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Pattern Identification of Robotic Environments using Machine Learning Techniques

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Abstract

Analysis of time series data collected from mobile robots is getting more attention in many application areas. When multiple robots move through an environment to perform certain actions, an understanding of the environment viewed by each robot is essential. This paper presents analysis of robotic data using machine learning techniques when the data consist of multiple views of the environment. Robotic environments have been classified using the data captured by onboard sensors of mobile robots using a set of machine learning algorithms and their performances have been compared The machine learning model is validated using a test environment where some of the objects are displaced or removed from their designated position.

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Keywords: Machine Learning; Time series data; Feature selection; Classification; Object displacement; feature reduction;

1. Introduction

The process of determining useful patterns and associations from a vast volume of data is termed as data-mining. Data mining is widely used in various domains such as insurance, banking, retail, research, astronomy, medicine, and government security. Mining the information from the time series data collected by robot is termed as robotic data

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mining. The focus of this work is to extract the knowledge (information) from robotic data using Machine Learning (ML) techniques to classify similar robotic environments.

Mobile robots are used in many commercial and industrial settings. For example, mobile robots are used in hospitals for movement of materials, in warehouses for efficient movement of materials from stocking shelves to order fulfillment, in service to assist humans for performing repeated jobs including household chores. The robot in these areas has to identify the environment and memorize it for performing the tasks. Once the environment is learned, the robot can perform the desired task. In many application areas where robots are used, the differentiating factor is the complex data processing requirements caused by partially unknown environment. For example, when multiple robots are collecting data from an environment, the environment viewed by each robot become relevant to avoid redundant data processing through collaboration of information. By sharing information between the robots, the performance of individuals in the group can be significantly improved, allowing for cooperatively performing complicated tasks in different domains including surveillance, search and rescue, and object manipulation.

There are significant challenges in a multi-robot environment when compared to a single robot environment. This paper addresses the identification of the environment seen by each robot even when there are minor changes in the environment. Robots are often equipped with multiple sensors to collect information about environments. The sensor data could include measurements that provide insights into objects present in these environments. The resulting data collected from simulated robotics environments could be used for the analysis of these environments. The data captured by the onboard sensors of a mobile robot is time series data captured at uniform time intervals. In data mining there are different sets of algorithms, each addressing a different task to uncover a unique face of the data. This paper investigates classification i.e. the process of grouping similar environments into predefined classes.

The main focus of the paper is to explore methods for i). Classifying the environment even when it is viewed from multiple directions using actual dataset and reduced data set after feature selection. ii). Identification of scenarios even when there are minor changes in the environment.

Remaining sections of this paper are organized as follows. Section 2 discusses some of the earlier work related to data collection from robotic environments and its use in identification and clustering of the environment. Section 3 discusses the approach followed in the design of experimental setup and the methods used for data collection. This section also discusses the pre-processing done and the data mining algorithms used for classification of environments. The characteristics of the data collected from the experimental setup are described in Section 4. Section 5 and 6 provides the results of classification and analysis of results. Conclusions from the results and possible future experiments are described in section 7.

2. Related Work

Data mining on time series data extracted from mobile robots would contribute significantly to the broad arena of Robotic research. Tim Oates et al. [1] have presented a clustering method for learning multivariate time series data. The work has utilized dynamic time warping (DTW) distance which gives the similarity measure of time series data. They have reported clustering accuracies in the range of 82 to 100%. An extension of this idea [2] utilizes the data captured from pioneer 1 mobile robot and sourced from the machine learning repository of University of California, Irvine. Complete linkage clustering algorithm has been applied in that work and the results obtained through this method fall in the range of 88 to 97%. A related work [3] uses experimental setup with a robot equipped with 4 sensors that follows a straight line path to collect information about the environment. Data thus collected have been clustered using agglomerative clustering techniques after applying DTW for measuring similarity. The accuracy obtained falls in the range of 73 to 98%. Artificial neural networks have been experimented widely for solving data analysis tasks. Multi-layer perceptron's (MLP) and time delay neural network (TDNN) using standard back propagation algorithm have been proved capable of classifying temporal patterns [4]. An experiment conducted on the time series data recorded from sonar sensors using back propagation neural network (BPNN) has claimed to achieve appreciable results for classification of robotic environments [5]. The work being confined to single direction they could achieve 100% accuracy. A technique to cluster image sequence data using k-medoid algorithm segments the images into 16 tiles and mean feature is extracted for each RGB channel of each tile of an image [6]. An accuracy of 87% is achieved by using mean color values alone. All these experiments have used simple simulated robotic environments. None of these experimental setups considers data collected from multiple time series sources. Shivendra Mishra et al. [7] present a