ATELIER « INFORMATION QUANTIQUE : CODES, GÉOMETRIE ET STRUCTURES ALÉATOIRES »
24–26 OCTOBRE 2011

WORKSHOP ON QUANTUM INFORMATION: CODES, GEOMETRY AND RANDOM STRUCTURES
OCTOBER 24–26, 2011

Quantum turbo codes with unbounded minimum distance and excellent error-reducing performance

Jean-Pierre Tillich *
jean-pierre.tillich@inria.fr

Quantum turbo-codes have been proposed several years ago as an alternative to quantum LDPC codes. Both families present the nice feature of having an iterative decoding of low complexity to decode them. Quantum turbo-codes are much simpler to construct though. However, it turned out that all quantum convolutional encoders which are recursive have catastrophic error propagation (which basically implies that iterative decoding does not work properly). Unfortunately, encoders which are non-recursive can only correct a bounded number of errors in the worst case. Until now, this problem has been addressed by either :

(i) observing that quantum codes with non-catastrophic encoders still enjoy rather good performances when the length of the code is moderate,

(ii) or using entanglement assisted versions of quantum turbo-codes which allow to decode successfully with catastrophic encoders.

We suggest here here to take another path, namely to use quantum catastrophic convolutional encoders but by adding a slight change in the construction which consists in allowing certain qubits of the outer code of the construction to go directly to the quantum channel. By an appropriate choice of the two constituent codes of the construction it turns out that it is possible to obtain a quantum turbo-code family which :

(i) can correct an arbitrary number of errors

(ii) turns out to be an excellent error reducing code.

It is able to operate at noise levels (and to reduce it to a tiny fraction) for which the only known quantum codes of reasonable decoding complexity operating successfully at this regime are families of codes with vanishing rate, such as for instance the toric codes. This is not the case in our construction, since we have a fixed rate of $\frac{1}{8}$.

This is joint work with Mamdouh Abbara.

*Projet SECRET, INRIA Rocquencourt, B.P. 105, 78153 Le Chesnay Cedex, FRANCE.