Biological system study has been an intense research area in neuroscience and cognitive science for decades of years. Biological human brain is created as an intelligent system that integrates various types of sensor information and processes them intelligently. Modern computers have been developed to meet our needs to handle computational tasks which our brains are not capable of performing with precision and speed. While in these existing man-made intelligent systems, most of them are designed for specific purposes. The modern computers could solve sophisticated problems based on fixed representation and association formats, instead of employing versatile approaches to explore the unsolved problems.

Because of the above limitations of the conventional machines, General Purpose Representation and Association Machine (GPRAM) System is proposed to focus on using a versatile approach with hierarchical representation and association structures to do a quick and rough assessment on multi-task tasks. Through lessons learned from neuroscience, error control coding and digital communications, a prototype of GPRAM system by utilizing Hamming code and short Low-Density Parity Check (LDPC) codes is implemented. Types of learning processes are presented, which prove the capability of GPRAM for handling multi-task tasks.

Furthermore, a study of low resolution simple patterns and face images recognition using an Image Processing Unit (IPU) structure for GPRAM system is presented. The IPU structure consists of a randomly constructed LDPC code, an iterative decoder, a switch and scaling, and decision devices. All the input images have been severely degraded to mimic human Visual Information Variability (VIV) experienced in human visual system. The numerical results show that 1) IPU can reliably recognize simple pattern images in different shapes and sizes; 2) IPU proves an excellent multi-class recognition performance for the face images with high degradation. Our results are comparable to popular recognition methods towards images without any quality degradation; 3) A bunch of methods have been discussed for improving the IPU recognition performance, e.g. designing various detection and power scaling methods, constructing specific LDPC codes with large minimum girth, etc.

Finally, a novel method to optimize M-ary PSK, M-ary DPSK, and dual-ring QAM signaling with non-equal symbol probabilities over AWGN channels is presented. In digital communication systems, MPSK, MDPSK, and dual-ring QAM signaling with equiprobable symbols have been well analyzed. Inspired by bio-systems, we suggest investigating signaling with non-equiprobable symbol probabilities, since in bio-systems it is highly unlikely to follow the ideal setting and uniform construction of single type of system. The results show that the optimizing system has lower error probabilities than conventional systems and the improvements are dramatic. Even though the communication systems are used as the testing environment, clearly, our final goal is to extend current communication theory to accommodate or better understand bio-neural information processing systems.

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