General-Purpose Representation and Association Machine (GPRAM) is proposed to be focusing on computations in terms of variation and flexibility, rather than precision and speed. GPRAM system has a vague representation and has no pre-defined tasks. With several important lessons learnt from error control coding, neuroscience and human visual system, we investigate several types of error control codes, including Hamming code and Low-Density Parity Check (LDPC) codes, and extend them to numerous directions. While in error control codes, solely XOR logic gate is used to connect different nodes. Inspired by bio-systems and Turbo codes, we suggest and study non-linear codes with expanded operations, such as codes including AND and OR gates which raises the problem of prior-probabilities mismatch. Several solutions are discussed, and challenges and numerical results in designing codes and iterative decoding for non-equiprobable symbols are presented, which may lead to a better understanding of bio-signal processing in future. The limitation of XOR operation in dealing with non-equiprobable symbols is demonstrated first. There are two possible ways to mitigate the limitation: quasi-XOR operation and intermediate transformation layer. How to construct codes for non-equiprobable symbols using quasi-XOR operation is shown and that the codes are very poor in terms of error correction capability is proven as well. Probabilistic messages for sum-product algorithm using XOR, AND, and OR operations with non-equiprobable symbols are further computed. The main motivation for these codes is not to perform error control coding, rather to build GPRAM systems. Large amount of operations available in the system with substantial over-complete basis will lay a foundation to develop a GPRAM system that can continuously discover better and simple approximations for complex tasks.

Because of the aforementioned prior-probabilities mismatch problem, how to decode LDPC codes with non-equiprobable binary symbols is discussed. For such symbols, the conventional Tanner graph needs to be modified because the message passing from check nodes to information bits and to parity check bits are distinct. In other words, the message passing along two directions are identical in conventional Tanner graph, while the message along the forward direction and backward direction are different in our case. A method to optimize signaling constellation which maximizes the channel mutual information is presented as well.

A simple Image Processing Unit (IPU) structure for GPRAM system is also proposed. The discussed IPU experiences images as its inputs. The quality of input images has been severely degraded to mimic visual information variability (VIV) experienced in human visual systems. The degraded images are then processed in the IPU, which consists of a randomly constructed LDPC code, an iterative decoder, a switch, and scaling and decision devices. The results show that (a) the IPU can reliably recognize digits despite the image quality being poor, (b) the IPU provides a hyper-acuity capability comparable to human visual systems, and (c) the IPU with the randomly constructed LDPC code can provide significantly improved recognition capability compared with the IPU without coding, even though the code is not optimized for our tasks.

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