DTU Fotonik
Department of Photonics Engineering

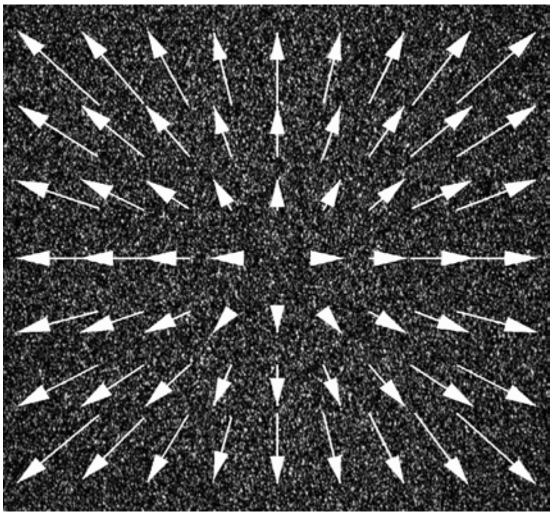
MSc Thesis Project.

Real-time axial motion detection by speckle dynamics and spatial filtering

Introduction: Laser speckles are the term used for the random optical granular structure, observed when illuminating most surfaces with coherent light. Therefore, they have often been considered as optical noise. Many efforts have addressed the speckles in order to reduce or remove them from e.g. interferometric measurements and coherent imaging/projection. However, speckles can also be considered as an imprint of the speckle-generating surface. Consequently, e.g. speckle dynamics contains unique information about how a surface moves in space. Speckle photography, speckle correlation and electronic speckle interferometry (ESPI) are just a few examples of applications relying on the nature of speckles.

In the Optical Sensor Technology Group at DTU Fotonik (DTU Risø Campus) we have been working with speckles and their dynamics as a tool for designing optical sensors, which address industrial or consumer applications. The benefits of speckle sensors are their robustness, compactness and in general they are low-cost, non-contact devices.

In this project we aim at using a newly perceived concept for measuring changes in distance with a low-cost, miniaturized optical system. We illuminate an object, having a rough surface, with laser light and at a distance we observe a speckle pattern. Then, moving the object either away from or towards the observer the speckle pattern will expand or contract, accordingly. A similar phenomenon can be observed when driving a car through a blizzard; the snowflakes will appear to emanate from a single position in front of you, and then spread radially out.

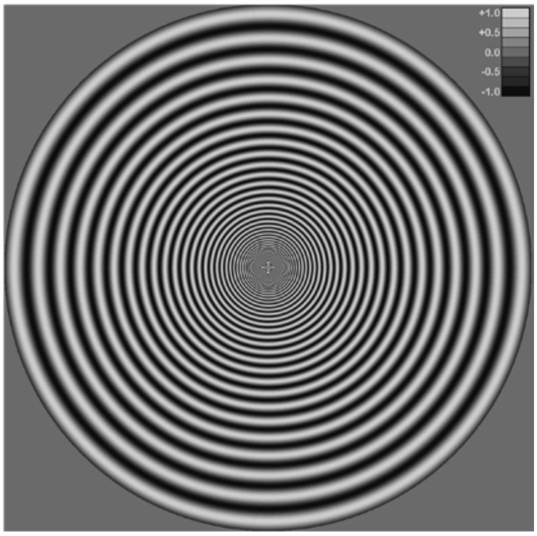


The information about the motion can be retrieved from the speckle dynamics by processing two images of the speckle pattern acquired with a small time lag. Both images are divided into small interrogation areas and cross-correlation functions of such a pair of interrogation areas provides the local displacement of the speckles – see figure. In order to do real-time processing of the expansion/contraction of the speckle pattern spatial-filtering velocimetry can be introduced [1].

The second figure illustrates a computer mask that can be applied to a long sequence of numerous speckle images of the moving object. It can be shown that such a filter has to be rotational symmetric and that the phase increments for each period has to be a logarithmic function of the radius. In the computer it is easy to implement a differential signal and two signals in phase quadrature (to gain the direction of the speckle dynamics)

The aim of this project is to build and demonstrate the real-time performance of such an optical device. An easy application for this device would be non-intrusive vibration measurements. In longer perspectives, the technique could provide an axial displacement sensor for robotics, navigational devices and much more.

In this project, the student will get a short introduction to speckle statistics and dynamics behind the technology. The student will design and construct an optical setup around the filter and demonstrate that this technique can facilitate real-time measurements of an object vibrating out-of-plane. Filters are available both as chrome masks, and refractive structures, see the figure.



The student will be using LabView in order to run the experiments and carry out the image post-processing. By and large, the students can modify existing codes for data acquisition, while doing their own codes for post processing.

Prerequisites:

- Preferably knowledge of lasers and optics.
- Preferably knowledge of programming in LabView.

Practical details: ECTS-points for the MSc students: 30.

Additional information:

[1] M. L. Jakobsen, H. T. Yura and S. G. Hanson, "Spatial filtering velocimetry of objective speckles for measuring out-of-plane motion", *Applied Optics* **51**, (9), 1396-1406 (2012). PDF

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