2004 Paper 7 Question 8

(Computer Science Tripos Part II)

Information Theory and Coding (MGK)

(*c*) Explain briefly:

(*i*) sensation limit; [1 mark]

(*ii*) critical band; [1 mark]

(*iii*) Bark scale. [1 mark]

(*d*) Which different aspects of perception do Weber's law and Steven's law model? [2 marks]

2004 Paper 8 Question 10

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(*c*) You are asked to compress a collection of files, each of which contains several thousand photographic images. All images in a single file show the same scene. Everything in this scene is static (no motion, same camera position, etc.) except for the intensity of the five light sources that illuminate everything. The intensity of each of the five light sources changes in completely unpredictable and uncorrelated ways from image to image. The intensity of each pixel across all photos in a file can be described as a linear combination of the intensity of these five light sources.

(*i*) Which one of the five techniques *discrete cosine transform*, *μ-law coding*, *2-D Gabor transform*, *Karhunen-Loève transform* and *Golomb coding* would be best suited to remove redundancy from these files, assuming your computer is powerful enough for each? [1 mark]

(*ii*) Explain briefly this transform and why it is of use here. [4 marks]

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(*c*)

(*i*) The sensation limit of a sense is the lowest amplitude of a stimulus that can be perceived.

(*ii*) If two audio tones fall within the same critical band, the ear is unable to recognize two separate tones and perceives a single tone with the average of their frequency instead. (The human ear has approximately 24 non-overlapping critical bands.)

(*iii*) The Bark scale is a non-linear transform of an audible frequency into the number range 0 to 24, such that if two frequencies are less than 1 apart on this scale, they are within the same critical band.

(*d*) Weber's law is concerned with how the difference limit, the smallest amplitude change of a stimulus that can be distinguished, depends on the amplitude of the stimulus. Steven's law on the other hand is concerned with how the amplitude of a stimulus is perceived in relation to other amplitudes, for example how much must the amplitude raise such that the stimulus is perceived as being twice as strong.

[This question relates to the psychophysics of perception, as discussed in the course section on coding audiovisual signals.]

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(*c*)

(*i*) The Karhunen-Loève transform.

(*ii*) The Karhunen-Loève transform decorrelates random vectors. Let the values of the random vector $\mathbf{v}$ represent the individual images in one file. All vector elements being linear combinations of five values means that for each file there exists an orthonormal matrix M such that each image vector $\mathbf{v}$ can be represented as $\mathbf{v} = M\mathbf{t}$, where $\mathbf{t}$ is a new random vector whose covariance matrix is diagonal and in which all but the first five elements are zero. The Karhunen-Loève transform provides this matrix M by calculating the spectral decomposition of the covariance matrix of $\mathbf{v}$. The significant part of the transform result $M^\top \mathbf{v} = \mathbf{t}$ are only five numbers, which can be stored compactly for each image, together with the five relevant rows of M per file.

[This question relates to the section on correlation coding, as discussed in the course section on coding audiovisual signals.]