3D shape measurement with temporal phase unwrapping and 1-D continuous wavelet transform

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ABSTRACT

The correct phase unwrapping in the presence of noise is a difficult problem and it has been of great interest since the last decades as observed in the literature. This is due to the spatial dependency that exists in traditional 2-D phase-unwrapping algorithms and, as a consequence, spreads errors in the reconstructed phase map. To solve this, algorithms known as temporal phase unwrapping (TPU) have been proposed; here the intensity of a fringe image sequence changes as a function of time, and therefore the elements of the phase-map are independent of each other. Thus, the 3-D measurement vision system by projection of fringe images presented here consists in capturing a sequence of images with sinusoidal fringes deformed by the height of the object. Then, the phase is processed by using a TPU technique based the one-dimensional Continuous Wavelet Transform (CWT). It should be noted that the use of CWT in one dimension is to analyze the intensity variations of the temporal sampled phase images, and the importance of this is in the detection of the frequency from which the phase is obtained as a linear function by means of an unwrapping in one dimension. We present simulated experiments and some real applications in digital archaeology and zoological morphometrics that validate the proposal.

Keywords: Profilometry, Wavelets, 3-D measurement.

1. INTRODUCTION

In the field of computer vision, profilometry for the measurement of three-dimensional objects based on fringe projection is a well-known technique.[1–8] The basic idea of profilometry is the projection of fringes over the measured object. This is an easy and efficient way to characterize three-dimensional information because the image of the projected grating is phase-modulated according to the 3-D shape of the object.

In the last two decades, there has been an increase in the research activities to develop the usually called temporal techniques which are a solution to some problems of classical phase measuring methods. The temporal techniques use a series of fringe images changing the fringe pitch.[9–16] Although temporal methods require the processing of several fringe images, most of them present three main advantages: (1) The phase computation is performed only in one dimension at every image pixel which is, in general, a simpler task. (2) The computed phase is already unwrapped. (3) Estimation errors are isolated at every pixel, avoiding error propagation over the image. Temporal methods for phase-measuring are based on the processing of phase change along the time axis. Some of them consist on the demodulation (frequency estimation) of the one dimensional signal at each pixel in the image using a spatial fringe carrier that introduces a temporal carrier frequency. Here, we describe a temporal fringe pattern method to compute the 3-D information, based on the Continuous Wavelet Transform (CWT) that requires a temporal fringe carrier. The CWT has already been applied in fringe pattern analysis and phase demodulation,[17–20] moiré interferometry[21] and profilometry,[22,23] being an adequate tool to process this kind of images. Although the proposed method requires a large number of images, they can be captured and processed in a reasonable time. The application of the proposal is verified in zoological morphometrics (skulls) and 3-D reconstructions of archaeological vestiges.

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