“Wavelets and Sparse Signal Processing”

Examination Paper

(The 1st Semester in Academic Year 2019-2020)

1. Proving and Programming. (required, 20’)

(1) (10’) For $1 \le n \le N$, we suppose that $f_n(t)$ is real and that $\hat{f}_n(\omega) = 0$ for $|\omega| > \omega_0$. An amplitude-modulated multiplexed signal is defined by

$$g(t) = \sum_{n=1}^{N} f_n(t) \cos(2n\omega_0 t).$$

Compute $\hat{g}(\omega)$ and verify that the width of its support is exactly $4N\omega_0$. Find a demodulation algorithm that recovers each f_n from g.

(2) (10’) Select three signals with zero-mean and do low-pass filtering to generate $f_1(t), f_2(t), f_3(t)$. Implement the modulation algorithm described in (1) and your demodulation algorithm to recover the signals.

2. Comprehension and Essay Writing. (required, 40')

Read the paper "Quantum machine learning" (doi:10.1038/nature23474, [1]) and answer the following questions. Remember to cite the literatures you use for reference in your answer.

(1) Conclude the main ideas of this paper, including its motivations and advances (8pts).

(2) Specify the similarities and differences between Quantum machine learning and traditional machine learning (6pts).

(3) Specify the strengths and limitations of Quantum machine learning in comparison to traditional machine learning. How can quantum methods achieve these strengths, considering the properties of qubit (10pts)?

(4) According to the specified strengths, list several potential circumstances under which quantum machine learning can be put into real-world applications (8pts).

(5) Regarding the specified limitations, propose possible improvements to address them for better performance (8pts).

[1] Biamonte J, Wittek P, Pancotti N, et al. Quantum machine learning[J]. Nature, 2017, 549(7671): 195.

3. Programming. (required, 40')

Implement wavelet-based method for image dehazing. Compare your methods with [2]. Use quantitative comparison criteria PSNR and SSIM (MATLAB functions: 'psnr' and 'ssim') to test the performance of your algorithm, using the hazing images and its ground truth provided on the website: http://min.sjtu.edu.cn/files/wavelet/wt_exam_003.rar.

Please include algorithm principles, implementation process, experimental results and the analysis of results in your answer.

[2] He K, Sun J, Tang X. Single image haze removal using dark channel prior[J]. IEEE Transactions on Pattern Analysis and Machine Intelligence, 2010, 33(12): 2341-2353.

4. Proving. (optional, 20')

Shannon wavelet. The scaling function of Shannon wavelet is *sinc* function:

$$\phi(t) = sinc(t) = \frac{\sin(\pi t)}{\pi t}$$

Prove the Shannon wavelet satisfies Equation (7.29) and (7.32) in Theorem 7.2 in the textbook [3].

[3] Mallat S, A Wavelet Tour of Signal Processing: The Sparse Way. Third Edition. Elsevier 2009.

5. Programming. (optional, 30')

Compress the album on SOLVAY CONFERENCE 1927, the famous conference convening the world's most notable physicist to discuss the quantum theory. You can download it from http://min.sjtu.edu.cn/files/wavelet/1927conference.bmp. Elaborate your compression algorithm, experiment settings and results in your answer.

(1) Implement an algorithm to compress this picture and calculate your compression ratio (Original_Image_Size/Compressed_Image_Size). A compression ratio that is greater than 6.0 is required. Note that a typical compression algorithm consists of transform, quantization and entropy encoding. You are allowed utilize open source code, but need to elaborate its process in your answer (10pts).

(2) For portraits, high quality of people's faces is desired. Please update your algorithm to improve the quality of people's faces in the reconstructed image and validate your method (compression ratio should keep equal). (20pts).