

**DIPARTIMENTO DI INGEGNERIA  
CORSO DI DOTTORATO IN INGEGNERIA INDUSTRIALE E  
DELL'INFORMAZIONE -  
PHD COURSE IN INDUSTRIAL AND INFORMATION ENGINEERING -  
35TH CYCLE**

Title of the research activity:	Development of hybrid methods for velocity field, stress and strain measurement through image analysis and computer vision algorithms
State of the Art:	<p>Image analysis methods are currently used in many different applications, such as velocity fields, stress and strain measurement. They bring many advantages respect to standard methods. In fact, they are all non-destructive contactless measurement methods, with high accuracy.</p> <p>The measure of velocity fields and the evaluation of the related maps is fundamental research topic in fluid dynamic. In fact, through velocity fields, it is possible to estimate fluid dynamic parameters and phenomena, such as vorticity, direction of motion and velocity magnitude. Usually the measurement of velocity fields is performed by established standard methods of image analysis, such as the Particle Image Velocimetry (PIV) [1][2] and the Digital Particle Image Velocimetry (DPIV) [3]. Particle Image Velocimetry is an optical method of flow visualization. It is usually used to obtain instantaneous velocity measurements and related properties in fluids. The fluid is generally seeded with tracer particles which, for sufficiently small particles, are assumed to follow the flow dynamics. The fluid with entrained particles is illuminated so that particles are visible. The motion of the seeding particles is used to estimate the velocity field of the flow. Furthermore, Optical flow methods are commonly used for the velocity mapping [4][5], even if issues like ambiguities, changing lighting conditions and occlusions limit the application of this methods. Another image analysis technique is the Thermoelastic Stress Analysis (TSA) [6][7][8]. It is an indirect non-contact technique for the measurement of the stress field on the surface of a structure subjected by a dynamic load. According to the thermoelastic effect, under the hypothesis of adiabatic and reversible transformation, the stress field and the relative variation of the temperature are strictly related. Furthermore, for strain and displacement evaluation, Digital Image Correlation (DIC) [9][10] is often used. This method is usually used to measure full-field displacement and strains, and it is widely applied in many applications. Compared to standard methods, such as strain gages and extensometers, the quantity of information gathered during mechanical tests is increased due to the ability to provide both local and average data using digital image correlation.</p> <p>On the other hand, computer vision is an interdisciplinary scientific field that deals with how computers can be made to gain high-level understanding from digital images or videos. From the perspective of engineering, it seeks to automate tasks that the human visual system usually do. Computer vision tasks include methods for acquiring, processing, analysing and understanding digital images, and extraction of high-dimensional data from the real world in order to produce numerical or symbolic information. For instance, Scale Invariant Feature Transform (SIFT) is a computer vision algorithm used to detect and describe local features in images [11][12]. This method is usually used for different applications, such in medical field [13], face detection [14], urban planning [15] or in surface topography [16]. From the SIFT algorithm, many other methods have been derived in last years. Speeded Up Robust Feature (SURF) [17] is one of the most applied, due to its robustness and efficiency.</p>
Short description and objectives of the research activity:	<p>The aim of the research is to develop hybrid measure techniques that merge different image analysis methods and include computer vision algorithms, in order to innovate and optimize measurements and data processing, in terms of robustness, efficiency, computational effort and economics of instrumentation. An example of merging two standard methods is to develop an algorithm that is able to measure the stress distribution through the Thermoelastic Stress Analysis, and, at the same time, apply the Digital Image Correlation to the</p>

	<p>thermal video in order to estimate a strain map which can be used as full-field scaling factor, instead of use the standard strain gauge calibration.</p> <p>Furthermore, an example of a computer vision algorithm combined with a standard image analysis technique is to use the TSA and SIFT. In fact, one of the most problematic issues that occurs during thermoelastic acquisitions is the steep motion of the body in exam between a frame and next one. It usually results in a blurring effect of the edges of the body. The SIFT algorithm can be used as a motion compensation technique in order to limit this issue in robust and rapid way.</p> <p>Lastly, the measure of velocity fields is another research topic where the application of computer vision algorithms can be really innovative. Usually they are evaluated through Particle Image Velocimetry, but the employment of methods such the Scale Invariant Transform can result in impressive innovation. In fact, PIV instrumentation is generally expensive and it requires strict acquisition conditions. However, SIFT algorithm is invariant from changes in illumination, perspective and scene points of view, so it can obtain the same results with less complex instrumentation but the same accuracy.</p>
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