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Classification of vessel motion pattern in inland waterways based on Automatic Identification System

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ABSTRACT

With the development of terrestrial networks and satellite constellations, vessel movement information can be effectively collected based on Automatic Identification System (AIS) receivers. Vessel motion pattern classification using AIS plays an important role in maritime monitoring and management. However, classifying vast amounts of vessel motion information is prohibitive workload. The aim of this study is to develop effective methods that can aid in automatic vessel motion pattern classification in inland waterways. First, the Least-squares Cubic Spline Curves Approximation (LCSCA) technique is used to represent the vessel motion trajectory. Then, a traditional classification model based on Lp-norm ($0 < p < 1$) sparse representation is improved to classify vessel motion patterns. And a Matching Pursuit - Fletcher Reeves (MPFR) method is developed to find the sparse solutions of the proposed model. To validate the performance of the proposed model, two AIS datasets from the Yangtze River are collected and applied in our experiment. According to the results, we can know that the proposed model can effectively classify vessel motion pattern in inland waterways. And the effectiveness of the proposed model is superior to those of other representative classification methods.

1. Introduction

The Automatic Identification System (AIS) data can be divided into three different types (International Maritime Organization, 2003): static data, dynamic data and voyage-related data. Vessel information such as vessel name, type, speed, position and heading can be obtained from AIS. In recent years, advancement in electronic tracking techniques, remote sensing techniques and communication techniques has enabled the development and application AIS. In addition, legislations are now mandatory to have AIS equipment on board of international voyaging ships with 300 or more gross tonnage and cargo ships of 500 gross tons for the Safety of Life at Sea (SOLAS). In China, inland waterways ships are required to install AIS by the Maritime Safety Administration (MSA). Therefore, due to these legislations and the development of sensor technology, AIS has been widely applied in the maritime monitoring and management.

Classifying vessel motion patterns is one of the most important aspects of analyzing the AIS data, and it is useful for enhancing maritime monitoring, ship safety, and management technology. For instance, ship accidents may be avoided if the maritime authority can understand and warn against making dangerous ship movements, according to historical movements of vessels that had the same class of motion pattern. Therefore, many researchers are increasingly starting to pay attention to analyzing AIS data.

As mentioned above, AIS can provide many kinds of vessel information. In addition, more and more vessels are applied in inland waterways in China due to low price and good policy. Thus, vast amounts of AIS dataset are collected. However, the manual analysis of such large volumes of data involves a prohibitively large workload. According to the needs of many practical applications, extensive scholars focus on the classification model to identify object (e.g. vehicle) moving patterns. However, few studies pay attention to classify vessel motion patterns. Therefore, it is imperative to develop an effective method that can aid in the automatic classification of vessel motion patterns using AIS data for improving maritime management techniques and safety awareness. In China, although inland waterways transportation is fast developing, the transportation management develops slowly. In order to improve vessel monitoring and management in inland waterways, we only focus on inland waterways in this study.

An object motion characterization can be described using motion

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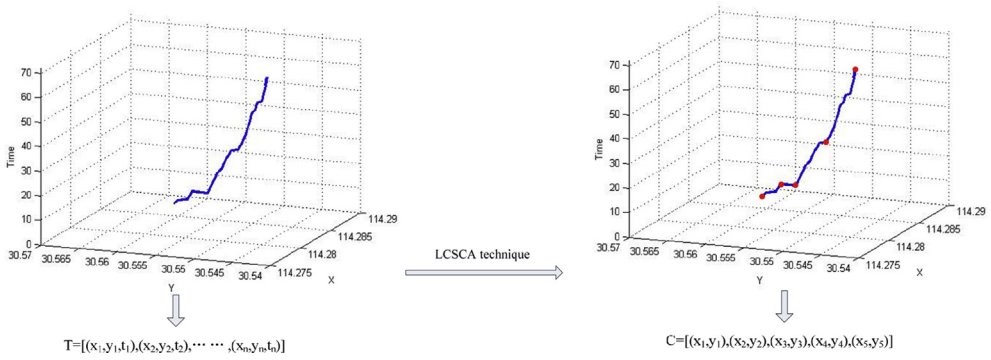

Fig. 1. Example of vessel trajectory representation with LCSCA (control points = 5).

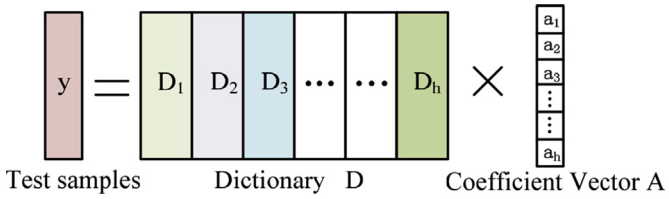

Fig. 2. Example of the data sample represented by a dictionary based on sparse representation.

trajectory that contain a sequence of position points. The motion trajectory has been widely employed to identify object motion patterns, action recognition, and so on (Bennewitz, 2005; Calinon et al., 2007; Moldenhauer et al., 2006; Psarrou et al., 2002; Yang et al., 2002; Hu et al., 2013). Thus, motion trajectories play an important role in the classification of moving patterns. For example, Schuldt et al. (Calinon et al., 2007) use motion trajectories to represent human action such as walking, jogging, and hand clapping. And a radial basis support vector machine (SVM) is employed to classify human actions (Yang et al., 2002).

A motion trajectory is used to describe the gesture motion, and gesture motion pattern can be classified using SVM model (Yu and Barner, 2008). Based on motion trajectory, Liao et al. (2007) propose a classification model using hierarchically structured conditional random fields to identify human motion patterns. Sun et al. (2015) propose a classification model to identify human motion patterns using beta process hidden Markov models (BP-HMM) based on human motion trajectories. Shao and Li (Cheng et al., 2016) propose two representation methods that are fingerlets for static gesture representations and strokelets for trajectory gesture representations. Based on two representation methods, Image-to-Class Dynamic Time Warping (I2C-DTW) method is proposed to classify hand gestures. Based on motion trajectory, a Dynamic Bayesian Network (DBN) model is used by Santos et al. (2015) to classify human action. In order to improve the performance and effectiveness of the model, a sliding window approach is applied. Fielda et al. (Field et al., 2015) use motion trajectory to describe human motions. Then an unsupervised classification method is developed based on a dynamic time alignment of Gaussian mixture model clusters. Using human motion trajectories, Chen et al. (2011) propose cluster method to classify human motion patterns. In this method, the long-term future motion can be also predicted.

Although the object motion patterns can be classified based on motion trajectory and learning methods, a large number of training trajectory is needed to training the model. For AIS dataset, labeling vessel motion patterns is a large workload by manually. In addition, the AIS dataset is often missing or incomplete. Thus, it is difficult to obtain sufficient training samples from AIS dataset. These learning methods introduced above may not achieve satisfactory performance.

The sparse representation classification (SRC) method is a novel idea in the field of classification. A good performance using SRC can

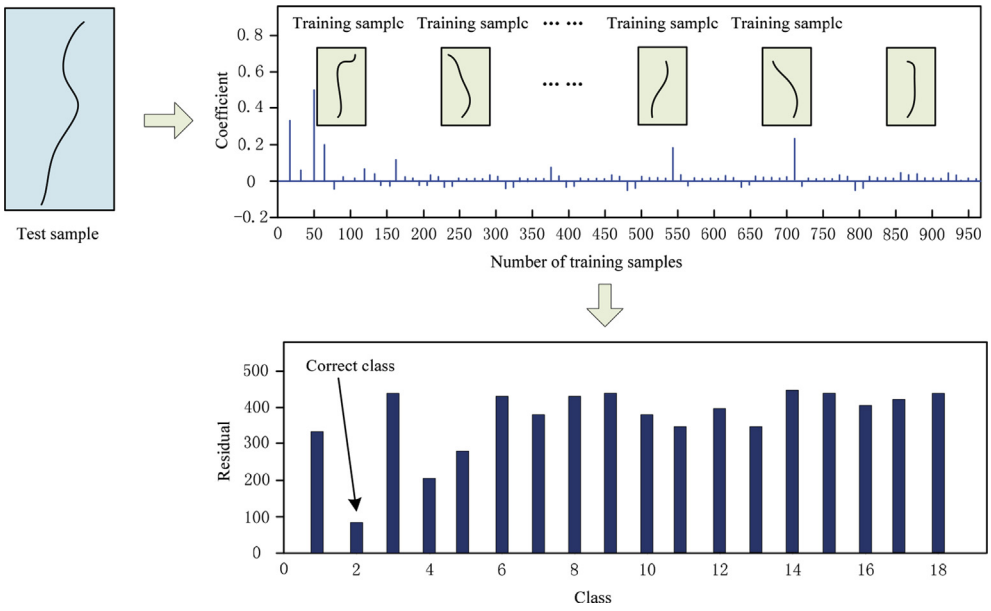

Fig. 3. An example illustration of vessel trajectory classification using SRC.