Hybrid Radar Emitter Recognition Based on Rough k-Means Classifier and Relevance Vector Machine

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A Presentation by Robert Newport

Purpose

Critical role of emitter recognition

Why recognize emitters?

Emitters are recognized to identify and assess hostile forces. Jamming and electronic offensive measures require recognition of emitter signals.

For example, a fixed field radar turning into an iSAR radar may indicate a threat escalation where counter-measures are critical.

Radar emitter

Electromagnetic wave introduction

Physical description

"electromagnetic waves … are synchronized oscillations of electric and magnetic fields that propagate at the speed of light …The electromagnetic spectrum includes, in order of increasing frequency and decreasing wavelength: radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays and gamma rays."

Maxwell, J. Clerk (1 January 1865). *"A Dynamical Theory of the Electromagnetic Field"*. Philosophical Transactions of the Royal Society of London.

Radar data

Pulse Descriptor Words

Data format and type

"The pulse describing words of the radar emitter signal include a radio frequency (RF), a pulse repetition frequency (PRF), antenna rotation rate (ARR) and a pulse width (PW). The type of radar emitter is the recognition result. Two hundred and seventy groups of data are generated on above original radar information for training. And the recognition accurate is calculated averaged over 200 random generations of the data set."

Table 1. Information of known radar emitter signals.

| No.	RF (MHz)	PRF (Hz)	PW (us)	Type
1	8,799	1,500	0.1	1
2	8,847	750	0.5	1
3	8,755	620	0.5	2
4	8,890	580	0.5	2
5	8,875	585	0.5	2
6	8,804	750	0.1	1
7	8,850	1,500	0.5	1
8	9,460	1,300	0.25	3
9	9,436	1,600	0.15	3

Overview

Ever increasing complexity of electromagnetic signals

Rough k-means classifier clustering areas
- certain area
- rough area
- uncertain area

Relevance Vector Machine
- Training inside rough boundary
- Recognize samples in uncertain area
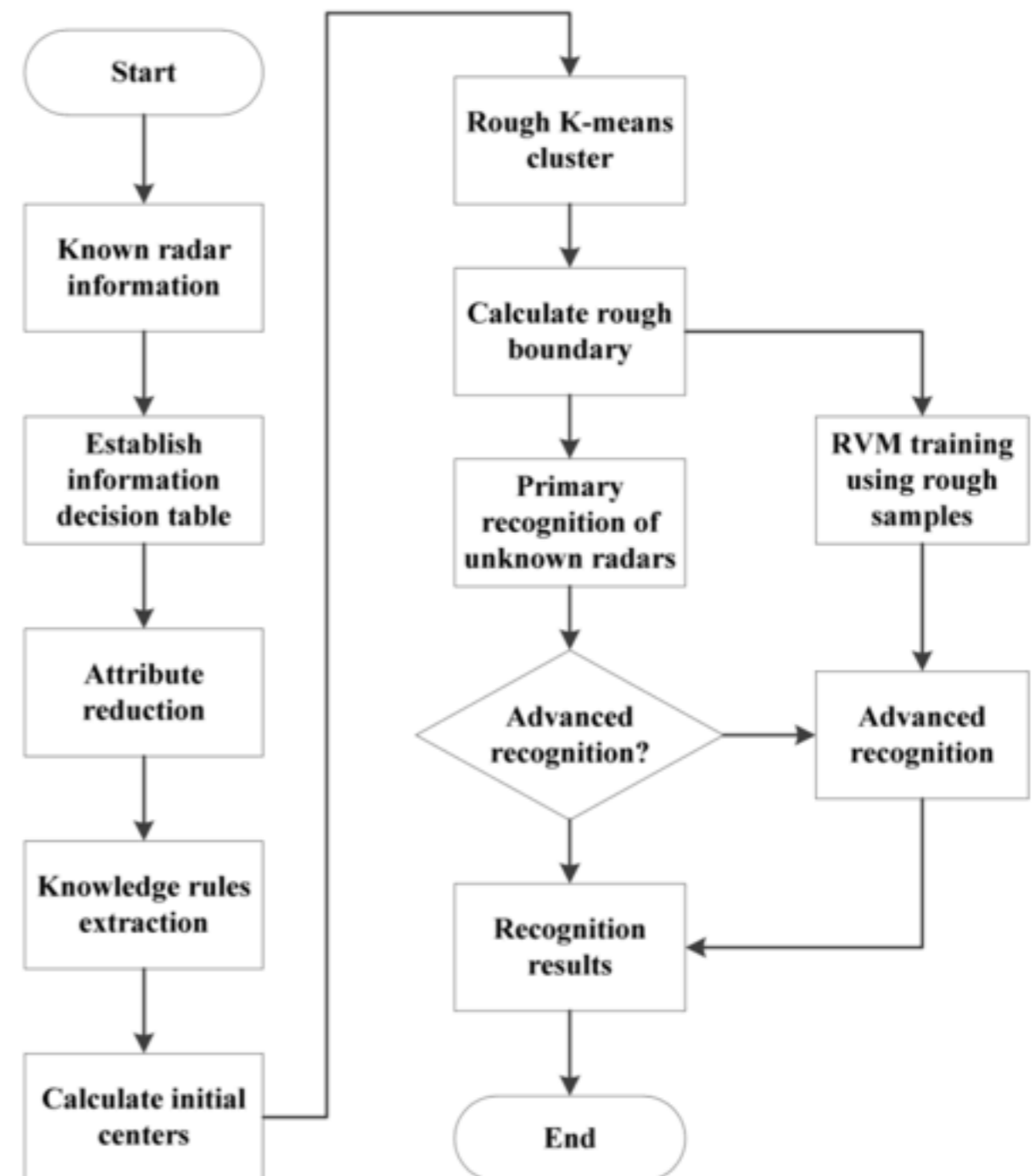
Methods

A comparative analysis

Neural Networks

"...the prediction accuracy of the neural network approaches is not high and the application of neural networks requires large training sets, which may be infeasible in practice."

SVM

"Compared to the neural network, the SVM yields higher prediction accuracy while requiring less training samples.

...the computational complexity of SVM increases rapidly with the increasing number of training samples, so the development of classification methods with high accuracy and low computational complexity is becoming a focus of research."

RVM

"Recently, a general Bayesian framework for obtaining sparse solutions to regression and classification tasks named relevance vector machine (RVM) was proposed."

Challenges

Method aims and goals

High level overview of the approach

"...the radar emitter signals consist of **both linearly separable samples and linearly inseparable samples**, which makes classification challenging, so in an ideal case, linearly separable samples are classified by linear classifiers, while only these linearly inseparable samples are classified by the nonlinear classifier."

"To deal with the drawback of the traditional recognition approaches, we apply two classifiers to recognize linearly separable samples and linearly inseparable samples, respectively. Samples are firstly recognized by the **rough k-means classifier**, while linearly inseparable samples are picked up and further recognized by using **RVM** in the advanced recognition."

k-means clustering

Problem solving

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k-means clustering

"the linearly inseparable samples are mostly at the margins of clusters, which makes it difficult to determine which cluster they belong to."

To solve this problem: "the rough k-means classifier, which is linear, is applied as the primary recognition. It can classify linearly separable samples and pick up those linearly inseparable samples to be classified in the advanced recognition."

Recognition

Primary recognition outputs

k-means clustering

"For those unknown samples in the certain area and rough area, the primary recognition outputs final results. Samples in the rough area train the RVM to recognize samples in the under certain area. "
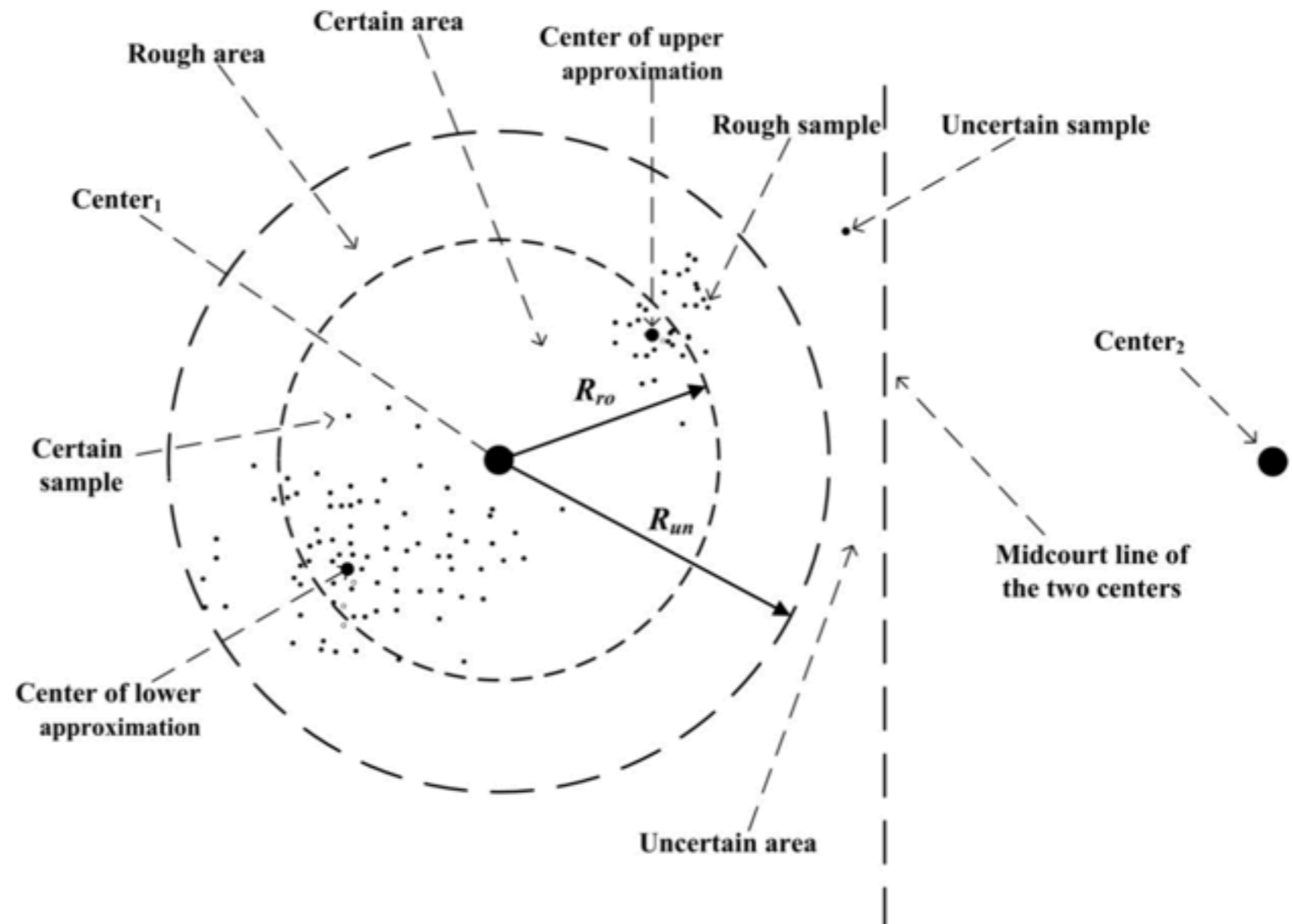
Problems

Algorithm issues

k-means clustering

"The number of clusters in the algorithm must be given before clustering.

The k-means algorithm is very sensitive to the initial center selection and can easily end up with a local minimum solution.

The k -means algorithm is also sensitive to isolated points."

Clustering

Uncertain boundary

k-means clustering

"In a cluster, the area beyond uncertain boundary (dx > Run) is the uncertain area. When unknown samples are recognized, they will be distributed into the nearest cluster. If dx > Run, these samples will be further recognized by the advanced recognition. For other unknown samples, the result of the primary recognition will be final."

Origins

Relevance Vector Machine

Automatic Relevance Determination

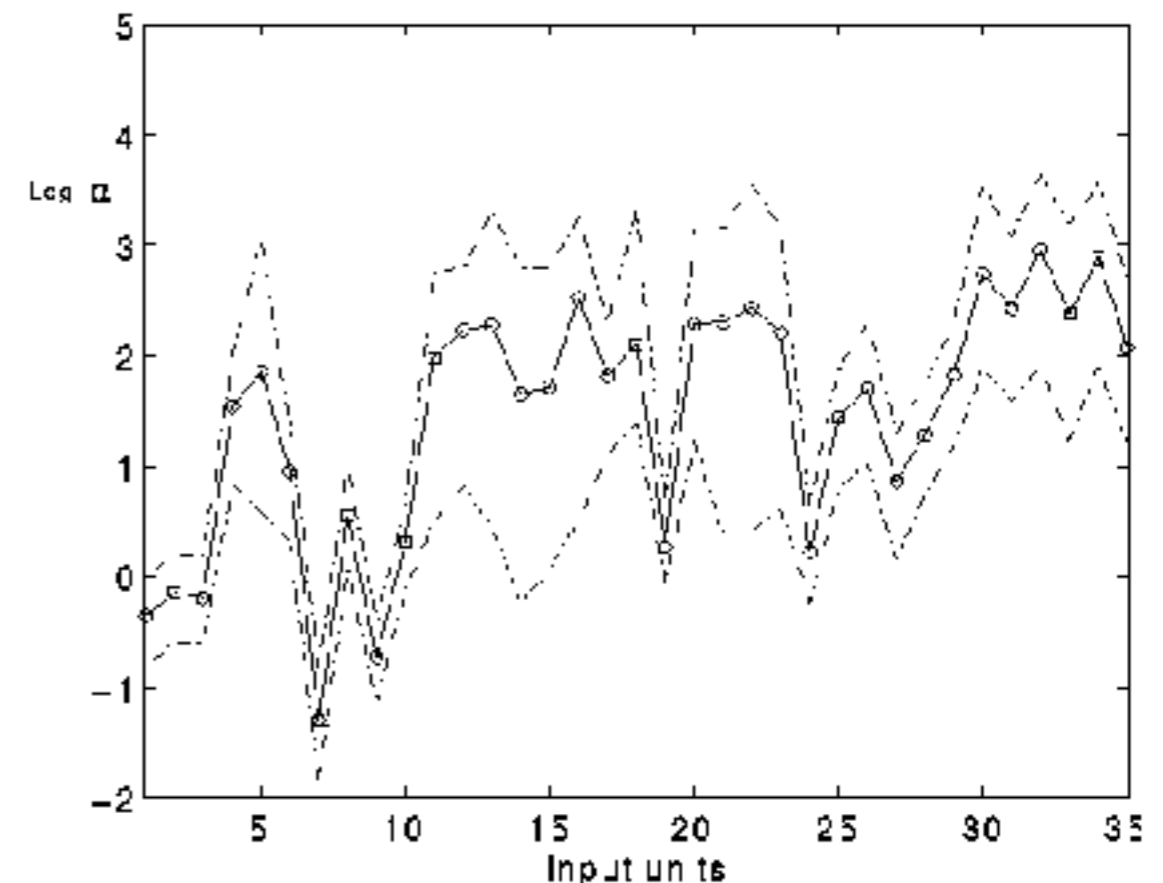Relevance Vectors comes from "Automatic Relevance Determination" (R. Neal and D. MacKay)

"Detect the relevant components of the input vector: this can be achieved by looking at the distribution of the synaptic weights which connect one input unit to all of the units in the next layer.

The variance of this distribution can give an idea about size of the weights controlled by each one of the input units.

A small variance suggests that the weights are quite close to 0: thus the input controlling those weights is not very relevant.

Conversely a large variance is typical of distribution of weights which are connected to a relevant input."

http://homepages.inf.ed.ac.uk/ckiw/bae/ard.html

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RVM

Introduction

Support Vector Machines

– Point predictions

– Many kernel functions

– Requirement to estimate a trade-off parameter

RVM does sparse classification well by:

– Linearly-weighting a small number of fixed basis functions

– From a large dictionary of potential candidates

– RVM kernel function doesn't have to satisfy Mercer's condition

RVM

– Predictive distributions

– Fewer kernel functions

– No Requirement to estimate a trade-off parameter