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A Novel Research in Low Altitude Acoustic Target Recognition Based on HMM

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ABSTRACT

This paper introduces an improved HMM (hidden Markov model) for low altitude acoustic target recognition. To overcome the limitation of the classical CDHMM (continuous density hidden Markov model) training algorithm and the generalization ability deficiency of existing discriminative learning methods, a new discriminative training method for estimating the CDHMM in acoustic target recognition is proposed based on the principle of maximizing the minimum relative separation margin. According to the definition of the relative margin, the new training criterion can be equation as a standard constrained minimax optimization problem. Then, the optimization problem can be solved by a GPD (generalized probabilistic descent) algorithm. The experimental results show that the performance of the algorithm is significantly improved compared with the former training method, which can effectively improve the recognition ability of the acoustic target recognition system.

KEYWORDS

Acoustic Targets Recognition, Hidden Markov Model (HMM), Margin

1. INTRODUCTION

Compared with the active sensors, such as radar and photoelectricity equipment, the acoustic target recognition has advantages in target detecting and tracing, such as anti-interference, costless, undetectable. It has been widely used in military and civilian applications (Djurek, Petosic, Grubesa, & Suhanek, 2020; Hui, Yang, & Yi, 2011; Liu, Yang, & Xue-Zhong, 2007; Wang Yi 2012; Zhu & Liu, 2018). There are similarities between acoustic target signals and speech signals, and the hidden Markov model (HMM) is the most successful speech recognition method(Abdulla, 2002; Huang & Jack, 1989; Jo, Kim, Park, Jung, & Yoo, 2019; Telmem & Ghanou, 2018). Therefore, the HMM has been applied to low altitude acoustic target recognition in our former wor(Hui et al., 2011; Liu, Yang, & Xue-Zhong, 2008; Wang Yi 2012; Yi, Yang, & Liu, 2010). The HMM is a statistical model with the ability to learn statistical properties of signals(Grewal, Krzywinski, & Altman, 2019; Wang & Fan, 2019). All the model parameters are obtained from a large amount of training data through specific rule training(Wang & Fan, 2019). The traditional Baum-Welch algorithm is a training algorithm based on the maximum likelihood criterion function(Huang & Jack, 1989; Mohamed, Satori, Zealouk, Satori, & Laaidi, 2019; Varga & Moore, 2002). A large number of samples are needed to ensure the accuracy of the HMM training. However, it is difficult to obtain the acoustic target signal in the battlefield. In addition, the estimation of Baum-Welch is not unique. The ability of the HMM training

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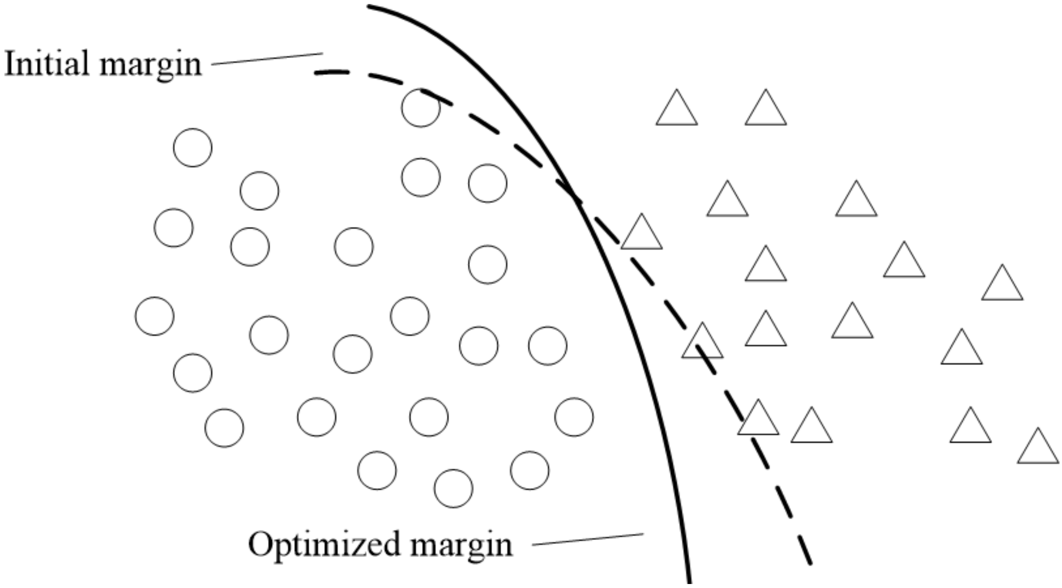
Figure 1. The principle of the relative margin HMM



based on this criterion is limited. In view of the shortcomings of the HMM, many scholars have put forward a series of ideas using discriminative training to minimize or reduce the classification errors in training. The most famous algorithms are the maximum mutual information (MMI)(Benyishai & Burshtein, 2004; Dua, Aggarwal, & Biswas, 2018) and the minimum classification error (MCE)(Jiang, Siohan, Soong, & Lee, 2002; Meng, 2017), which greatly improve the recognition and classification ability of the HMM, but there are still many problems to solve. The biggest disadvantage is the poor generalization ability whereby the model has a good recognition effect on training data while the recognition effect is not good for testing data.

The theory of machine learning states that a classifier with a larger classification margin has a better generalization ability. In this paper, a new HMM discrimination training and estimation method based on the relative margin is proposed. The HMM model that has been estimated by Baum-Welch is taken as the initial model. The classification difference between each category is taken as the initial margin. The relative margin is defined and optimized to make it larger to update the HMM parameters to overcome the problem of an insufficient generalization ability of the discrimination training algorithm. As shown in the Figure 1, for two-category Classification, the dotted line is the initial margin while the solid line is the optimized margin. The new HMM is obtained by making the distance between the interface and all the training samples as large as possible. The classification and generalization ability of the new HMM will be obviously improved.

The remainder of this paper as follows. In Section 2, the basic principle of the relative margin HMM(RM-HMM) and the problems that should be solved are presented. Section 3 deduces the solution of the optimization and Section 4 gives the training algorithm. The experiments and results are detailed in Section 5. Finally, in Section 6, the conclusions are presented.

2. PROBLEM FORMULATION

Given the acoustic signal sequence $\boldsymbol{O}$, a classifier based on maximum a posteriori(MAP)criterion will determine a category $\boldsymbol{A}_i$ as the category of sequence $\boldsymbol{O}$ as follows: