Literature Review on Applications of Fuzzy Logic Modelling Approaches to Cognitive Radio Systems

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Abstract

Purpose of this review is to gain an understanding of Fuzzy Logic and its use on Cognitive Radio Systems. Articles reviewed will have a clear indication of separation with their original titles. Topics are categorized under Applications, Optimizations and Modelling Schemes. Sources required for this can be found under references. They show a promise of improvement under various areas about Cognitive Radio Systems. This review points out the mechanisms affecting said improvements.

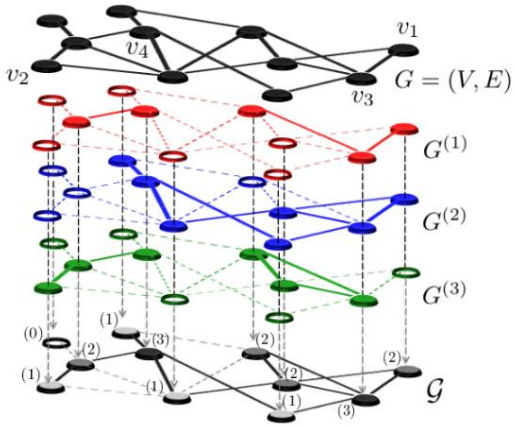
Keywords: Fuzzy Logic, Cognitive Radio Systems, Modeling, Optimization

Modeling Approaches for Multi-layer Fuzzy Cognitive Maps

Stephen T. MOHR

9 April 2019

Multilayer cognitive maps are presented as decompositions of complex ones. These are significantly different from the general multi dimensional networks. Here is an example of a network with three layers.



The concepts on this paper offer additional concepts useful in the development and simulation of fuzzy cognitive maps. This paper focuses on offering a better expressive power in the model. Performance issues regarding the multilayer fuzzy cognitive maps are also considered, specifically when using the adjacency matrix.

Stephen T. Mohr presents multiple fuzzy cognitive maps based on node alignment and interlayer edges. Their design decisions are discussed. He also examines the issue of accurately calculating the global activation levels of couples concepts.

Formally, fuzzy cognitive maps are defined by a graph or a network usually introducing a set of related concepts and a set of casual influences. This definition does not include fuzzy logic while calculating activation levels. With multilayer networks, many systems need a method to express multiple types of relationships. This is solvedby expressing the overall concept as a set of simple graphs.

With at least one aspect in a model developed with multilayer fuzzy cognitive maps, assigned with a role, can help prevent aspect proliferation. This way, while keeping the decomposition only one level deep, we can observe a greater detail. Complex systems can benefit greatly from this.

Application of Fuzzly Logic to Cognitive Radio Systems

M. MATINMIKKO, T. RAUMA, M. MUSTONEN, I. HARJULA, H. SARVAN KO, A. MÄRMELÄ

12 December 2009

Acknowledging that in the future, complex and dynamic systems will require more advanced decision making and environmental awareness methods that are capable of handling advanced and conflicting decision making problems.

This paper shares a novel fuzzy scheme for cognitive radio systems and reviews applications of said logics to telecommunications.

Results indicate that a fuzzy logic can be used in cognitive radio systems, to better improve their flexibility. Fuzzy logic can also be combined with existing methods.

Cognitive radio systems emerge for a more efficient use of resources. Resources include networks, operational environments and policies. In the future, this paper mentions the possible challenges that a cognitive radio system will face. Their heterogeneous operational environment with multiple access points and technologies with diverse sets of terminals crowd and overburden future applications.

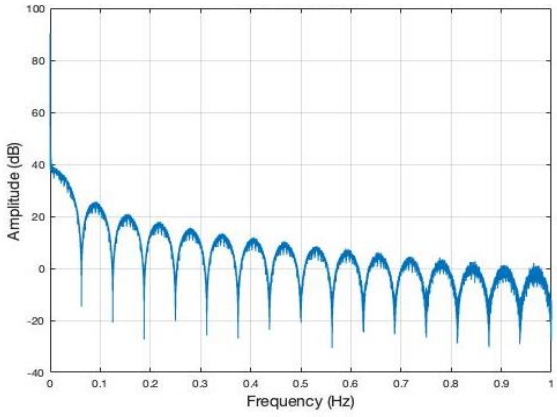
Lately telecommunications are more mathematical oriented than to human experience based on knowledge. These areas vary greatly from radio interfaces to resource management algorithms.

Spectrum sensing is a starting point algorithm and a fundamental technique for identification of spectrum opportunities for cognitive radio systems. Dedecting the presence of primary users is done by simple two-hypothesis testing. Signal is either present or absent. The receiver operating characteristics typically characterize the performance of spectrum sensing. This measures how well the cognitive radio system can detect the presence of primary systems and is thus a critical design parameter.

While simulating in terms of the receiver operating characte-

ristics, the performance of the fuzzy logic combining model is compared with majority decision rules with AND and OR. Simulations state that complex quadrature phase shift keying signals are transmitted while the fading is slower compared to the observation interval. This means that the channel should remain constant during the data block but will vary between consecutive blocks. Spectrum sensing in the system is done accordingly to Welch's periodogram.

Welch's Method is an approach for spectral density estimation. It uses periodogram spectrum estimates which are the result of converting a signal from the time domain to the frequency domain.



While it seems like telecommunications is not a major source of growth for fuzzy logic algorithms, fuzzy logic is used to solve different problems in vast areas. These application areas vary greatly from spectrum searches to resource management and even optimization problems. Benefits of fuzzy logic are apparent in systems requiring less computational complexity, less development work or managing power usage.

While overviewing our use of fuzzy logic applications to telecommunications, characteristics of future cognitive radio systems enable applications of new and developed fuzzy logic based techniques with great potential. This paper proposed a combining scheme for interdependent spectrum sensing based on fuzzy logic, providing flexibility to existing methods.

Fuzzy Logic Power Control in Cognitive Radio

Zelshko TABAKOVIC

Sonja GRGIC, Mislav GRGIC

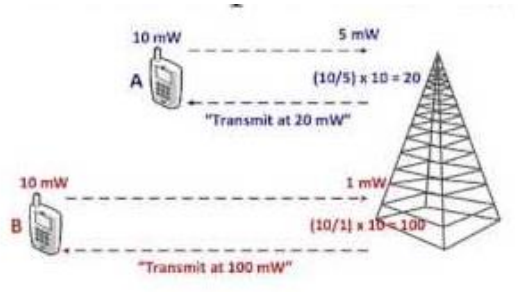
1 September 2009

This paper mentions topics like radio spectrum access and utilization, balancing goals and performance with minimal interference. There is a new strategy proposed for the fuzzy logic transmit power control that enables secondary cognitive user to achieve required transmission rate and quality while maintaining minimal interference over primary users and other concurrent secondary users.

Observing the demand for wireless communications in the recent years exceeded previous predictions greatly. Satisfying the future market demand for broadband and mobile services also required the next generation mobile networks and services need fast and flexible access to radio spectrum. Due to the policy of exclusive assignments of frequencies, radio spectrum has become scarce and overcrowded. Luckily, there was proof of most of the allocated spectrum was underutilized. To counter the rising conflict of spectrum congestion and spectrum utilization, cognitive radio technique that allowed secondary users to utilize the spectrum opportunistically was proposed. Opportunistic access like this has the possibility to improve spectrum utilization and in perspective allowing the next generation devices to access this radio spectrum.

Main problem to an opportunistic radio spectrum access lies in balancing the conflicting goals of satisfying performance requirements for secondary user while keeping the primary user satisfied. Secondary user should not be able to degrade the performance of licensed primary users. To achieve this, secondary user has to acknowledge the primary user, adjust to the environment characteristics and hastily adapt its system to the operating environment. Cognitive radio with this will have the main abilities like spectrum sensing,

dynamic frequency selection, and adaptive transmit power control.



Studies on transmit power control have progressed in order to better investigate different strategies for opportunistic radio systems. In one example under these strategies, opportunistic transmit power control is presented which enables the cognitive user to maximize its tranmission rate while assuring primary user outage probability.

This paper proposes an alternative transmit power controlling strategy. Proposition ensures that each secondary user receives and transmits the required energy to convey information. Spectrum sensing and other governing requirements define the maximum acceptable secondary user transmit power. Depending on the service quality, secondary user receiver sets required SINR*. Comparison of measured and required SINR determines transmit power control ratio and minimum required transmit power for secondary user. Secondary user transmit power is determined by balancing these two requirements. Maximum acceptable secondary user transmit power that satisfies the interference constraints and, minimum transmit power require to satisfy the levels of service.

Proposition is implemented using fuzzy logic system. These systems have been successfully applied in fields such as automatic control, classification and decision systems. Fuzzy logic systems can merge objective analysis and experience based knowledge to our advantage.

This strategy shines in minimizing interference and reduction of frequency reuse distance for primary user and other secondary users. This in turn brings a radio spectrum utilization optimization and increased network capacity with available resources.

**SINR: Signal to interference plus noise ratio.*

Hybrid Fuzzy Logic Scheme for Efficient Channel Utilization in Cognitive Radio Networks

M. SIDDIQI, A. ALI, L. ABBAS, M. SHAFIQ, M. AFZAL, H. LIAQAT, K.KWAK, A. BASHIR

7 March 2019

Significant raise of mobile devices and the heterogenous environ-ment of wireless communications have demanded an additional spectrum for data transmission. Unfortunately, completely alloca-ting a new band to all networks is not possible, therefore the demand for an efficient use with an already setup spectrum is significant. Cognitive radio spectrum and its technology is a promising solution for effective utilization. Cognitive radio devices or secondary users can opportunistically exploit available spaces. Secondary users even adjust to a coming of a primary user by switching channels. However, consequtive switches cause performance issues for the secondary user. Moreover, cognitive radio systems do not provide enough or reliable information and taking this switching action can not be based on crisp logic.

This paper proposes a fuzzy logic based decision support system. This system deals with channel selection and switching to enhance the cognitive radio system. The scheme reduces the switching rates for the secondary user and makes the selection of channels more adaptable. Simulation results for this scheme are promising in terms of the throughtput and handoffs thus rendering this a good candidate for secondary users while making decisions in the cognitive radio environment.

Widespread growth of demand for wireless and mobile devices grows by 30% every year therefore research community focuses on fulfilling the demand for available spectrum. This situation dragged the community into enhancing the efficient utilization of spectrum bands.

Cognitive systems is a promising wireless technology and a potential way out since its architecture is opportunistic.

Performance Enhancements of Cognitive Radio Networks Using the Improved Fuzzy Logic

P Ebby Darney

I. Jeena Jacob

February 2019 JSCP

Cognitive radio systems are efficient on allocation of the spectrum. This technology provides a decent service in the managing the white space allocation of the spectrum by providing the vacancies with secondary users. This causes a deterioration in the performance of the secondary user, due to their immediate evacuation when a licensed user requests spectrum.

This paper talks about an effective way of selecting and switching the channels. This method provided by this paper uses an improved fuzzy logic that relies on the decision support system*. This support system handles both the switching and selecting while a genetic algorithm selects the proper spectrum.

Tremendous innovations in the wireless technology created a way for researches that provide captivating outcomes. Results observed or obtained are never a solution since the growth in these technologies lead to more issues and challenges. A simple case is spectrum allocation for mobile and wireless devices. To have an effective allocation, the cognitive radio networks are employed.

This paper proposes an entailment in a cognitive radio network. To better utilize its capacity and identify the free spectrum to handle secondary user switches. Adjusting their switching rates using fuzzy logic in handoff, this method combines the interference avoiding method mentioned before and overlay method also mentioned before to convey simultaneously. Genetic algorithm handles the channel selection while fuzzy interference handles handoffs.

Results indicate a right proportion per number of secondary users their throughput percentage has increased, thus enhancing the overall performance.

**IFDSS-GA*

Other sources:

- https://www.researchgate.net/figure/Multilayer-network-with-three-layers_fig1_324231850
- https://en.wikipedia.org/wiki/Welch%27s_method
- https://dsp.stackexchange.com/questions/54890/periodogram-and-welch-periodogram-comparison
- https://www.youtube.com/watch?v=eNgQ1VaBPu8

Mentioned articles can be found attached.