over time. JPDA demonstrates better efficiency than GNN in cluttered environments. JPDA is susceptible to incorrect associations, as only a single scan is taken into account and associations are irreversible. JPDA requires a specified number of tracked objects, whereas MHT requires an unspecified number of tracked objects.[5-7, 10]

Tracking

Tracking techniques frequently used include the Particle Filter (PF) and Extended Kalman Filter (EKF). PFs have fewer losses and can include several data associations. EKFs offer simplicity and have lower computational complexity. Motion models may be defined using Interacting Multiple Models (IMM).

Tracking can be achieved through either model free or model-based approaches. Model free approaches have the ability to detect any type of dynamic object with no prior knowledge about the object.

Model-based approaches aim to eliminate the disadvantages of object segmentation when using laser scanners for tracking. Models are used to detect and classify dynamic objects. According to Vu[5] this results in more accurate tracking (Refer to **Figure 3**). A model-based approach, however, is limited to the set of predefined models, and cannot identify objects that are not included in the model set.[5, 11]

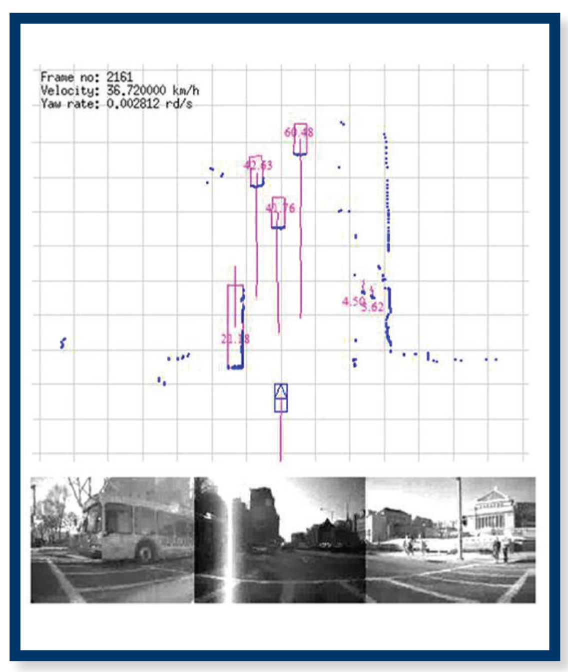

Figure 3: Vu[5] demonstrated that different objects may be tracked by using object models. People are modelled by points, and cars and buses by boxes[5]

THE MICROSOFT KINECT

The Microsoft Kinect sensor was designed by PrimeSense to serve as a controllerless user interface for the Microsoft Xbox 360 (Refer to **Figure 4**).

It comprises:

- A 640x480 RGB CMOS image sensor
- A 320x240 monochrome CMOS image sensor, and
- A class 1 infrared laser projector.[12]

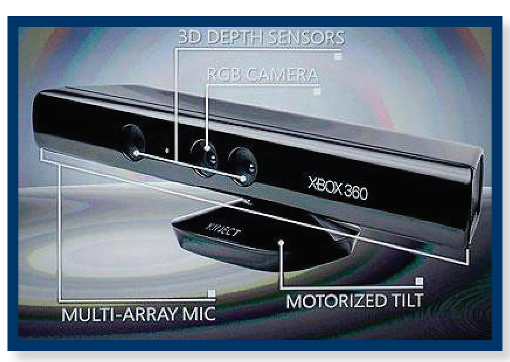

Figure 4: The Microsoft Kinect sensor with its RGB camera and 3D depth sensors[14]

The Kinect transmits an infrared structured light pattern and performs stereo triangulation to produce depth images. Kinect data will be used to differentiate between moving and stationary objects, and to construct a map of the environment.[12, 13]

CONCLUSION

In order for mobile robots to perform their tasks reliably in dynamic environments, moving and stationary objects need to be clearly differentiated in maps. By detecting and tracking moving objects, their future positions can be estimated and maps of a higher quality can be produced. Tests will be conducted on a mobile robot operating in a dynamic indoor environment to determine system performance.

In order for mobile robots to operate in dynamic or real world environments they must be able to localise themselves while building a map of the environment, and detect and track moving objects. This work involves the research and implementation of mapping and tracking techniques that enable mobile robot task completion in dynamic environments.

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