Sample questions for INF244 Oral exam

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December 6, 2013

Note: the oral exam will also include some questions not listed here.

1. Explain how to marginalise a function down to a single variable. (FGSPA: pp. 5–6).

2. Explain how to use factoring to construct a factor graph from a global function. (FGSPA: pp. 7–9).

3. Explain how one can use cycle-free factor graphs to exactly compute a single marginal in an efficient manner. (FGSPA: pp. 5–19).

4. Explain how the sum-product algorithm works on a factor graph with cycles. (FGSPA: pp. 20–27).

5. Explain how the sum-product algorithm can be applied to behavioural modelling, linear coding theory, and SAT. Explain, further, how hidden variables may be accomodated by the sum-product algorithm and show how this applies to trellis representations and state-space modelling. (FGSPA: pp. 32–36).

6. Explain how factor graphs may be used to encode and model APP distributions, Markov chains, and hidden Markov models. (FGSPA: pp. 38–44).

7. Describe how to implement the forward-backward algorithm in terms of the sum-product algorithm. (FGSPA: pp. 45–56).

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8. In what fundamental way does maximum-likelihood detection (MLD) differ from MAP decoding? Explain the principle of max-product and min-sum variants of the sum-product algorithm. How can min-sum be used to obtain the Viterbi algorithm from the BJCR algorithm? (FGSPA: pp. 59–66).

9. How can one use factor graphs in the context of turbo codes, and LDPC codes? What are repeat-accumulate codes? (FGSPA: pp. 73–78).

10. Explain how elemental sum-product algorithm computations may be simplified in the binary case. Explain how likelihood and log-likelihood ratios may be used to re-express these computations. (FGSPA: pp. 79–89).

11. Explain how the methods of clustering, stretching, and spanning trees may be used to eliminate cycles from a factor graph. (FGSPA: pp. 90–98).

12. Explain how factor graphs may be used to implement the fast Fourier transform. (FGSPA: pp. 99–104).

13. What is a quaternary symmetric channel?

14. Describe the operation of local complementation on a graph. How is it generalised to a directed graph?

15. Describe how to associate a simple graph with a self-dual $\mathbb{F}_4$-additive code.

16. Describe the $n \times 2n$ binary matrices that form the graph class, and how local complementation is realised on the graph class.

17. What $\mathbb{F}_4$-additive matrices correspond to the graph class. Describe how local complementation operates on these $\mathbb{F}_4$-additive matrices, and how to interpret local complementation on a directed graph in terms of an action on the associated $\mathbb{F}_4$-additive matrix.

18. Define the symplectic inner product of binary matrices and the corresponding Hermitian inner product of $\mathbb{F}_4$-additive matrices.

19. Describe how to perform the sum-product algorithm on the simple graph associated with a self-dual $\mathbb{F}_4$-additive code.

20. Discuss the working of the sum-product algorithm on the equivalent binary interpretation of the previous system. How does the quaternary symmetric channel prevent a trivial decomposition of the system?
21. Consider the simple graph C_5. Give some reasons why this is an interesting graph in the context of self-dual $\mathbb{F}_4$-additive codes.
22. How can local complementation be realised as a matrix transform?
23. What is the probability of a random graph containing a bipartite member in its local complementation orbit? Sketch a possible argument that justifies your answer.
24. Describe how to perform the sum-product algorithm on the directed simple graph associated with a half-rate $\mathbb{F}_4$-additive code.
25. What problems do we encounter when we consider message-passing (sum-product algorithm) on a dynamic graph (i.e. on a graph regularly updated by LC operations.

26. Describe, very briefly, what is meant by phase-shift-keying modulation. How does a matched-filter acquire the received signal? (LectureNotes: pp. 4–5).

27. Explain what is meant by maximum-likelihood decoding, and how is this interpreted on a binary-symmetric channel? (LectureNotes: pp. 7–9).
28. What are the most important parameters that constrain the capacity of a channel? Relate these parameters by an equation. (LectureNotes: pp. 10).
29. What is meant by the asymptotic coding gain of a code on a given channel? (LectureNotes: pp. 10–13).
30. Sketch the typical decoding performance, on a typical channel, of a classical code and a turbo/LDPC code, with respect to the Shannon limit. (LectureNotes: pp. 14).

31. Explain how the generator matrix of a binary linear block code can be put into trellis-ordered form. What are the typical optimality criteria used to decide which trellis-ordered form is best? (LectureNotes: pp. 15,17).

32. What is correlation discrepancy? Relate it to the reliability of a received bit. (LectureNotes: pp. 26–27).

33. Explain how reliability-based soft-decision decoding can make use of the least-reliable or most-reliable bit positions to improve decoding performance. (LectureNotes: pp. 28–33).

34. What are convolutional codes? Explain by referring to the shift-register representation, the scalar matrix representation, and the polynomial matrix representation. (LectureNotes: pp.44–54).

35. Explain what is meant by a systematic convolutional code, and use the polynomial representation to find the parity check matrix for a systematic convolutional code. (LectureNotes: pp. 56–60).

36. What is a catastrophic convolutional encoder, and why is it undesirable? (LectureNotes: pp. 71).

37. Show how one can derive state diagrams for convolutional encoders. (LectureNotes: pp. 72–75).

38. How may the weight-enumerating function (WEF) of a convolutional code be obtained from its state diagram? Give an overview of Mason's formula (I won't ask you to derive or use Mason's formula for an explicit example, but you should be able to describe the steps involved). Show how the WEF may be generalised to the input-output weight-enumerating function (IOWEF). (LectureNotes: pp. 76–85).

39. How does one modify the input-output weight-enumerating function (IOWEF) of a convolutional code to reflect its truncation/termination? (LectureNotes: pp. 86).

40. Show how to obtain a trellis diagram from a state diagram that represents a convolutional code. (LectureNotes: pp. 95–96).

41. Explain how the Viterbi algorithm can achieve maximum-likelihood decoding for a 2-input 4-output discrete memoryless channel, and show how the decision process may be modified/simplfied for a binary symmetric channel. (LectureNotes: pp. 103–108).

42. Explain how one might compute the maximum independent set of a graph using message-passing. Discuss both binary and $\mathbb{F}_4$ methods. (MessPassIS.pdf).