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Development of a Speckle–Interferometry Software with Applications to Optical Imaging: Preliminary Results.

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In this paper, we describe the structure and characteristics of a software package, which supports information processing activities in speckle interferometric imaging. The software allows the generation of speckle patterns from atmospheric turbulence models having optical and statistical parameters. The software can take into account different types of noise and the point spread function of the optical system. Several object reconstruction algorithms are used, which allows comparison of results obtained from different reconstruction algorithms and also to design simulations with parameters emulating measurement conditions. It helps to determine the experimental conditions to be fulfilled to obtain successful reconstruction. The software is interactive in nature and guide the user in experiments and simulations design.

INTRODUCTION

Speckle interferometry plays today an important role in astronomy by exploiting the phase information content of short exposure images taken sequentially (also called speckle frames) in order to reduce the lost of angular resolution due to the non–stationarry fluctuations of the refraction– index of the atmosphere, by means of statistical methods. Since the pionneer work by Tatarski [1] and Fried [2] in the 1960s, mathematical models describing the phase fluctuations of incoming optical and electromagnetic waves propagating through a turbulent medium are fairly well known and their validity proved experimentally. In particular, Fried [2] provided a mathematical description of a "frozen" turbulent atmosphere affecting a short exposure image and leading to a speckle–like distribution of intensity. In the 1970s, Labeyries [3] followed by Knox and Thompson [4] introduced statistical averaging methods allowing the recovery of the object up to the diffraction limit of the optical system, thus greatly reducing the effect of the atmosphere. These methods are essentially based on the averaging of the power and cross spectra of each speckle frames over a large number of frames. The object is recovered by integrating the phase gradient estimates over different paths to reconstruct the object phase and then computing an inverse Fourier transformation of the estimated complex spectrum. Later on, Bates [5] introduced the so–called Shift–and–Add method which can be seen as a coherent averaging of the frames by aligning together the maximum–intensity pixel of each frame and then summing up. The diffraction limited object emerge from a low intensity background. The advantage of this method, compared to the previous ones, is that no reference unresolved source is required as well as no object phase needs to be reconstructed. The simplicity of this algorithm makes it very attractive for practical situations. Its main disadvantage appears when several pixels are brightest having roughly the same intensity such as with extended objects or including similar magnitude stars.The above algorithms have been implemented in a software package aiming at supporting astronomers' activities in speckle interferometric imaging.

SOFTWARE DESCRIPTION AND EXAMPLE

The software package includes the handling of measured data and experimental set–up information as well as simulated data. The software allows the generation of speckle patterns from atmospheric turbulence models (Fried). It can take into account different types of noise and the point spread function of the optical system as depicted by figure 1. The subsequent figures illustrate an example involving 100 speckle frames each one with a SNR of 30 dB. The object is composed of 5 point sources as shown in figure 2. The scale axis are unitless. The flexibility of the software allows the user to compare results obtained from different reconstruction algorithms and also to design simulations with parameters emulating measurement conditions. In this sense, these simulations can help the user to determine the experimental conditions to be fulfilled (ex. number of frame, exposure time SNR etc...) to obtain successful reconstruction. During the first phase, the modular software package is being implemented using MATLAB, a high level mathematical software. A subsequent version in C language is planned.

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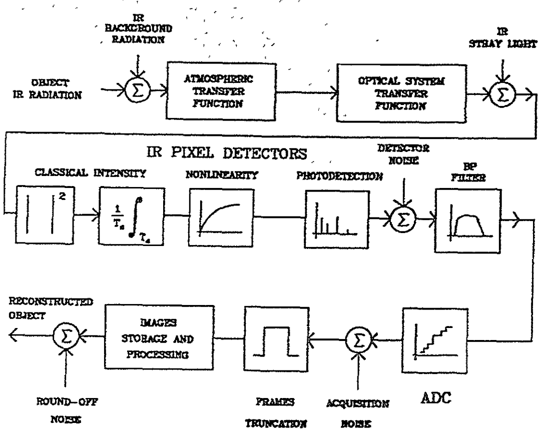

Fig. 1: model for speckle imaging simulation.

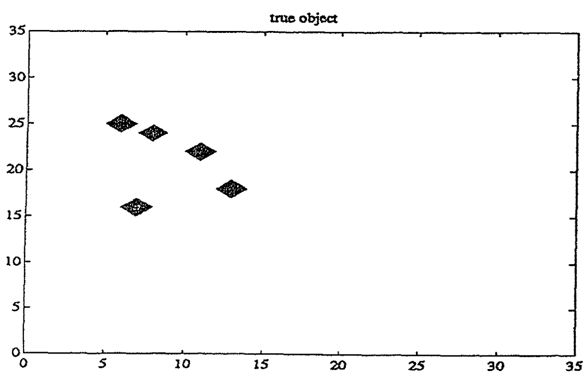

Fig. 2: example, true object.

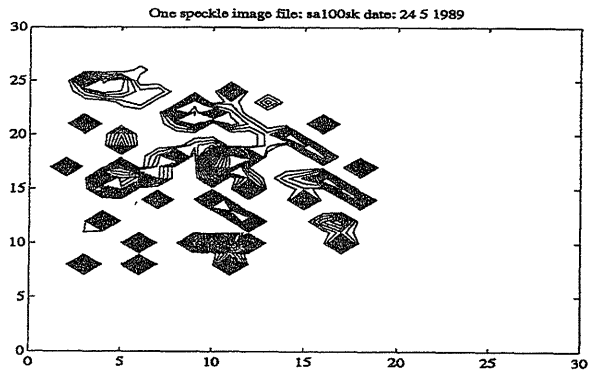

Fig. 3: example, one speckle frame.

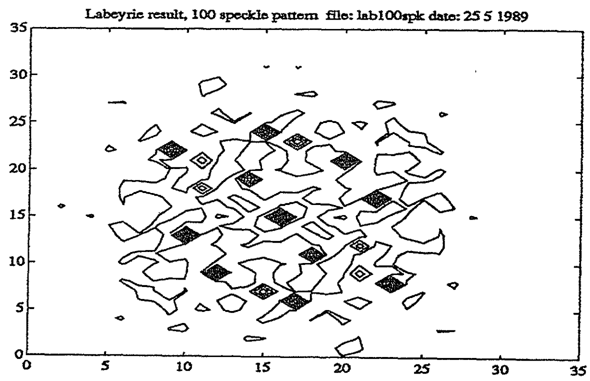

Fig. 4: example, Labeyrie's method (no phase).

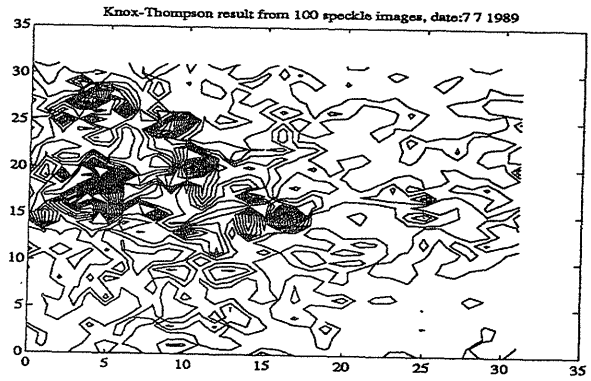

Fig. 5: example, Knox and Thompson method.

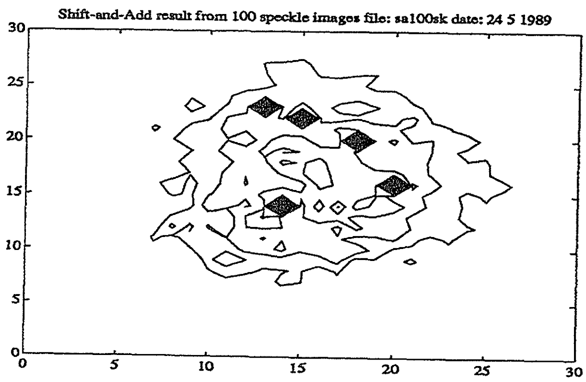

Fig. 6: example, Shift–and–Add method.