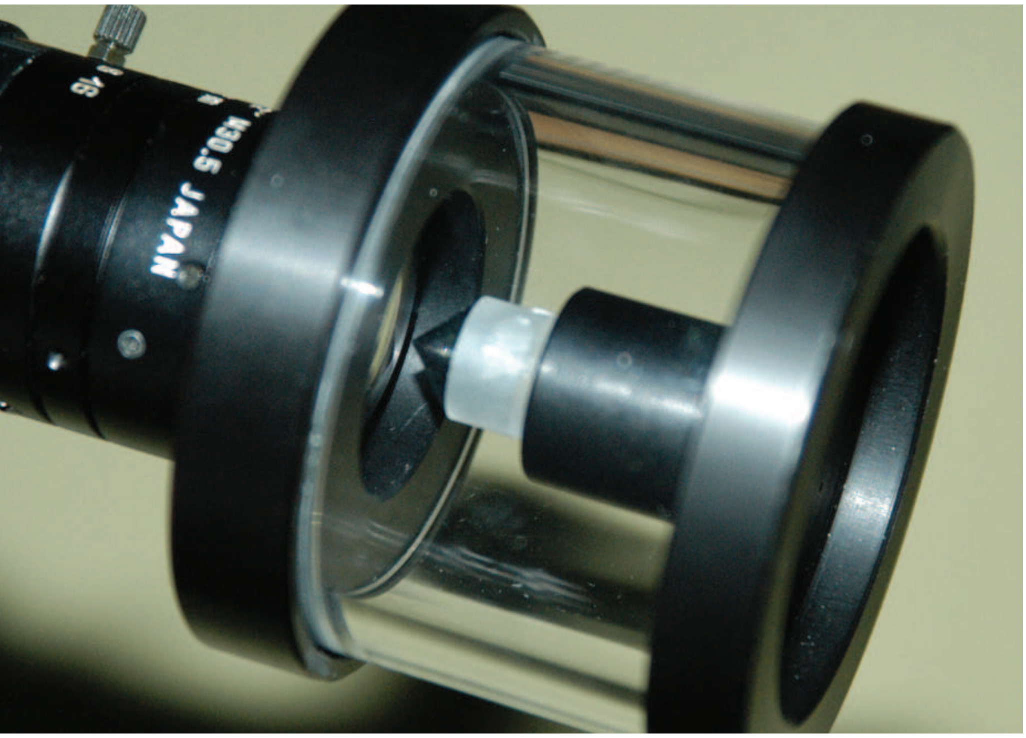
Grace

inteGration of pRocess and quAlity Control using multi-agEnt technology



1 Conic vision system

Grace project

The EU FP7 Grace project aims at **integrating process and quality control within a production line**. This goal is fully in line with the trend to develop modular, intelligent and distributed manufacturing control systems.
The system is based on a collaborative Multi-Agent System (MAS) which operates at all stages of a production line and it is complemented by self-adaptive control schemes developed at the level of process resources and quality control stations as well as at line or factory level. The MAS aims to individually tune parameters of each product taking into account information collected during the whole production process, so to compensate production process variance.
The innovation is the **new vision of the production process which leads to a deep integration of process control with quality control and finally product value**.

Conic Vision

Catadioptric vision system based on conic mirror for dimensional measurements inside near-cylindrical cavities

Cylindrical objects are quite common in engineering: pipes, ducts, reservoirs and many other things can be considered as examples; we may call them cylindrical cavities. An **omnidirectional vision system provides an innovative solution** for non-contact dimensional measurements inside near-cylindrical objects. The main advantage of an omnidirectional vision system consists in the possibility to have a full field measurement inside the cylinder, with the acquisition and processing of one single image.
An omnidirectional vision system overcomes the limitations and reduces the complexity of state-of-art alternative solutions, which are generally based on scanning devices. Indeed, a classic layout to measure dimensions inside a cylindrical surface implies to rotate the measurement device and scan the whole cylinder; the measuring device could be a camera or a line scanner. Such a solution would imply building an accurate scanning device with moving parts and would provide a sequential acquisition of data. All this is mechanically complex and slow.
The catadioptric vision system developed in Grace project, consists in a coaxial conic vision system which allows to **measure dimensions all around the cylindrical cavity with one single image** acquisition, thus being faster than using a conventional profilometry techniques and eliminating any moving parts, except for the insertion of the vision system inside the cylindrical object to be measured.

The conic vision system

The catadioptric system is composed of a conic mirror, with a 90° tip angle, coaxial to the camera lens optical axis (Figure 1). Such a vision system performs a geometric transformation that maps a cylindrical surface (object surface), whose

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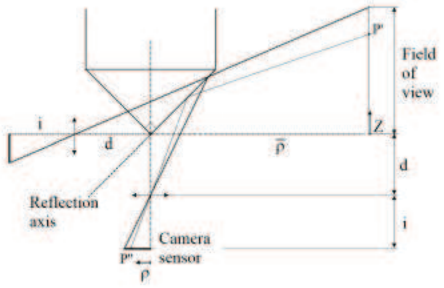
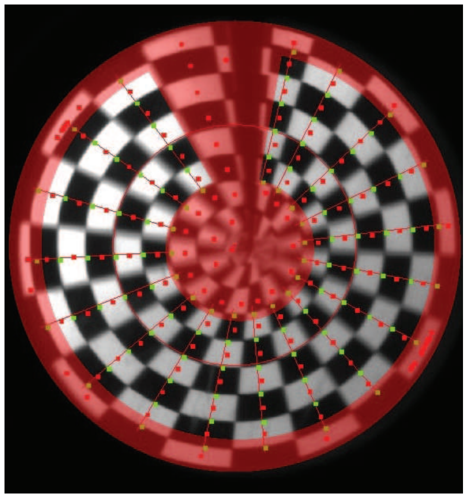
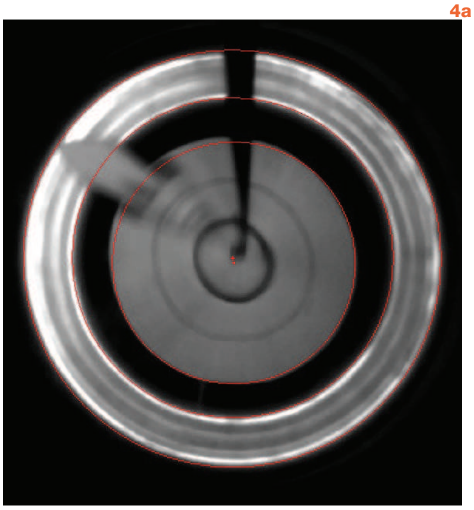


3a

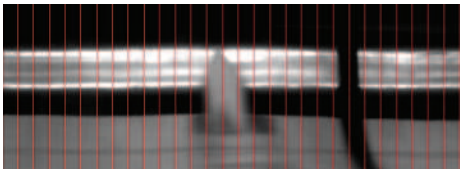
3b



4a



4b



2 Optical schema of the conic vision system

3a 3D model of the cylindrical chessboard pattern target used

3b Cylindrical chessboard pattern image acquired by the catadrioptic vision system and calibration procedures

4a-4b Acquired image and its unwrapping

axis coincides with the camera optical axis, into a circular annulus in the image plane domain (Figure 2).
In any coaxial conic mirror vision system it is possible to establish a geometrical correlation between linear dimensions over the cylindrical object surface and the image plane.

The two coordinate systems which locate points on the two surfaces are:

- (z', θ') belonging to the cylindrical object surface (defined by $\rho' = \bar{\rho} = const$);
- (ρ'', θ'') belonging to the image plane on the camera sensor (defined by $z'' = -(d + i) = const$).

The angles θ' and θ'' are mapped 1:1 in the two coordinate systems if camera/lens, conic mirror and object cylinder are exactly coaxial, aligned along the optical axis. Therefore we have only a linear relation between z' and ρ''. This relation that maps z' to ρ'' is Equation (1), which can be derived through simple geometrical considerations from the scheme of figure 2:

$$z = (\rho' \cdot (d+\bar{\rho}))/i \qquad (1)$$

System calibration

The geometrical calibration of the conic vision system is performed by a cylindrical chessboard pattern used as reference (Figures 3a-3b); this compensates for geometrical aberrations and possible misalignment of optical elements with respect to the cylinder axis.
Calibration allows to estimate measurement uncertainty; system sensitivity between output ρ'' and input z' is equal to 10.56 pixel/mm on a camera having 1388x1038 pixels and a focal length of 12 mm, measuring over a cylindrical surface having diameter 320 mm. Measurement uncertainty, expressed as expanded uncertainty at a confidence level of 95%, is 0.32 mm over a full length measurement range in z direction equal to 18 mm.

Results

Dimensional measurements in axial direction can be performed by processing the acquired image. Figure 4a shows an example of image taken by the conic vision system inside a washing unit of a washing machine; the gap thickness between drum and gasket can be measured over 360° by image unwrapping (Figure 4b).