Protograph-Based Raptor-Like Codes

The proposed codes have the advantage of low-complexity encoder and decoder implementation.

NASA's Jet Propulsion Laboratory, Pasadena, California

Theoretical analysis has long indicated that feedback improves the error exponent but not the capacity of point-to-point memoryless channels. The analytic and empirical results indicate that at short blocklength regime, practical rate-compatible punctured convolutional (RCPC) codes achieve low latency with the use of noiseless feedback. In 3GPP, standard rate-compatible turbo codes (RCPT) did not outperform the convolutional codes in the short blocklength regime. The reason is the convolutional codes for low number of states can be decoded optimally using Viterbi decoder. Despite excellent performance of convolutional codes at very short blocklengths, the strength of convolutional codes does not scale with the blocklength for a fixed number of states in its trellis.

Protograph-based (PB) Raptor-like codes can provide good performance in an incremental redundancy scheme with noiseless feedback over an additive white Gaussian noise channel. Additionally, these codes are also desirable for other applications were there is a need for simple generation of various code rates.

The proposed codes are based on protograph construction and they represent a novel contribution. In the original Raptor code, the redundant bit generation is based on a random selection of precoded bits that are produced from an unstructured LDPC (Low Density Parity Check) code. These redundant bits are selected based on some optimized distribution. Due to the nature of random selection, the original Raptor code required some additional information to be transmitted to the receiver in order to enable the decoding process. In the proposed codes, the redundant bits are generated based to optimized protograph structure with degree-1 nodes. Thus they do not need any additional information to be transmitted to the receiver. The proposed codes with protograph-based structure have the advantage of low-complexity encoder and decoder implementation. The proposed codes were designed for short block sizes, but a similar construction method can be applied to longer block lengths for other applications.

Hybrid ARQ (hybrid automatic repeat request — HARQ) is an error control method. In standard ARQ error detection, symbols such as cyclic redundancy check (CRC) are added to the information data. In HARQ, forward error correction code such as LDPC code symbols are also added to the existing error detection symbols, such that small random errors are corrected without retransmission, and major errors are corrected via a request for retransmission. The hybrid scheme performs better than standard ARQ in poor signal conditions. The proposed protograph-based Raptor-like codes can be used with HARQ.

This work was done by Dariush Divsalar of Caltech; and Tsung-Yi Chen, Jiadong Wang, and Richard D. Wesel of UCLA for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

The software used in this innovation is available for commercial licensing. Please contact Dan Broderick at Daniel.F.Broderick@jpl.nasa.gov. Refer to NPO-48128.

Fuzzy Neuron: Method and Hardware Realization

Simple and effective learning functions and adaptive elements can be placed into small hardware systems to include instruments for space, bioimplantable devices, and stochastic observers.

John H. Glenn Research Center, Cleveland, Ohio

This innovation represents a method by which single-to-multi-input, single-to-many-output system transfer functions can be estimated from input/output data sets. This innovation can be run in the background while a system is operating under other means (e.g., through human operator effort), or may be utilized offline using data sets created from observations of the estimated system. It utilizes a set of fuzzy membership functions spanning the input space for each input variable. Linear combiners associated with combinations of input membership functions are used to create the output(s) of the estimator. Coefficients are adjusted online through the use of learning algorithms.

This innovation has been demonstrated to be capable of creating usable models that can effect any number of complex transfer functions such as a continuous exclusive OR function, time domain (slew rate) filter, automatic gain controller, non-linear algebraic function calculator, and more. This innovation was created specifically for embedment within microcontrollers, allowing for simple and effective placement of learning functions and adaptive elements into small hardware systems to include instruments for space, bioimplantable devices, stochastic observers, etc.

Small spaceflight (and other) instruments have been confined to simple systems utilizing microcontrollers and a microcontroller core. Since most learning algorithms typically reside in larger computational frames and are rather complex (neural nets, for example), a simpler solution to self-learning, auto-adaptive systems would be attractive for smaller embodiments. Fuzzy logic systems lend themselves well to microcontrollers, but adaptive fuzzy systems also require a good deal of computational power. Thus, the simpler components of both fuzzy systems (input membership functions) and the back error propagation neural net (the linear combiner) were selected and fused into a simple two-layer system that can be easily embedded into common microcontrollers.

The training method used is an LMS (least mean square) algorithm based on a modification to the Widrow-Hoff learning algorithm. Coefficients and constants for each linear combiner were initialized to random values. Training data from observations of a user's