Dynamical Structures in Iterative Decoding

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R.M. Tanner, D. Sridhara, T. Fuja, in *Proc. ISCTA 2001* (Ambleside, UK, July 15–20, 2001), p. 365.

Frame-Error-Rate



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Instanton method



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Tanner graph of [155, 64, 20] code



One special subgraph of Tanner graph



One special subgraph of Tanner graph





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400 iterations

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Instanton for Tanner's [155, 64, 20] **code**



Effective distances:

- Iterative decoding: 12.5
- Linear programming decoding: 16.4
 - Hamming distance: 20

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Instanton "robustness"

number of iterations until a successful decoding



Instanton "robustness"

number of iterations until a successful decoding



Smoothed (relaxed, damped) decoding

Iterative scheme (BP):
$$\eta_{i\alpha}^{(n+1)} = h_i + \sum_{\beta \ni i}^{\beta \neq \alpha} \tanh^{-1} \left(\prod_{j \in \beta} \tanh \eta_{j\beta}^{(n)} \right)$$

$$\eta_{i\alpha}^{(n+1)} + \frac{1}{\Delta} \sum_{\beta \ni i} \eta_{i\beta}^{(n+1)} = h_i + \sum_{\beta \ni i}^{\beta \neq \alpha} \tanh^{-1} \left(\prod_{j \in \beta} \tanh \eta_{j\beta}^{(n)} \right) + \frac{1}{\Delta} \sum_{\beta \ni i} \eta_{i\beta}^{(n)}$$

$$\Delta \rightarrow \infty$$
 — standard BP
 $\Delta \rightarrow 0$ — slow dynamics

Stepanov, Chertkov, Allerton 2006 [cs.IT/0607112]

Instantons effective distance



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Summary

- the performance of iterative decoding is determined by most dangerous noise configurations (instantons)
- the fixed point of iterations in decoding is unstable, if the noise configuration is damaging
- the iterative decoding cycles on instantons
- making the iterations smoother helps (shifts the instantons to larger distances)