University Defence Research Collaboration in Signal Processing

LSSC Consortium White Paper

Embedding Cognition within Multi-Static Radars

Introduction

The proliferation of wireless devices coupled with the severe shortage of space in the radio spectrum has resulted in interference-congested environments in which such devices must operate. There is therefore a strong need to regulate these devices in their use of radio spectrum and power. Controlling these devices in a centralised manner is not desirable for reasons of avoiding information exchange overhead and the need for maintaining autonomous operation. On the other hand, distributed optimization and control of electronic devices is very challenging. This is especially due to the need to achieve a close to optimal solution without explicit communication and to mitigate against disruption by competitive and/or malicious transmitters within the environment. At Loughborough University, we have been developing mathematical optimization techniques including game theory and convex optimizations to model the interaction between wireless devices and to embed intelligence. This enables the wireless devices to adapt to the changes in environment, optimise operational parameters in a distributed manner and interact strategically to mitigate disturbances caused by malicious transmitters.

Mathematical Approaches

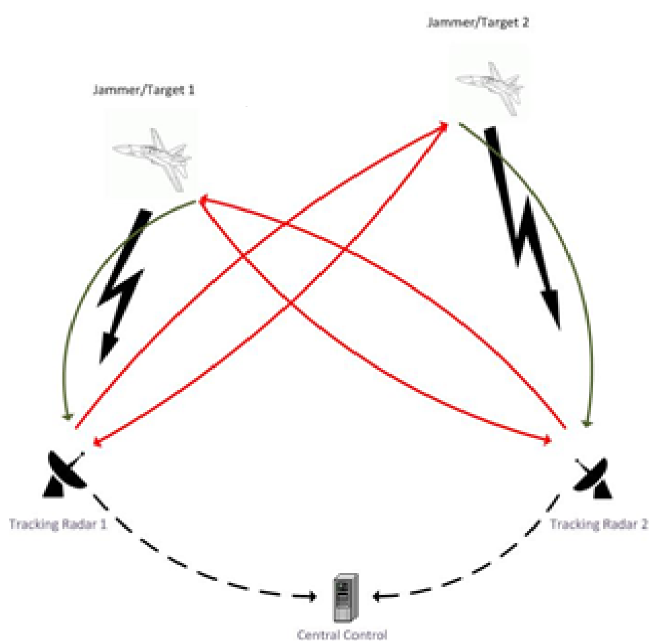


Figure 1. Multi-static radar network with with multiple targets.

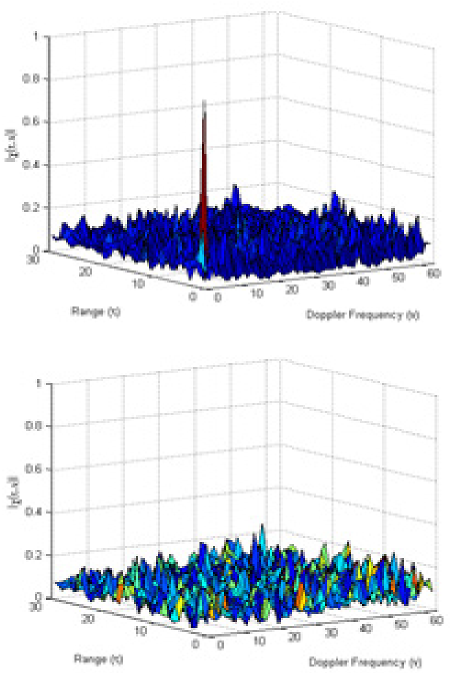
Game theory is a branch of mathematics that models and analyses strategic interactions between rational players or entities. Though widely used in economics for understanding market competition, there are emerging applications in engineering including understanding network attacks, collaborative data mining and distributed control of wireless networks. Modelling the behaviour of the devices as a strategic interaction facilitates distributed optimization without the need for explicit communication among them. In addition, wireless devices require optimization of various criteria like the signal to noise ratio under many practical constraints, such as transmission power and bandwidth. Convex optimizations naturally solve these problems and provide mathematically tractable solutions.

EPSRC Engineering and Physical Science Research Council

[dstl]

UDRC

Technology



We have developed novel convex optimization and game theoretic methods for distributed optimization in multi-static radars. Using game theoretic methods, we are able to show that radars can optimise their transmission power and/or waveform to achieve a certain performance criterion, without a need for explicit communication [1, 2]. The game theoretic algorithm also facilitates distributed beamformer design for enhancing signal to noise ratio while aiming to minimise interference leakage. We have developed a Stackelberg game based resource allocation technique for simultaneous operation of surveillance radar and distributed tracking radars.

We have also proposed convex optimization based radar waveform design that incorporates domain knowledge and reacts optimally to the changes in the environment. Accordingly, multi-static radars are able to choose waveforms optimally to enhance signal to noise ratio while maintaining good orthogonality among waveforms in the presence of severe clutter, as shown in the auto and cross-ambiguity functions in Figure 2.

Figure 2: Auto and cross ambiguity functions of cognitive bi-static radar waveforms

References:

[1] A. Panoui, S. Lambotharan, J.A. Chambers, "Game theoretic power allocation for multistatic radar network in the presence of estimation error", Sensor Signal Processing for Defence (SSPD) Conference, Edinburgh, UK, 2014

[2] A. Panoui, S. Lambotharan, J.A. Chambers, "Waveform Allocation for a MIMO Radar Network Using Potential Games", IEEE International Radar Conference, Arlington, VA, 2015