QUALITY CONTROL BASED ON ARTIFICIAL VISION
Computer Vision is used for understanding and interpreting visual information. Computer-vision systems bring together imaging devices, computers, and sophisticated algorithms in order to solve problems in areas such as tool-machining, medicine, document analysis, autonomous navigation, robot teleoperation, etc.

Nowadays, manufacturers look for reliable and consistent automated visual inspection of their products to reduce manual involvement in the application of pass/fail criteria. Often, high speed, high quality, and high resolution applications require an innovative and customized solution, outside the scope of standard systems.

Currently, plain products such as circuit boards, electronic products, clothing products, etc. are inspected by vision systems. In the future, other examples could be found in welding inspection, surface inspection of materials such as semiconductors, ceramic, metal, wood, weaves, and stone.

Active vision is being investigated for industrial inspection because of its efficiency, flexibility, and advancement in imaging technology. For example, variable magnification optics allows the system to be used for a wide range of applications even for particle size dimensions.

In typical painting plants, sealing and cavity waxing operations take place to ensure water tightness and sheet metal edge corrosion protection. Defects may consist of small particles bonded to the steel, which are more difficult to detect. In the case of small particles, their sizes increase incrementally with each additional paint application until they do not meet the quality control standards, resulting in the rejection of the product.

Keeping in mind that 400.000 million m² of sheet are painted every year for car's or household appliance's their long-life is a serious matter. Many manufacturing companies in Europe and all over the world are facing similar problems because nowadays, there are no automatic systems developed and available to solve this problem.

Modern industries are providing services to a more demanding client base. Factories of the future will have to increase quality requirements and it is not surprising that the leading industries are trying to integrate automated systems in their manufacturing processes in order to increase consistency of product quality.

There have been European projects related to the optimization of paint process such as: “Efficient low volume high variant robotized painting”, “Improved removal of particulate contaminants from surfaces to increase functionality appearance of products”, and “Rheology engineered water borne dispersions for high performance paints”.

In today's car factories, skilled operators inspect the product for defects, detecting less than 50% of minor defects. These non-detected defects constitute corrosion sources that reduce the life of the products. However, even if the defect is detected before the product leaves the factory, the cost of repairing it is very high.

As a consequence, human inspection constitutes a barrier in the automation of the whole process of detection and correction.
The completely automated inspection system (inspection tunnel) for defect detection and monitoring of painted car-bodies based on computer vision techniques and distributed is composed of:

1. A vision system based on cameras, an acquisition and lighting subsystem along with sophisticated defect detection and classification algorithms.

2. A Cartesian mechanical structure for moving image acquisition devices (cameras) and lighting elements.

3. A set of displays as man-machine interfaces, where defects are highlighted for later manual repair.

The image acquisition subsystem is composed of 12 digital CCD high resolution cameras acquiring at 15 frames per seconds, assembled with high quality optics with variable focal length. Each camera covers a part of the body where some overlapping is established for adjacent cameras in order to avoid missing defect detection. These cameras are fast enough to meet the temporal requirements initially established. They are connected to acquisition boards that run on a dedicated industrial PC. The lighting subsystem uses high frequency fluorescent lamps mounted on 11 arcs moving at a constant speed. A Cartesian robot constitutes the inspection tunnel where the fixed structure supports the acquisition subsystem while the lighting subsystem is on the mobile structure (gantry type).

A display subsystem based on several screens provides information about the nature and location of the defects in the polishing area. A priority criterion for the repairmen is given by displaying large defects in red while small defects are displayed in green. These criteria can be modified according to the quality control department.

The completely automated inspection system (inspection tunnel) for defect detection and monitoring of painted car bodies has been running for more than 2 years at the Almussafes (Valencia, Spain) factory of the FORD Company. It currently inspects 1,500 vehicles per day, in a processing time less than 10sec. With this system, it is possible to detect and classify defects with an improvement greater that 90% with respect to human inspection.

Traditionally, the inspection and correction of the painted surfaces was carried out by workers under quite uncomfortable conditions: they used their eyes and hands as their only tools in an environment with a high luminosity level, and with limited time for each item to inspect. This consequently accelerates their ocular fatigue and leads to less reliable defect detection.

Moreover, some defects that workers are unable to discover, due to their small size or their less-accessible location on the product. The new vision system improves the working conditions and comfort levels of the workers on the factory paint lines.

As a result of all of this, an international patent (PCT type, ref. PCT/ES2007/000236) has been generated based on artificial vision and distributed computing aspects, in addition to another international patent (ref. PCT/IB2010/052193) describing the industrial system already implemented at the Factory.
Defects appear as an inevitable variation of the optimum conditions because of powder, worker mistakes, temperature variation, etc. and show up as surface alterations in the layer they are present.

Automatic painting processes are normally performed as a continuous process, with the product passing through different sections. Paint coats are sometimes applied electrostatically by spraying under controlled conditions of temperature, humidity, and down-draft air speed.

The defect detection process is based on the application of computer vision techniques, establishing the following phases:

1. Acquisition of images
2. Merging of images
3. Matching of deviations in the image with respect to a model image
4. Blurring of the different levels of illumination by the tubes
5. Thresholding for binarisation of the image
6. Detection and classification of defects

Therefore, for each camera, images from the sweeping of the lighting subsystem over the body car are merged into a resulting image. This image is processed with the aim of obtaining a binary image showing the defects in black on a white background. The selected defects are then classified following the criteria provided by the quality control department and marked on the display screens.

There is an automatic self-adjustment process of the threshold image wherein the level of each pixel depends on the zone visualized, such as distances, inclinations, and color of the surface. In the threshold image, the defect may appear as a single pixel or as a group of pixels.

A catalogue of detected defects can be summarized up in five types:

- Fibers: Elongated shape (0.5x6 mm²).
- Rest of putty: circular shape with diameter from 3 to 6 mm.
- Husk of tools: shape with diameter from 3 to 6 mm.
- Human hair: Elongated shape with variable-length (20 mm aprox.) and 0.3 mm thick.
- Dust from sanding and priming: circular shape with diameter of 0.3 mm.

Based on a feature set, such as position, area, perimeter, length, area/perimeter, major axis, minor axis, and elongation, extracted from each defect, it is possible to carry out accurate classifications.

The application is completely configurable and allows the tuning of the following variables:

- Minimum and maximum sizes of the defects to be detected.
- Manual and automatic regulation of the exposure time of the camera for each car body, depending on its color (information provided by the management system of the company).
- Manual and automatic regulation of the lighting of the central lamps.

At the end, the processing software displays resulting images and also generates reports containing the number of defects found, their classifications, and locations.

Defects are classified and displayed in accordance with color coding as a function of size, defect type, and other characteristic. Operators receive an image with duly-coded defects prior to the process of polishing and repair.
DESIGN AUTOMATION AND SIMULATIONS

Using simulations, it is possible to take into account aspects such as lighting variations, limitations of the inspection area (hidden zones), high-speed production line, high resolution required, and 3D data registration.

We have implemented a simulation application enabling the reproduction of the inspection process of a car body based on CAD models according to a set of parameters. In addition, the simulation is linked with an optimization process, which computes the optimal location of cameras and lights as well as their movements. In addition, genetic algorithms for the design automation process of the inspection tunnel have also been developed.

The simulator has been developed with a high degree of flexibility and performs the functions listed below.

1. Calculation of the electromechanical structure of the inspection tunnel.
2. Placement of fixed and mobile elements.
3. Calculation of optimal locations of cameras and moving lights.
4. Focal length and zooms of cameras
5. Range in the intensity of lights.

The simulator provides the ability to verify and validate the position of cameras and lights, ensuring that there are not hidden parts as a consequence of structural interferences.

Common situations and solving actions are listed below:

- Reflecting condition variations due to 3D painted metal shape
  The reflection could not appear in the desired place with the proposed illumination system because of the surface curvature. An optimal solution has been obtained for camera and light source locations based on car body geometries.

- Reflecting condition variations due to the colour of the painted metal
  This is overcome within a solution based on the design and implementation of robust artificial vision algorithm.

- Lighting variations due to external sources
  The inspection system is located inside a black chamber (tunnel) in addition to the implementation of robust defect detection algorithms.

- Uncertainty on body car movement and vibrations
  Small movements are considered as noise and they are filtered by appropriate algorithms. In addition, certain kinds of matching and predicting algorithms are also introduced in order to avoid uncertainty of the position of the car body.

- Hidden zones to inspect
  In this case, an increase in the number of light sources and cameras is the solution.

- Information overflow, due to the resolution required and production line speed
  A distributed system inspection based on several processing units for separately processing the image corresponding to the different parts of the body.

- Unsuccessful classification of defects. (i.e. bubble of paint or metal defect require different treatment)
  An expert system is introduced for identifying defects and their origin.
FURTHER DEVELOPMENTS

Further developments are focused on two directions:

1. The introductions of Human-Machine Interfaces (HMI) based on multitouch screens.
2. The developments of robotic systems for the polishing phase.

The interface is focused on experimenting with a more natural way of interaction between humans and machine tools or robotic systems based on multi-touch screens; this is in order to provide an innovative improvement of supervision control for the whole system.

Large screens (42 inches or more) will also include live pictures of the car body, defect location maps, primary classification of defects as well as enhanced images with different degrees of enlargement, and visual control tools for the purpose of executing direct orders to the robot for accomplishing the correction task.

Experiments so far have probed the success of the system functionality based on different usability tests, first in a virtual environment, and later in industrial environments.

Several missions that will be taken by people that already work on this industrial sector have been implemented. The methodology of tests covers quantitative and qualitative data retrieved from potential users.

In this context, the implementation of an automated correction system has obvious strategic importance to the industry and society as it satisfies clear needs expressed by consumers, manufacturers, and even workers. It will produce an important step forward in quality and energy savings. It will be based on Polishing Robot System.

A manpower interface, which would initially enable the worker, and subsequently the robotic system, easy localisation and classification of the defects could be very interesting.

As an additional target, it will be necessary to redesign or update automatic polishing tools to fit process time, methods, and line speed conditioning. The interface will include tool movement simulations, information about robot trajectory planning as well as feedback force controllers in robotic systems.

It is essential to study present manual techniques applied in the polishing stages (time evaluations, methods, line speed conditioning etc.) before designing new tools to be installed in the robots. These tools will be first tested manually in order to define proper actions, and later on assembled as end-effector of robotic systems.

It is important to take into account the allocation of the robotic system in the cell, as well as the implementation of force control algorithms in the context of the polishing phase.

In terms of research, the force/position control in robot selected polishing, and the passivity-based controllers, in comparison with inverse dynamics controllers, are expected to have enhanced robustness since they do not rely on the exact cancellation of non-linear terms.

As in typical passivity-based control schemes for robot manipulators, the resulting control laws consist of a non-linear model-based term and a linear compensator action. In other passivity-based hybrid force/position controllers, the reference vector is related both to the end-effector position error and to the contact force error.
The Institute is a non-profit research association promoted by some of the most important automotive industries of the region.

The Institute constitutes a specialized technological center to conduct research within the industries which are mainly involved in the automotive sector, through national and international projects. In this sense, IDF is establishing itself as a recognised partner for carrying out R&D projects.

In addition, the Institute hosts COMPO-Networking, an association of some of the most important European producers of polymer materials.

The Institute carries out R&D projects in the following areas:

Product Design, supports a wide range of services such as design management, auditing, and evaluation; assesses scenarios and also provides methodologies for creating new products and services, opportunity detections, modelling, prototypes, and visual communication of the product. Extensive use of CAD/CAM/CIM systems is made for the design of new products.

Manufacturing: high-speed machining using robot arms (CAD/CAM/Robotics) as well as research in resin transfer moulding numerical simulation, monitoring and control for mould filling and resin cure; and manufacturing with thermoplastic matrix composites (GREEN-COMPOSITE).

Robotics and Automation: industrial solutions in terms of monitoring, diagnostics, control and communication systems, in addition to teleoperation and remote control systems, sensor fusion, smart sensors, etc. for mobile robots and vehicles.

New Energies: research area in opto-electronics specialises in the structural, electricals and optical characterisation of compound semiconductor materials for optoelectronic applications such as solar panels and photoemitting devices.

Information Technologies: knowledge management and information auditing, standardization and e-learning, multimedia development, user-friendly interfaces based on virtual reality; design and implementation of Human Machine Interfaces (HMI) including functionality, ergonomics, and usability.