

INFORMATION RETRIEVAL FROM NOISY IMAGES -  
DETECTION PERFORMANCE

by

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CERTIFICATE

This is to certify that the dissertation, "Information Retrieval from Noisy Images - Detection Performance", which is being submitted by P. Mohana Shankar for the award of the degree of Doctor of Philosophy to the Indian Institute of Technology Delhi, is a record of bona fide research work.

This dissertation has reached the standard fulfilling the requirements of the regulations relating to the degree. The results obtained in this dissertation have not been submitted to any other University or Institute for the award of any degree or diploma.



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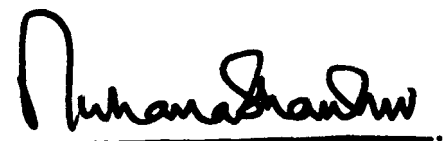
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### ABSTRACT

Optical and holographic information storage systems have assumed great importance in the present day scientific world. This is largely due to the huge capacities and rapid access times of these forms of memories. But these memories, where the information is stored as light amplitude transmittance variations or images, suffer from different forms of noise, both at the recording and retrieving stages. The prime source of noise is the laser speckle, arising from the coherent laser beam being used for reading/writing these memories. This form of disturbance is multiplicative in nature and has a Gaussian probability distribution. Another form of noise is the one arising out of the background radiation, being generated partly by the unwanted radiation sources within the field of view of the system like dirt, dust particles etc., and partly due to the imperfection of the systems involved. This noise is essentially additive in nature and has a zero mean Gaussian distribution. Yet another form of distortion is generated by the film grain-noise when photographic film is used as the storage medium. At low noise values, film grain noise is multiplicative and has a lognormal distribution. Apart from these disturbances, the photodetectors used to collect light intensity are limited by Poisson distributed quantum noise.

Statistical detection theory has been applied for the study of images containing information. The storage plane is assumed to be divided into small elemental areas, the sizes of which are decided by the Rayleigh resolution limit of the optical systems involved. Analysis has been carried out when the information bearing images are received using (i) a point detector, (ii) an image scanner and (iii) a spatial matched filter. The point detectors are considered

as simple square law devices and are assumed to be kept at the centres of the elementary areas. In the case of an image scanner, a simple top-hat aperture scanner is assumed which moves across the storage plane and is analogous to a square-law device followed by an integrator. The correlation observed through the spatial matched filter is measured using a square law device. The summary of the work carried out is given below.

The thesis contains six chapters. Chapter I presents an introductory note, incorporating the different facets of the art of signal detection as applied to optical information processing. The terminology and methodology associated with different statistical techniques are elucidated. The various receivers that will be encountered and utilized are also discussed.

In Chapter II, information read out and detection wherein the areas have a constant light amplitude is analysed. Simple binary case is considered, where the areas are either bright or dark. Performance is evaluated when the point detectors have been placed at the centres of the areas. The case of an image scanner is discussed in detail. The probability density functions of the sufficient statistic\* under the various noisy conditions are arrived at using the sampling method. The performance is compared with that in the case of a point detector. The use of a scanner brings down the error probability, due to the diversity being introduced by the integrator. It is shown that speckled images or the information in the presence of speckle and background noise gives rise to a higher error probability even at high SNRs, while in the absence of speckle the error probability at high SNRs is very small. Similar results have been observed in the study of digital communication systems in fading.

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\*The sufficient statistic summarises the whole of the relevant information supplied by the sample. (Ferguson, T.S.: Mathematical Statistics, Academic Press, 1967, p. 112).

The effect of spatial cut-off frequency on the performance is also mentioned. The distortion due to this is treated along the lines of intersymbol interference. The effect of the film grain noise as a multiplicative disturbance is to increase the error probability further.

Chapter III is, in effect, an extension of the above mentioned work for a multilevel information storage system, wherein the areas may have any of the  $m$ -values of the light amplitude. This would be analogous to the  $m$ -ary signalling in digital communication systems. It has been observed that speckle masks the multi-level images.

Chapter IV deals with the case of a spatial matched filter receiver for binary images. Here the signal considered is space varying, while in the previous chapters, it had been treated as a constant in an elementary area. Correlation is measured by a square law device and decisions are based on this measured value. Here again it has been shown that speckle degrades the system. Film grain noise worsens the performance.

In all the previous chapters, it has been assumed that photodetectors are ideal. But they are seldom ideal and are limited by the quantum noise. Also, the speckle has been assumed to be a constant in an elementary area, which is not generally true. In Chapter V, detection performance of an image scanner is evaluated where the speckle is treated as space-varying in an area and the photodetectors are limited by Poisson distributed quantum noise. It has been assumed that the additive disturbance has been suppressed. It is shown that the effect of more dark current, that is, a higher quantum noise level, is to increase the error probability.

Chapter VI contains conclusions and suggestions for future work.

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