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Multi-function radar emitter identification based on stochastic syntax-directed translation schema

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Abstract To cope with the problem of emitter identification caused by the radar words' uncertainty of measured multi-function radar emitters, this paper proposes a new identification method based on stochastic syntax-directed translation schema (SSDTS). This method, which is deduced from the syntactic modeling of multi-function radars, considers the probabilities of radar phrases appearance in different radar modes as well as the probabilities of radar word errors occurrence in different radar phrases. It concludes that the proposed method can not only correct the defective radar words by using the stochastic translation schema, but also identify the real radar phrases and working modes of measured emitters concurrently. Furthermore, a number of simulations are presented to demonstrate the identification capability and adaptability of the SSDTS algorithm. The results show that even under the condition of the defective radar words distorted by noise, the proposed algorithm can infer the phrases, work modes and types of measured emitters correctly.

1. Introduction

Multi-function radar (MFR)[1,2] emitter identification (EID) module emerges as a critical function unit in an electronic support measure (ESM) system.[3,4] Because of various interferences in the complex electromagnetic environment,[5] the radar words,[6] picked up from received emitter pulses by the receiver equipments, always have warps compared with their true values. Therefore, it is of great importance to identify the measured MFR emitters correctly.[7,8]

At present, there are only a few public studies about MFR EID owing to the agility characteristics of MFR parameters.[9,10] In the aspect of MFR modeling, Visnevski[6] considered multi-function radars (MFRs) as stochastic discrete event systems and put forward a novel model-centric approach for MFR modeling, by utilizing the theory of formal language and syntactic pattern recognition. These models, which model MFR as three levels: the pulse-level, the word-level and the phrase-level, are compact formal representations that can form a homogeneous basis for modeling complex radar dynamics. Dilkes and Visnevski[11] described the behavior of many MFR systems in terms of context-free grammars (CFGs), which represent all possible combination of sequences that radar could ever execute from power-up to shutdown. They

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supposed that most CFGs used to describe radar models are non-self-embedding (NSE). Visnevski et al.[12] considered the signals from an MFR to be strings from some formal languages that can be modeled by a compact syntactic representation, which is called the NSE CFG, and made use of the theory of finite-state automata (FSA) to the electronic warfare (EW) signal processing of MFRs. Considering the aspect of radar words extracting, in Refs.[6,13], a hidden Markov model (HMM) is derived for constructing radar words templates and a modified version of the Viterbi algorithm is developed to extract radar words from noisy and corrupted pulse sequences. This model shows better performance compared with the standard time of arrival (TOA) histogram technique. In the aspect of application of MFR modeling, it is shown in Refs.[14,15] that the stochastic context free grammar (SCFG) is an adequate model for capturing the essential features of the MFR dynamics, where a maximum likelihood estimator is derived to estimate the threat of the MFR and a Bayesian estimator is given to deduce the system parameter values. Furthermore, it is demonstrated in Refs.[16,17] that SCFG, modulated by a Markov chain, can adequately represent MFRs' dynamics. They also derived a maximum likelihood sequence estimator to estimate the system state, and a maximum likelihood parameter estimator to infer the system parameter values. Cote[18] discussed the principal features of typical architecture for modern naval multi-function radars and analyzed the impact of the required missions on the system design. Besides, Charlish et al.[19] proposed a novel approach based on information theory to improve the quality of the allocation of MFR resources. All such achievements mentioned above provided important supports and improvements for MFR EID, but when the radar words picked up by receiver equipments are uncertainty, those methods are helpless.

To solve the problem of EID caused by the radar words' uncertainty of measured MFR emitters, this paper proposes a new identification method based on stochastic syntax-directed translation schema (SSDTS). This method, which is deduced from the syntactic modeling of MFR, can not only correct the defective radar words by using the stochastic translation schema, but also identify the real radar phrases and working modes of measured emitters at the same time.

2. Syntactic modeling of multi-function radars and problem formulation

2.1. Syntactic modeling of multi-function radars

Syntactic modeling, which can be viewed as a form of data compression that can reduce the demand for data storage, can describe MFR more compactly and accurately. With clear insight into the physical principles of the system and the environment, this model is competent to represent MFR functionality more correctly compared with traditional methods. In this paper, we construct the identification frame based on MFR syntactic modeling, as shown in Fig. 1.

From Fig. 1 it can be seen that an MFR can be modeled with three levels: the pulse-level, the word-level and the phrase-level.[6] Notice that a radar word represents a specific pattern of a group of pulses that occur over a short period of time. Fig. 1(a) illustrates two words marked with symbols "a" and "b" on behalf of fixed sequences of pulses with their own characteristic set of pulse-to-pulse intervals (PPI). The radar phrase is a sequence of some consecutive radar words. Each phrase mapped into different modes is allocated to one task, and these tasks are independent from each other. Fig. 1(b) shows a phrase made up of the group of radar words "$abbaa$". The radar clause is a sequence of some consecutive radar phrases. For example, the radar clause C_1 in Fig. 1(b) is composed of four consecutive radar phrases $P_i (i = 1,2,3,4)$, which correspond to different radar tasks.

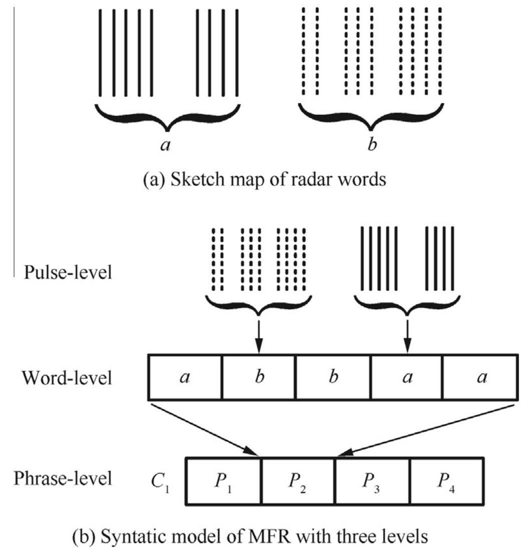

Fig. 1 Sketch map of syntactic modeling of MFR.

2.2. Problem formulation

In this paper, the objective of EID is to infer the MFR emitters' phrases, modes and types through matching measured MFR emitters with the known MFRs in emitter database, which stores the parameters information of MFRs and can be used as emitter templates in identification processing. As mentioned above, a phrase, which can be mapped into different modes, is a sequence of some consecutive radar words. The sketch map of a radar phrase $w_2w_4w_5w_1$ of one MFR in search mode is shown in Fig. 2(a). Based on the syntactic model, it is very useful to take advantage of SCFG to construct a stochastic push-down automaton (PDA)[20] or FSA[21] to identify the emitter clauses. Those methods achieve good performance in MFR emitter identification. But if the received emitter words are uncertain, such methods are powerless. Because of various interferences in the complex electromagnetic environment, the receiver equipments always pick up noisy, incomplete or pathological radar words compared with their true values,[6] which may form three kinds of radar word errors as shown in Fig. 2. It is noticed that in Fig. 2, the vertical axis, which denotes the normalized amplitude of the received pulses.

(1) CH error. Due to the effects of interference or noise, a radar word in one radar phrase may be changed into another radar word. The sketch map of this kind of radar word error is shown in Fig. 2(b), in which the real radar word w_1 is converted into an error radar word w_3.