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EFFECTIVE LIMITS TO SUBPIXEL ACCURACY IN TRACKING MOVING TARGETS

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ABSTRACT

Sub-pixel methods increase the accuracy and efficiency of image detectors, processing units and algorithms thus providing very cost-effective systems for object tracking. Published methods usually achieve maximum resolution increases of two to three orders of magnitude, but no reasons for such limits have been presented. In this paper, we demonstrate that this threshold can be theoretically overcome by several orders of magnitude, permitting micro- and sub-micro-pixel accuracies. The necessary condition for movement detection is that one single pixel changes its status. We show that with the appropriate target one can increase the probability of a pixel change for arbitrarily small shifts, thus increasing the detection accuracy of a tracking system. The method is useful for long distance vibration measurement of structures.

Keywords: pattern recognition, target trucking, superresolution, long distance vibration measurement.

INTRODUCTION

Image processing techniques on video sequences are often used for direct measurement of vibrations. Majority of these techniques are based on mathematical morphology, Doppler vibrometry or speckle interferometry. Usually, in all these methods the nominal resolution of the system determines the accuracy of the measurement. Nevertheless, by imposing a priori knowledge about the object to measure, one can increase the resolution above this limit. By means of a known geometrical shape on the tracked target, some authors (Bruckstein, 1998; Mas, 2012) found resolution enhancements of two orders of magnitude. Since the better accuracy obtained with sub-pixel techniques, the less demanding hardware (detector and optics) is needed; it is worth to investigate about further increases of accuracy and if there is a theoretical limit to such improvement.

The most used methods to increase resolution are based on object shape recognition. Thus, accuracy is increased by means of analytical interpolation and precision does not really depend on the object movement since it is done inside the frame.

A completely different approach is proposed now. Since object movement implies changes in the image and, consequently, in detected pixels, we propose to use this information change in order to increase the accuracy of the system. Using numerical simulations, we demonstrate that micro-pixel resolutions can be achieved and further improvements are possible provided that the number of pixels in the sensor is large enough.

RESULTS AND CONCLUSIONS

The necessary condition to detect movement is that one single pixel changes its status. Let us consider that an object (or some of its parts) can be imaged on an area smaller than one pixel. If one manages to locate this object in the inner border of a pixel, a small movement will provoke an effective pixel change. Thus, an appropriate target design may increase the probability of this effect to take place and increase the detection accuracy of a tracking system.

In Figure 1 we show a sequence of this effect. With an object composed by randomly distributed dots, each one smaller than the pixel size, one can obtain a subpixel accuracy of the order of the inverse number of pixels in the detector, i.e. 1/(NxN)

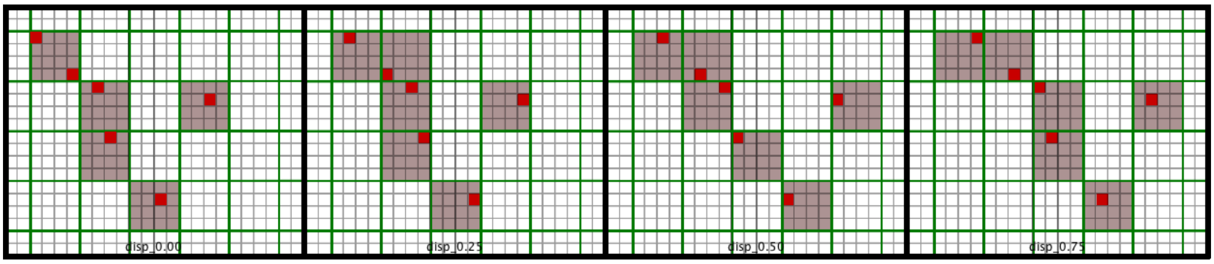

Fig. 1 - Detection of a horizontal displacement with accuracy 0.25 px with a random-dot cloud target. Notice that each displacement of ¼ pixel is detected through changes in the active detectors (shadowed).

The finding and the method with this particular target opens new ways to measure vibrations by tracking objects in a very cost effective way. Thus, this method can be used in the vibration measure of structures located at a very large distance from the point of measurement. This can be very useful, for example, to bridges with traffic located over a river; in which it is very difficult to approach without people risk or without stop the usability of the bridge. Alternatively, the method also makes possible the use of very low cost devices, which may be convenient in aggressive environment were there is potential damage for the measuring instruments.

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