Methods of Artificial Intelligence for Error Control Coding and Multi-User Detection

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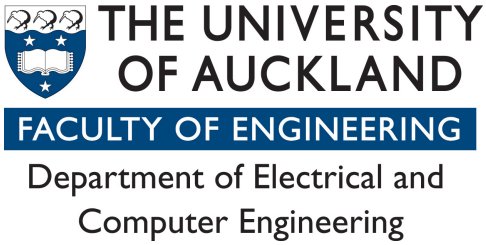

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Abstract

This thesis investigates error control coding and multi-user detection for a single and multi-user communication system using methods of artificial intelligence. The main motivation of the research is to improve on the drawbacks and the constraints of the existing decoding/detection algorithms by proposing alternative methods based on the principle of soft computing.

This thesis contains two main parts: the first part investigates the decoding of convolutional codes using a recurrent neural network and a support vector machine on a classical single-user communication system, and the second part studies a multi-user detector for a CDMA system based on a support vector machine. In particular, this thesis investigates a chaos-based CDMA system and compares it with other conventional systems. The theoretical analysis of the proposed methods are studied in detail by mathematical modeling and numerical examples, where all relevant design parameters and issues are considered. A quantitative approach is used to measure and compare the performance of the system by a series of Monte-Carlo simulations.

The regular methods for convolutional decoding such as the Viterbi and the Turbo algorithms are reviewed and compared with the proposed methods. It is shown that the recurrent neural network decoder has a similar performance to the conventional Viterbi decoder, while the complexity reduces from an exponential to a polynomial function with respect to the encoder size. The inherent parallel processing capability of this decoder makes it suitable for high data-rate applications. On the other hand, the support vector machine decoder can learn and adapt to the surrounding environment, hence it achieves an extra coding gain of 2dB over the Viterbi decoder under a Rayleigh fading channel. Furthermore, the semi-blind support vector machine detector has a comparable performance with the well-known MMSE detector, and it is suitable for the forward link. The

complexity of the detector is made even simpler than a matched filter receiver once feature extraction is incorporated.

The results from the thesis suggest that these proposed methodologies can effectively make the radio links smarter and more flexible for future wireless systems.

Acknowledgment

"*If I have seen further it is only by standing on the shoulders of giants.*"

- Sir Isaac Newton, 1676.

Upon completing this thesis, I could not agree more with the above great insight of Sir Isaac Newton. Over the last four years, I have had the privilege and the honor of standing on the shoulders of many giants, who have helped me to take a little glance at the deep fields explored in this thesis.

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List of Abbreviations and Acronyms

3G	3rd generation
4G	4th generation
AI	artificial intelligence
APP	a posteriori probability
AWGN	additive white Gaussian noise
BER	bit error rate
BPSK	binary phase shift keying
CDMA	code division multiple access
CPSK	chaotic phase shift keying
CV	cross-validation
DS-CDMA	direct sequence code division multiple access
ECC	error control coding
ECOC	error-correcting output codes
FDMA	frequency division multiple access
FH-CDMA	frequency hopping code division multiple access
GA	Gaussian approximation
GDA	gradient decent algorithm
Gold-DS-CDMA	gold sequence direct sequence code division multiple access
GRBF	Gaussian radial basis function
HOVA	hard output Viterbi algorithm
IC	interference cancellation
ICT	information and communication technologies
iid	independent and identically distributed
ISDA	Iterative Single Data algorithm

KKT	Karush-Kuhn-Tucker
LLF	log-likelihood function
LTE	long term evolution
MAP	maximum a posteriori
ML	maximum likelihood
MMSE	minimum mean square error
MSLE	maximum sequence likelihood estimation
MUD	multi-user detector
MUI	multi-user interference
NN	neural networks
NRZ	non-return-to-zero
OSCH	optimal separation canonical hyperplane
PIC	parallel interference cancellation
PRBS	pseudo-random binary sequences
PN	pseudo-noise
QP	quadratic programming
RBF	radial basis function
RFE	recursive feature elimination
RNN	recurrent neural network
RSC	recursive systematic convolutional codes
SC	stopping criterion
SIC	successive interference cancellation
SMO	sequential minimal optimization
SMS	short messaging service
SNR	signal-to-noise ratio
SOVA	soft output Viterbi algorithm
SRM	statistical risk minimization
SV	support vector
SVM	support vector machine
TDMA	time division multiple access
VA	Viterbi algorithm

WEP	word error probability
WLAN	wireless local area network
WTA	winner-takes-all