Faculty of Electrical Engineering & Computer Science
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City University of Applied Sciences

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Nils Müller

Gradient Estimation from Multiple Spots Images.

ABSTRACT - Masterthesis

in the metrology of optical surface measurement, one may determine the surface of an optical component indirectly using the spatial direction of a reflected light beam, followed by an integration of the measured slopes. Usually, the angle of the reflected beam is determined using a camera sensor at two different positions. The shift of the detected light spot at both camera position can be used to derive the slope of the reflected beam. This requires a movement of the camera at two positions for every measured slope.

A newly developed Etalon Sensor is used for the direct determination of an incident light beam in rotational and incident angles. An incident light beam with an angle larger than 0◦ can be subject to multiple reflections when passing through a glass plate. The distance between the occurring reflection varies with the incident angle and therefore can give information about the characteristics of the incoming beam.

A single light spot can easily be detected by calculating the centre of mass of an image. This is not applicable if multiple spots occur on the camera surface. So far in Lünings work the multiple spots were detected using a simple contour finding method. However, this method is prone to misdetection of overlapping spots, which occur at small incident angles, resulting in a very limited measurement range. The main objective of this work is the development of an algorithm that is able to detect multiple, highly superimposed spots accurate and reliably increasing the sensors measurement range in particular for small incident angles.

In this work an image segmentation approach is investigated, that detects multiple light spots using a clustering algorithm. Since the intensity distribution of a laser beam can be described using a modified Gaussian bell shape, a Gaussian mixture model (GMM) is a potential approach for the clustering and detection of multiple laser spots. The Parameters of a GMM can be determined using the iterative expectation maximization (EM) algorithm. Even though this algorithm improves or keeps the determined log-likelihood at each iteration, it is still prone to the local optima problem. In order to ensure the determination of the optimal parameters for the GMM, a modified EM algorithm is derived. This algorithm utilizes a novel modelling that is parsimony with regard to the number of parameters and can be applied for this

specific application. Furthermore, this work investigates additional numerical optimization methods like evolutionary algorithms, in particular the artificial bee colony algorithm (ABC), which has been shown to find the global optimum with higher probability than the classical EM algorithm.

The data provided are grey scale images from a CCD or CMOS camera, which are interpreted as the realization of a 2-dimensional histogram. Accordingly, the grey value of each pixel is understood as the frequency with which the respective pixel coordinates occur as the outcome of a sequence of random experiments.

The algorithms are evaluated on simulated and measured data, where various beam incident angles are created using a light source placed on a Stewart platform and a fixed Etalon sensor.