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3D Inspection Technology for Industry

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Abstract: The paper gives a short overview of a Eureka EUROSTARS project, which has dealt with the development of 3D vision technology for inspection testing. The work was performed by an international consortium, consisting of Spanish, Austrian and Hungarian partners, both from research-oriented industrial SMEs, and from academic research institutes.

Keywords: 3D photography, orto-images, end-of-line testing, 3D video

1 Introduction

Digital image capturing has turned to be so simple and cost-effective, that its wide application is not at all considered a big fuss. With the advent of cheep digital cameras, even with a digital networking interface as a built-in feature, it is a common appliance, used even by non-professionals, by children and persons of any age.
The international initiative of EUREKA has inspired R&D oriented entities, like SME-s and research partners, to combine their efforts and initiate international cooperation that aims to bring new technologies and high-tech-oriented services to reach marketable level in a short time-frame (20-30 months).
The formation of a EUROSTARS project had to be based on the cooperation of SMEs and research entities, from preferably 3 European countries. Our consortium was formed this way, and 2 Spanish partners from Asturias, an Austrian partner from Steyr, and 2 Hungarian partners started to cooperate. Hungary established the consortium.

2 Problem Formulation

General, simple pictures are sometimes not good enough to run serious, robust, industrial control tasks. Even a simple task, such as commanding a robot to go and insert a tool into a slot, could need smart visual devices (sensors, etc.) [1]
Completeness inspection is an important step in industrial assembly processes. It is usually an end-of-line inspection task to check whether any parts are missing, or whether all parts are correctly positioned and assembled. Completeness inspection with cameras in 2D faces a few challenges that are hard to overcome with conventional methods (see Figure 1):

Figure 1. Audio equipment assembly for testing, where 2D pictures are not enough for completeness inspection

(1) Limited contrast: the single parts that should be seen cannot be identified in the current view because of low contrast compared to the background.
(2) Only rough presence detection: 2D systems are often only able to detect the presence/absence of parts, but are usually unable to check if a plug is securely mounted or not.

(3) Non-rigid parts: parts such as cables, hoses or similar, can change their shape with a very high degree of variation. They cannot be fully inspected without information about depth.

The main source of all these problems is the fact that 3D information is missing and that it is economically infeasible - and sometimes even impossible - to obtain an optimal view of each single part of the assembly.

We solve this problem by developing a technology that allows the creation of a 3D appearance model from a number of regular 2D images taken with conventional cameras. From this set of oblique images we produce "ortho-images" that represent a parallel, orthogonal projection of the object, similar to technical line drawings, but extended with color and texture. This enables us to calculate a very large number of views of the object, each chosen in such a way that the part to be inspected can be optimally seen in the image. With this technology we are able to substantially extend the capabilities of completeness inspection systems.
The target market is the end-of-line inspection systems for manufacturing and assembly lines with cycle times in the range of 2-30 seconds. The resulting product is based on the CIS-3D project and consists of an image acquisition system, including high-resolution cameras and illumination, and a software that performs the completeness inspection on an arbitrarily large set of ortho-images that are generated from a few oblique 2D images.

The intended market of the CIS-3D product is machine vision companies and system integrators. The machine vision market in Europe has a size of approximately 3.000M EURs. In the area of "discrete inspection", which amounts to 40% of all machine vision systems, the subtopic of "completeness inspection" accounts for roughly 50% of the applications. [6] Thus it's aiming at a significant share (around 20%) of all machine vision applications. In addition to this the technology has a high potential of opening new market opportunities, because many of the applications that involve complex assemblies, detailed inspection and non-rigid objects are among those that are not yet solved.

The leading SME in the project is METRIA, who have developed a technology for the fast conversion of oblique 2D images into 3D appearance models. This technology has so far been used for documentation of cultural heritage and architecture and it has been transformed for the use in industrial completeness inspection.

3 Problem Solution

There are four technological alternatives, all of which can only partially address the problems that we intended to solve.

3.1 3D SCANNING

3D Scanners, which may be profile scanners based on laser triangulation, or methods based on stripe projectors, typically generate a shape model only. They thus provide 3D information. However, they do not capture color or surface texture and have thus limited capabilities with respect to completeness inspection. E.g. with 3D scanners it is very hard to determine whether a flat label (e.g. with a bar code) is attached to the object in the correct position. Recent developments, such as those by SICK AG [**] allow the combined acquisition of reflectance and shape. However, the light source used for this purpose has to be a laser and thus it is not possible to obtain a color image; only reflectance in the wavelength of the laser can be acquired. White light scanners can also bring some kind of grayscale information which in certain conditions can also be used for barcode reading or OCR applications.

3.2 MULTIPLE CAMERAS

A couple of cameras are mounted in fixed positions and they produce a number of different views of the viewed object (see Figure 2).

Figure 2. Testing with multiple cameras.

The main problem is that one would like to have a much larger number of different views in order to

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see each section of the part under inspection from an optimal point of view. Clearly, there the costs and also the available space limit the number of cameras that can be used. In addition to this, such fixed setups suffer from inflexibility. Even small changes of the shape of the object quite often require re-adjustments of cameras to optimize their field of view.

3.3 ROBOTIC POSITONING INSPECTION

Instead of having a large number of cameras, a robot places the object in front of a single camera in a number of different poses. An image is recorded from each of the poses and checked for completeness. The main problem with robotic inspection systems is the time it takes to acquire all the different images. Thus such robotic inspection systems are usually limited to larger assemblies, with high cycle time that require a large degree of flexibility.

3.4 ROBOTISED CAMERA SETUP

The fourth version is also a robotic setup, but the robot holds and positions the camera in its "hand" to a required number of positions in the space, while the target, inspected part is on a table, below, or the parts are moving on a conveyor one after the other. In the Robotic Lab of MTA SZTAKI have initiated tests also with this 4th version, and also by applying 2, or 3 cameras, preset at given locations, with set viewing positions.

3.5 MATHEMATICAL BACKGROUND

The software elements referring to the mathematical model of the solution are elaborated by the Spanish and Austrian project partners and their work summary is accessible as the Eureka project summary report. [7]

4 3D Inspection application areas

There are numerous application areas, where 3D inspections are relevant. In the presentation of [2], at the MANUFACTURING 2012 International Conference, we have given a long list of novel, technologically relevant and engineering-wise challenging solutions or potential applicability.

5 Offering 3D features

In addition to inspections and testing, our activities were also involving tests with the generation of 3D views on screens, e.g., on web pages. As it has been tested, there are good reasons to add 3D capabilities for sophisticated web pages, in order to get the messages more targeted, or to highlight comfort of views, and pleasure of seeing. [3], [4].

With our investigation scenarios, we have integrated a technology to easily adapt 3D pictures into documents and display-oriented output devices. We have selected an excellent environment for generating such fancy views: we visited the great ball-room of the palace of the Hungarian Academy of Sciences, which is furnished with statues all around the hall (see Figure 3). The halls, like the library of the Central building if the Academy of Sciences, with its intern pillars are also excellent target areas for showing the 3D view advantages Figure 4.

3D technology is progressing in such a great speed, that during the last 16 months, a number of high-tech companies have offered 3D video-recorders on the market. (eg. Sony, Panasonic, JVC, Fuji, Olympus)

Figure 3. The great ball-room of the palace of the Hungarian Academy of Sciences.

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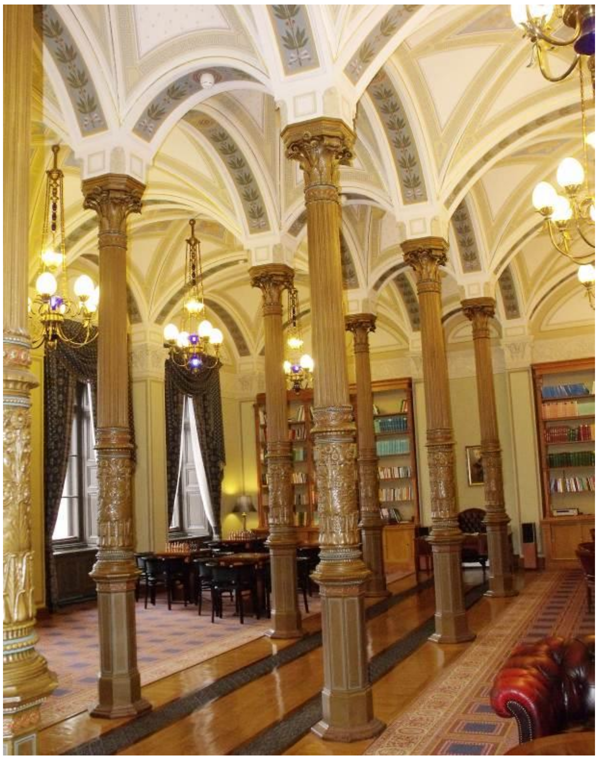

Figure 4. The library hall of the palace of the Hungarian Academy of Sciences.

With a Sony model, we have extended our service capabilities, to include 3D video-recordings in addition to 3D photography services for inspection and testing.

6 3D visualization

The acquired 3D data and images should also be displayed properly for the viewer. Commercial 3D displays already enable a large number of people to enjoy the benefits of these technologies. With non-conventional environment, the view and feeling can be enhanced in a number of ways. In our case the software we have been using to visualize 3D information is VirCA [5], a system developed in MTA SZTAKI. This way we can combine simulated data or equipment with real hardware and information gained from our sensors. With 3D viewing glasses, we do not just look at a single TV screen, but instead, we build several square-meter walls all around us, thus, directing our head in any direction, the full surrounding virtual environment changes according to the needs, and to the position and orientation of our head-mounted glasses.

7 Conclusion

3D technology can serve as a high-tech solution for many tasks, but since it is gaining a large momentum in our every-day and personal life as well, naturally the industrial application scenarios will become also very common. We were glad to have the first-hand experiences and engineering tasks applying 3D technologies.

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