

Cognitive Radar Special Issue—Part I

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Since the pioneering works by Simon Haykin and Joe Guerci over a decade ago, the field of cognitive radar has become well established in research and industry, as can be clearly seen by the growing number of special sessions, citations, and patents. The objective of this Special Issue is to provide the readers with both overview articles on the state of the art and philosophy behind cognitive radar, as well as implementation details and application examples. Due to the high number of excellent contributions, we were able to fill two special issues. This first part covers high-level concepts and cognitive radar architectures as well as first experimental achievements. The second part illustrates concrete applications and case studies of cognitive radar systems in practice.

COGNITIVE RADAR-APPROACH

A fundamental underlying concept of cognitive radar is the “Perception-Action-Cycle” as illustrated on the cover page. A cognitive radar shall hence be able to continuously adapt its sensing parameters to the environment, in order to optimize its performance in a closed-loop fashion. With the recent progress in software-defined radar, arbitrary waveform generation, artificial intelligence, and machine learning, it is the right time to make this claim reality. Cognitive radar has many roots and was influenced, among others, by adaptive and knowledge-based radar concepts, resource-management, cognitive radio, and waveform diversity as, e.g., covered in an IEEE AEROSPACE AND ELECTRONIC SYSTEMS MAGAZINE double special issue from 2016.

Significant progress and a consolidation in the diverse field of cognitive radar was made in a NATO lecture series NATO-SET 216 and the NATO-SET 227 research task group from 2015 to 2018. The research task group discussed various definitions of the term cognitive radar, which ultimately led to the current IEEE definition that emphasizes self-learning capability:

“A radar system that automatically forms an on-going perception of the target scene and takes actions accordingly. It may use short and long-term memory to improve performance of a given function. In comparison to adaptive radar, cognitive radar *learns to adapt* operating parameters as well as processing parameters and may do so over extended time periods. [IEEE Std P686-2017]”

ACHIEVEMENTS, CHALLENGES, AND THE WAY AHEAD

Even though a lot of progress has been made recently, as illustrated in this Special Issue, the goal of a truly cognitive radar system is quite ambitious and requires cross-discipline cooperation. In particular, experimental validation (due to the inherent real-time adaptivity of a cognitive radar) is still a big challenge that requires novel approaches and suitable hardware. However, with the increasing interest from industry, a growing research community, and proven benefits from concrete applications, the path forward shows great promise. We hope that you as readers can extract some new knowledge from this Special Issue and that it raises your awareness about the exciting field of cognitive radar.

We also take this opportunity to warmly thank all the authors for their highly professional contributions. Special thanks go to Prof. P. K. Willett and Prof. M. S. Greco for the effort they put into this Special Issue as editors of the magazine.



Albert Huizing



Alexander Charlish

ARTICLES IN THIS ISSUE

The five articles in this first issue cover concepts, architectures, and experimental results.

The first article “An overview of cognitive radar: Past, present and future” by Gurbuz *et al.* gives an overview of the historical context and mechanisms for cognitive processing in engineering systems. A survey of trends in cognitive radar research provides an understanding of techniques and applications and the technical and practical challenges that remain.

The second article “Cognitive radar principles for defence and security applications” by Bockmair *et al.* provides an industrial insight into cognitive radar concepts developed at Hensoldt. The architecture is based on a closed-loop perception–evaluation–action cycle that augments a software-defined radar sensor with memory, attention control, and intelligence. Application examples are given in the field of RF-coexistence and spectral management, automatic target recognition, adaptation to a changing environment, and resource management.

The third article “Cognitive radar for classification” by Brüggewirth *et al.* presents the cognitive radar architecture from Fraunhofer FHR with application examples for NCTI. The architecture is based on a three-layer model of human cognitive performance. Signal-oriented, skill-based behavior is realized by target-matched-waveform adaption and deep-learning approaches. Rule-based behavior is achieved by optimal decision strategies in a multistage target classification problem.

In the fourth article “A cognitive radar testbed for outdoor experiments” by Oechslin *et al.*, the cognitive radar testbed CODIR is presented along with results from a series of experimental campaigns. As the testbed incorporates a controller possessing a perception–action loop, the testbed was able to demonstrate adaptation to environmental conditions, target characteristics, and optimization objectives in real experiments.

The fifth article “Development and calibration of a low-cost radar testbed based on the Universal Software Radio Peripheral (USRP)” by Christiansen and Smith shows the development and characterization of a radar testbed based on a USRP that allows testing of adaptive or cognitive algorithms. The testbed is flexible in parameter selection and enables the selection of radar parameters on a dwell-by-dwell basis. An experiment with this testbed demonstrates the tracking of a small UAV with an adaptive track update interval.