Enlarging computer-vision sensing-capabilities using pseudo-periodic patterns on the target of interest

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Abstract: Using pseudo-periodic patterns on the observed target releases usual computer-vision constraints by allowing subpixelic resolutions together with supra field-of-observation absolute measurement ranges. The allowed range of working distances is also tremendously extended using digital holography.

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1. Improved visual sensors using pseudo-periodic patterns on the target of interest

Computer vision is a powerful contact-less measurement tools successfully applied in numerous domains of application. In classical configurations however, optimal trade-offs have to be fund between resolution - that improves with higher magnifications - and measurement range - that is tied to the field of observation and increases with lower magnifications. Depth of field and working distances are also constrained by the imaging magnification chosen.

The use of pseudo-periodic patterns on the target of interest releases these usual computer-vision limitations in two main ways: *i)* The periodic pattern character allows phase measurements leading to subpixelic resolutions thanks to data averaging and efficient noise rejection. *ii)* Finely designed alterations of the periodic frame allows unambiguous pattern position encryption that makes the absolute measurement range independent of the field-of-observation of the imaging system [1]. Range-to-resolution ratios of about 10^6 were demonstrated with standard imaging devices [2].

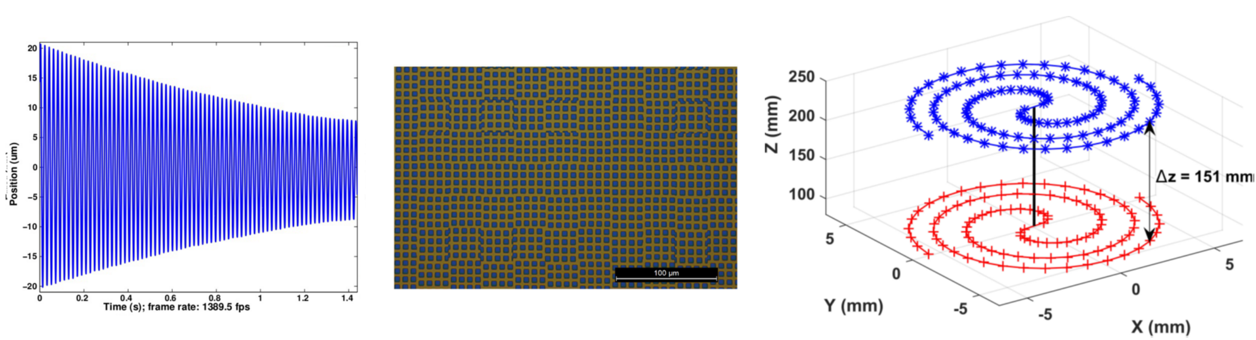

Fig. 1. Left: Free oscillations of a compliant structure measured versus a single direction at 1989fps. Middle: 2D pattern for displacement measurements in 2D. Right: Same trajectory reconstructed by digital holography at working distances separated by more than 15cm.

This approach was successfully applied to position registration [3], in-plane displacement measurements [2, 4] and micro-force measurements [5]. The approach was also validated using digital holography as imaging method with a tremendous enlargement of the allowed working distance range [6]. This paper presents an overview of this computer-vision sensing approach that seems very well suited to address diverse application needs, especially in the micro-robotic and biomedical domains.

Different patterning strategies are suited for in-plane position sensing. Fig.1.left presents the free oscillations of a compliant structure reconstructed at a 1989fps image rate by means of a 1D pattern made of two slightly different periods [2]. Displacements can be converted into micro-forces through the determination of the compliant structure stiffness [5]. Fig.1.middle presents a 2D pattern suited for 2D in-plane displacement. The method allows a sub-nanometer resolution over a unambiguous range of 221μm [5]. Fig.1.right presents the same in-plane trajectory reconstructed by digital holography over a working distance range of more than 15cm with a lateral resolution of 0.05μm.

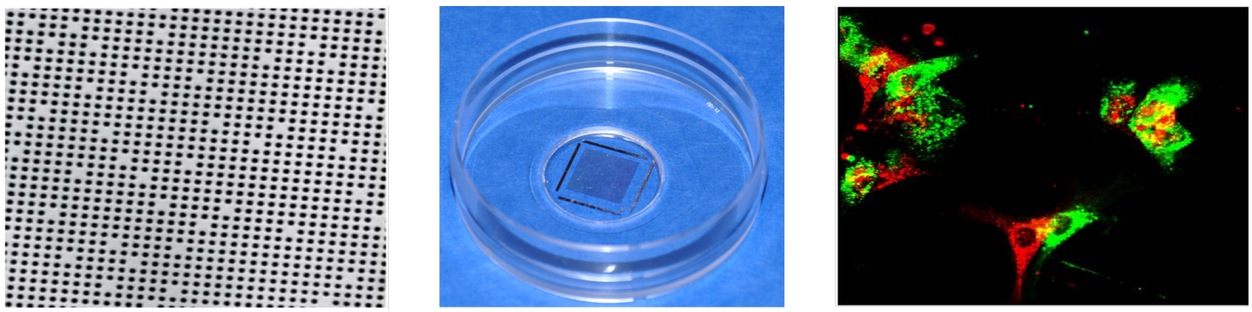

Fig. 2. Left: Example of pseudo-periodic pattern used as position reference pattern (PRP). Middle: Cell culture dish with integrated PRP. Right: Images (red and green) of the same culture area recorded after a 2h time interval. The PRP allows image registration despite the culture returned to the incubator between the successive microscopy analysis.

Fig.2 depicts the application of the method to the documentation of biological events in a living cell culture by fluorescence microscopy [3]. A pseudo-periodic pattern (Fig.2 left) forms a position reference placed a few tens of microns in the depth of a cell culture dish (Fig.2 middle). Images of cells are localized with respect to the cell container thanks to a second image recorded after shifting the focus at the pattern depth. Once returned on the microscope stage after a while inside a cell incubator, the area of interest is easily retrieved with the pseudo-periodic pattern and the cell images (red and green) are numerically registered within a single coordinate reference system (Fig.2 right).

The next step will consist in combining the high performances of in-plane position sensing by means of pseudo-periodic patterns with imaging methods sensitive to out-of-plane displacements to address the six degrees of freedom with a single visual sensor.

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