Preface

“Essentially, all models are wrong, but some are useful” (George E. P. Box, 1978)

Model: This is probably the word one will hear the most when talking about cognitive technologies. After all, much of cognition—natural or artificial—is concerned with building more suitable models and finding the structures that better capture the most relevant aspects of reality. In present days, deep neural networks are the “hottest models” in artificial intelligence (AI), driving some of the most revolutionary technologies currently being built. A few years ago, statistical models were the dominant cognitive technique, just as rule-based models were before them.

Model design is a key issue not only for cognitive technologies but also for science and engineering in general. Good models are able to represent relevant characteristics of a complex phenomenon into an abstract representation, either enabling a better comprehension of a target system or producing testable predictions that can be used to validate a theory. With an accurate model at hand, for instance, one can control a system by forecasting responses to different inputs and, thus, determining the set of inputs that can take the system closest to the desired state.

There are many different types of models. Besides the widely used mathematical and statistical formulations in the cognitive technology context, other examples are textual descriptions and scale models. One feature, however, is common to all models: all of them miss some aspects of the systems they are intended to model, due to simplifications and idealizations, ignoring characteristics of the real-world in the name of treatability. This occurs when one overlooks particularities and considers, for instance, that all electrical batteries of a given type produced by a factory have exactly the same behavior observed in a set of prototypes thoroughly evaluated in a laboratory test. We also simplify reality when we avoid considering that users may interact in a very specific way with a device such as a smartphone, designing a user experience that is adequate for an idealized typical individual.

Some of these simplifications and mismatches are introduced because we lack, at design time, the data or the knowledge needed to create more accurate models or because it would be prohibitively laborious to create models that capture more aspects of the system we intend to represent. Imagine how costly the production of a wireless router would be if all possible scenarios of the radio spectrum occupation that can be faced by this router were considered, in order to define the best answer for each case.

Until recently, a new system design would only require a theory that roughly explained its behavior and how it was used. Such approach, however, is no longer sufficient. On the one hand, the widespread adoption of technologies increases the unpredictability of their usage and the ever-faster pace of technological and social changes makes models easily outdated. On the other hand, a relentless drive for efficiency and accuracy, as well as the design of applications that tackle more complex tasks, some of which we lack a complete understanding, such as language and image processing, demand that engineers look for new types of models.

How should we respond to this reality? There is where cognitive technologies come in.

Cognitive technologies—especially those linked to machine learning—refer to adaptiveness as a crucial feature for developing better systems, reducing their reliance on the knowledge available at design time. The cognitive approach prescribes that, if we fail to determine a priori how a system will behave and the environment it will meet, such systems should be able to gather data and autonomously adapt to the observed reality, anticipating future states whenever possible. With an increasing number of sensors deployed around the world, meaning that each individual produces, on average, more data than an entire city the size of São Paulo used to produce 25 years ago, data-oriented techniques are especially convenient. Furthermore, the growth in the amount of data and applications requires dynamism and heterogeneity of communication networks. In this sense, cognitive technologies can be applied to current optical and wireless networks, which should be aware of current conditions and have the ability to respond autonomously in order to dynamically reconfigure the network, providing efficient allocation of the spectrum and improving end-to-end performance.

This book presents a wide range of applications, within the cognitive technology context, that are currently being developed at Fundação CPqD: from classical statistical methods and machine learning techniques to cognitive networks and adaptive control.

Part I texts are focused on classical applications of cognitive technologies, such as speech processing and statistical models. In chapter "Exploring Convolutional Neural Networks for Voice Activity Detection", authors employed Convolutional Neural Networks (CNN), a technique initially designed to solve problems in the computer vision scenario, to partition an input audio into parts that contain voice and parts that only have background noise. To enable such transposition of methods, each audio is converted into a spectrogram and then processed as an image. The methodology was tested on a dataset containing 600 hours of audio at different noise scenarios, outperforming state-of-the-art techniques. Chapter "Distributed Averaged Perceptron for Brazilian Portuguese Part-of-Speech Tagging" assesses the application of Averaged Perceptron to grammatically label words in a sentence in Brazilian Portuguese. This labeling task, known as Part-of-Speech Tagging, is common to problems of natural language processing and speech synthesis and recognition. The technique was evaluated on a corpus consisting of newspaper texts with approximately one million words, 50,000 sentences and 30 different grammatical labels, surpassing the previous state-of-the-art performance for purely supervised classification of Brazilian Portuguese. Chapters "Method for Estimating Confidence Intervals for DEA Efficiency Models Using Regression Models" and "Considerations about Adding Aggregated Variables to the DEA Model" discuss extensions to the Data Envelopment Analysis (DEA), a mathematical technique to compare the performance and evaluate the efficiency of organizations like business companies, schools, and hospitals. In their first work, the authors used a technique known as bootstrapping to estimate confidence intervals for the computed efficiencies. In their second paper, the authors tackled the problem of adequately estimating efficiencies with insufficient data, reducing information loss through the aggregation of variables.

Part II is devoted to the study of cognitive technologies applied to wireless networks, which can be adapted for dynamically optimizing overall system performance and autonomously adapt to the radiofrequency operation environment changes. Chapter "Cognitive Radio Networks" introduces the concept of cognitive radio and presents a framework comprising spectrum management functionalities for addressing typical white space scenarios. In chapter "5G Cognitive Wireless Mesh Network without Common Control Channel", Collaborative Cognitive Mesh Networks (CCMN) are presented as a potential 5G network technology, since they provide high flexibility and efficient spectrum usage. Besides regular cognitive radio mechanisms, such as spectrum sensing, the common control channel and the Multi-Channel-Single Interface Manager (MC-SIM) algorithm enable dynamic channel allocation and maximize spectrum usage. Based on empirical testing, the MC-SIM algorithm provided a throughput enhancement of up to 30% compared to that of a regular system. Chapter "4G/LTE Networks for Mission-Critical Operations: A Cognitive Radio Approach" proposes two innovative strategies based on cognitive radio technology for preventing jamming attacks in 4G/LTE networks, aiming at attending requirements of military and public safety applications. The algorithm performance evaluation is based on Cell Frequency Reconfiguration and Frequency Hopping strategies, considering video streaming service in different jamming scenarios. Extending the scope to radiating elements of a radio system, chapter "A Fast and Efficient 3D Beamforming Algorithm for Cognitive Radio Networks" presents a fast, flexible and accurate algorithm to enable 3D beamforming for cognitive radio networks. Such algorithm mitigates the interference between primary and secondary users in cognitive radio networks, thus reducing the power required per connection and increasing system capacity. The radiation pattern of the algorithm was compared to the results obtained from an RF simulation tool, and the absolute difference was found to be less than −30 dB, which has proven to be an excellent accuracy level.

Part III addresses cognitive technologies applied to optical communications networks, with cognitive approaches employed to reconfigure physical network devices, namely the Erbium-doped Fiber Amplifiers (EDFA)—currently the most deployed device aimed at amplifying the transmitted signal in optical links. Chapter

"Simulation-Based Optimization of OSNR on Under-Monitored EDFA-Based Optical Links Using Backpropagation Correction" employs cognitive technologies aiming at optical signal-to-noise ratio (OSNR) optimization by predicting gain behavior of EDFAs. In particular, a feedback assisted network simulation applying backpropagation error correction technique is proposed and validated on in-lab real network tests with different traffic loads. Meanwhile, chapter "Optical Amplifier Cognitive Gain Adjustment Methodology for Dynamic and Realistic Networks" explores a cognitive methodology to adjust EDFA operating points based on Case-Based Reasoning (CBR). The methodology was validated through simulations in different topology networks and then compared with other approaches.

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