L_WP2: Game Theoretic Framework for Radar Waveform Design

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Our Goals

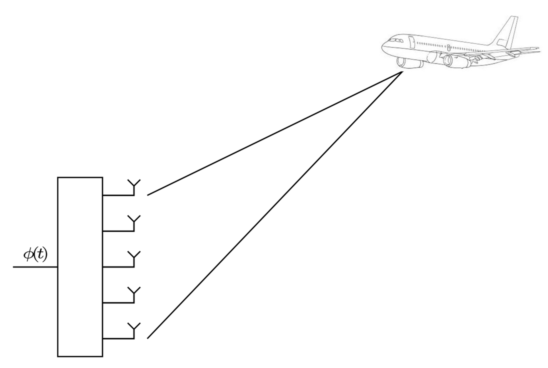
Develop game theoretic methods for

- defence against intelligent targets equipped with a jammer,
- distributed power allocation and waveform design for a radar network where each radar aims to maximise its corresponding detection performance.
- Particular focus will be on MIMO radars.

MIMO RADAR

Phased array

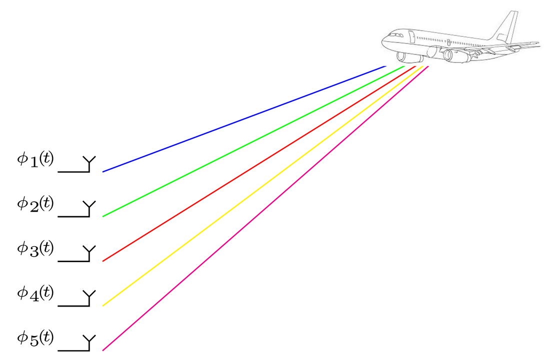
- coherent beam
- high antenna gain (good SNR)
- good detection performance in low SNR



MIMO Radar

(Multiple-Input-Multiple-Output)

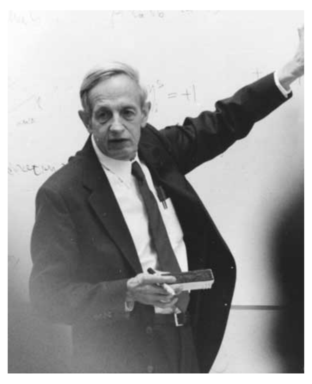
- transmission of independent signals (waveform diversity)
- time-energy management
- detection of slow moving targets
- improved parameter identifiability



Game Theory

Game theory provides the means to model, analyse and understand situations involving interactions among various decision-makers.

- A game G is a tuple $< N, (A_i), (u_i) >$, where
  - N is a set of players
  - A_i is a set of actions associated with each player i
  - u_i is a payoff function, which represents the players' preferences on the actions
- The solution of a game is a systematic description of the outcomes that may emerge in a family of games [1].



John Forbes Nash, Jr.

Nash equilibrium is the action profile such that no player can profitably deviate from their strategy.

Radar Network

Players: radars in the network

Aim:

- maximize the detection performance
- minimize interference

Strategy: waveform design,beamforming design, power allocation

Payoff: SINR, Mutual Information

Radar-Jammer Games

Players: radar vs intelligent target equipped with a jammer

Aim:

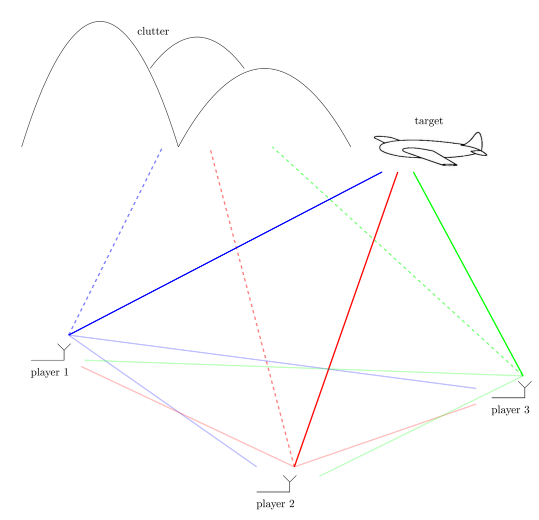
Radar: maximize detection performance

Target: deliberate interference with the radar signal (jamming)

Strategy: waveform design, beamforming design, signal polarization

Payoff: SINR, Mutual Information

Simulation



Players: radar network

Aim:

- maximize the detection performance
- minimize interference

Strategy: detection threshold (λ), power allocation p

Payoff: function of SINR (γ) and probability of false alarm (P_{FA}) and miss-detection (P_{MD})

$$u(p,\lambda) = \frac{\left(1 - P_{MD}(\gamma,\lambda)\right)\left(1 - P_{FA}(\lambda)\right)}{pT}$$

Problem formulation

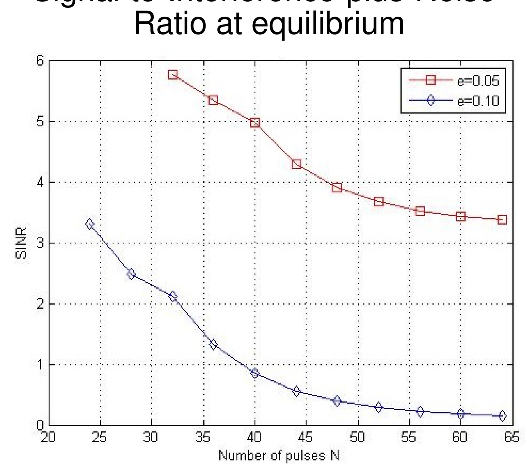
$$\max_{p,\lambda} u(p,\lambda)$$

$$\text{s.t.} \quad P_{MD}(\gamma,\lambda) + P_{FA}(\lambda) \le e$$

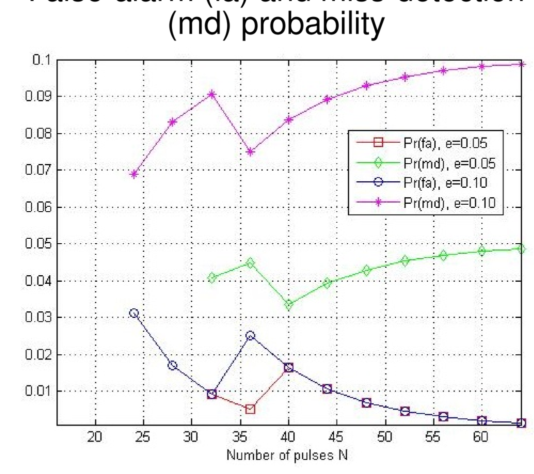
G. Bacci, L. Sanguinetti, M.S. Greco, M. Luise "A game-theoretic approach for energy-efficient detection in radar sensor networks", *IEEE 7th Sensor Array and Multichannel Signal Processing Workshop (SAM)*, 2012.

Simulation Results

Signal-to-Interference-plus-Noise-Ratio at equilibrium



False-alarm (fa) and miss-detection (md) probability



- e is an arbitrary small design parameter: $P_{MD} + P_{FA} \le e$

Generalized Nash Equilibrium Games

The generalised Nash equilibrium games are games where the strategy of a player depends on the strategies of the other players.

- The interdependency of the strategies is usually indirectly represented through the constraints of the problem.

Current Research Direction

Game theoretic framework for beamforming design for a radar network and power allocation, where the beamforming is considered in both transmission and reception.

- The radars in the network aim to detect the same target
- Each radar acts independently (non-cooperative game)
- Each radar should not deliberately interfere with the signal of the other radars
- The radars have limited power

Case I

Players: network of phased-array

Aim:

- maximize the detection performance
- minimize interference

Strategy: beamforming design, power allocation

Payoff: SINR, probability of false alarm and miss-detection

Case II

Players: network of MIMO radars vs intelligent target equipped with a jammer

Aim:

Radar Network: maximize detection performance

Target: deliberate interference with the radar signal (jamming)

Strategy: waveform design, power allocation

Payoff: SINR, probability of false alarm and miss-detection

References

[1] M.J. Osborne and A. Rubinstein, "A Course in Game Theory", The MIT Press, 1994

[2] M. Piezzo, A. Aubry, S. Buzzi, A. Maio, A. Farina, "Non-cooperative code design in radar networks: a game-theoretic approach", *EURASIP Journal on Advances in Signal Processing*, vol.2013, no.1, 2013

[3] X. Song, p. Willett, S. Zhou, P.B. Luh, "The MIMO radar and jammer games", *IEEE Transactions in Signal Processing*, vol.60, no.2, pp.687-699, 2012

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