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THE ESSENCE AND APPLICATIONS OF MACHINE VISION

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Subject review

Machine vision (system vision) comprises using computer vision in industry. While computer vision is focused mainly on image processing at the level of hardware, machine vision most often requires the use of additional hardware I/O (input/output) and computer networks to transmit information generated by the other process components, such as a robot arm. One of the most common applications of machine vision is inspection of the products such as microprocessors, cars, food and pharmaceuticals. Machine vision systems are used increasingly to solve problems of industrial inspection, allowing for complete automation of the inspection process and to increase its accuracy and efficiency. In the case of manual inspection on the production line as well as in the case of application of machine vision systems, digital cameras, smart cameras and image processing software have been used. This paper presents the principle of image processing, the components of the system and possible applications of machine vision in the present.

Keywords: *image processing, inspection, machine vision*

Bit strojne vizije i primjene

Pregledni članak

Pojam strojne vizije (vizijskih sustava) obuhvaća industrijsku primjenu računalnih vizijskih sustava. Dok je računalna vizija usmjerena uglavnom na obradu slikovnih zapisa na hardverskoj razini, sustavi strojne vizije najčešće zahtijevaju uporabu dodatnog izlazno/ulaznog sučelja i računalnih mreža za prijenos podataka generiranih od strane drugih procesnih komponenti, primjerice robota, manipulatora itd. Jedan od najčešćih primjena strojne vizije jest kontrola kvalitete proizvoda, primjerice mikroprocesora, automobila, hrane i farmaceutskih proizvoda. Sustavi strojne vizije učestalo se upotrebljavaju za rješavanje problema industrijske kontrole, te omogućuju potpunu automatizaciju procesa i povećanje pouzdanosti i učinkovitosti. Takvi sustavi rabe digitalne fotoaparate, kamere i odgovarajući softver za obradu slikovnih zapisa kako kod ručne, tako i kod automatske kontrole na proizvodnoj liniji. U radu su opisana temeljna načela obrade slikovnih zapisa, dijelovi sustava i današnje mogućnosti primjene sustava strojne vizualizacije.

Ključne riječi: *kontrola, obrada slikovnih zapisa, strojna vizualizacija*

1 Introduction

The introduction of the automation has revolutionized the manufacturing in which complex operations have been broken down into simple step-by-step instructions that can be repeated by a machine. In such a mechanism, the need for the systematic assembly and inspection has been realized in different manufacturing processes. These tasks have been usually done by the human workers, but these types of deficiencies have made a machine vision system more attractive. Expectation from a visual system is to perform the following operations: the *image acquisition* and *analysis*, the *recognition* of certain features or objects within that image, and the *exploitation* and *imposition* of environmental constraints.

Scene constraint is the first consideration for the machine vision system. The hardware for this sub-system consists of the light source for the active imaging, and required optical systems. Different lighting techniques such as the structured lighting can be used for such purpose. The process of vision system starts with the image acquiring in which representation of the image data, image sensing and digitization is accomplished. Image sensing is the next step in order to obtain a proper image from the illuminated scene. Digitization is the next process in which image capturing and image display are accomplished. The last step in this process is the image processing in which a more suitable image is prepared. The first aim of this article is to describe a simple machine vision system. Second goal is to show typical examples of the visions systems in the automated manufacturing systems [1].

Finally, authors try to present some ideas about the development of the new machine vision systems by suggesting new acquisition systems. In this respect, by the advent of the suitable laser light sources, design of a 3D camera vision system based on the laser scanning method has been an interesting issue.

2 Operation of a machine vision system

A visual system can perform the following functions: the image acquisition and analysis, the recognition of an object or objects within an object groups. As can be seen in Fig. 1, the light from a source illuminates the scene and an optical image is generated by image sensors. Image acquisition is a process whereby a photo detector is used to generate an optical image that can be converted into a digital image. This process involves the image sensing, representation of image data, and digitization. Image processing is a process to modify and prepare the pixel values of a digital image to produce a more suitable form for subsequent operations. The main operations performed in the image processing are outlined in Tab. 1. Segmentation seeks to partition an image into meaningful regions that correspond to part or whole objects within the scene. Feature extraction in general seeks to identify the inherent characteristics, or features, of objects found within an object. Pattern classification refers to the process in which an unknown object within an image is identified as being part of one particular group among a number of possible object groups [1].

3 The components of machine vision system

A typical machine vision system consists of several components of the following (Fig. 2):

- one or more digital or analogue cameras (black and white or colour) with optical lenses,
- the camera interface to digitize the image (the so-called frame grabber),
- processor (this is usually PC or embedded processor such as DSP),
  (In some cases, all the elements listed above are included in one device, the so-called smart cameras),
- device I/O (input/output), or communication links (e.g. RS-232) used to report the results of system,
- lens for taking close-ups,
- adapted to the system, specialized light source (such as LEDs, fluorescent lamps, halogen lamps, etc.),
- software to the imaging and detection of features in common image (image processing algorithm),
- sync-sensor to detect objects (this is usually an optical or magnetic sensor), which gives the signal for the sampling and processing of image,
- regulations to remove or reject products with defects.

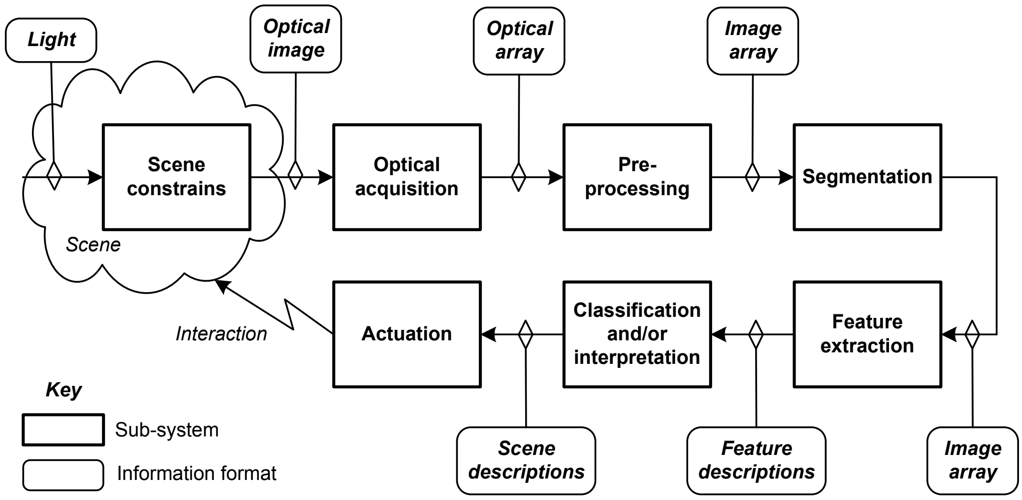

Figure1 A simple block diagram for a typical vision system operation [1]

Table 1 General operations performed in the image processing [1]

Operation				
Point	Global	Neighbourhood	Geometric	Temporal
Brightness modification	Histogram equalization	Image smoothing	Display adjustment	Frame-based operations
Contrast enhancement	-	Image sharpening	Image wrapping	-
Negation and thresholding	-	-	Magnification and rotation	-

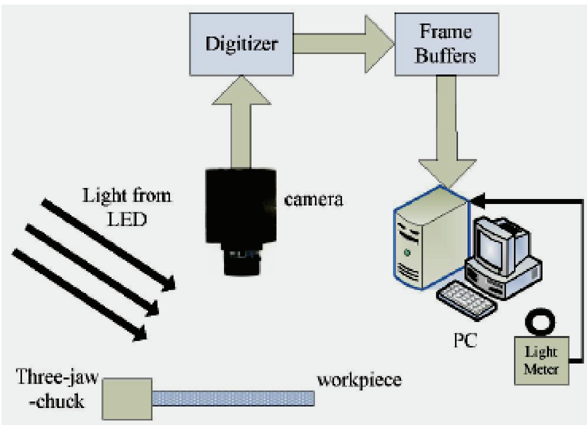

Figure 2 A typical vision system operation [2]

Sync-sensor determines when a product (e.g. running on a conveyor) has reached the position in which it can be inspected. The signal from the sensor starts the camera, which starts downloading the image of the product, and sometimes (depending on the system) gives a signal to synchronize the lighting in order to obtain a good image sharpness. Light sources are used in vision systems for lighting products in order to offset the dark places and to minimize the adverse effects of the emergence of conditions for the observation (such as shadows and reflections). Most of the panels to be used with LEDs.

The image from the camera is captured by frame grabber, which is a digitalize device (included in each intelligent camera or located in a separate tab on the computer) and converts image from a digital camera to digital format (usually up to two-dimensional array whose elements refer to the individual image pixels). The image in digital form is saved to computer memory, for its subsequent processing by the machine vision software.

Depending on the software algorithm are typically executed several stages, making up the complete image processing. Often at the beginning of this process, the image is noise filtering and colours are converted from the shades of grey on a simple combination of two colours: white and black (binarization process). The next stages of image processing are counting, measuring and/or identity of objects, their size, defects, or other characteristics. In the final stage of the process, the software generates information about the condition of the product inspected, according to pre-programmed criteria. When it does a negative test (the product does not meet the established requirements), the program gives a signal to reject the product, the system may eventually stop the production line and send information about this incident to the staff.

4 Types of light source

In any camera-based application the illumination is a critical part of the system. At the most basic level, there must be "enough" light so that the camera can acquire a good image. Beyond this it is almost always necessary to use the orientation, geometry or colour of light to highlight relevant details or minimize the appearance of unhelpful parts of the image, such as glare.

The three main types of light source are [3]:

- Incandescent (filament bulbs), including Halogen bulbs. These work by passing electric current through a metal filament until it glows white hot (Fig. 3a),
- Fluorescent tubes (discharge lamps). These use an arc (electrical spark) through an inert atmosphere to create light (Fig. 3b),
- LEDs (light-emitting diodes). These are semi-conductor devices where electro-luminescence occurs in p-n junction (Fig. 3c).

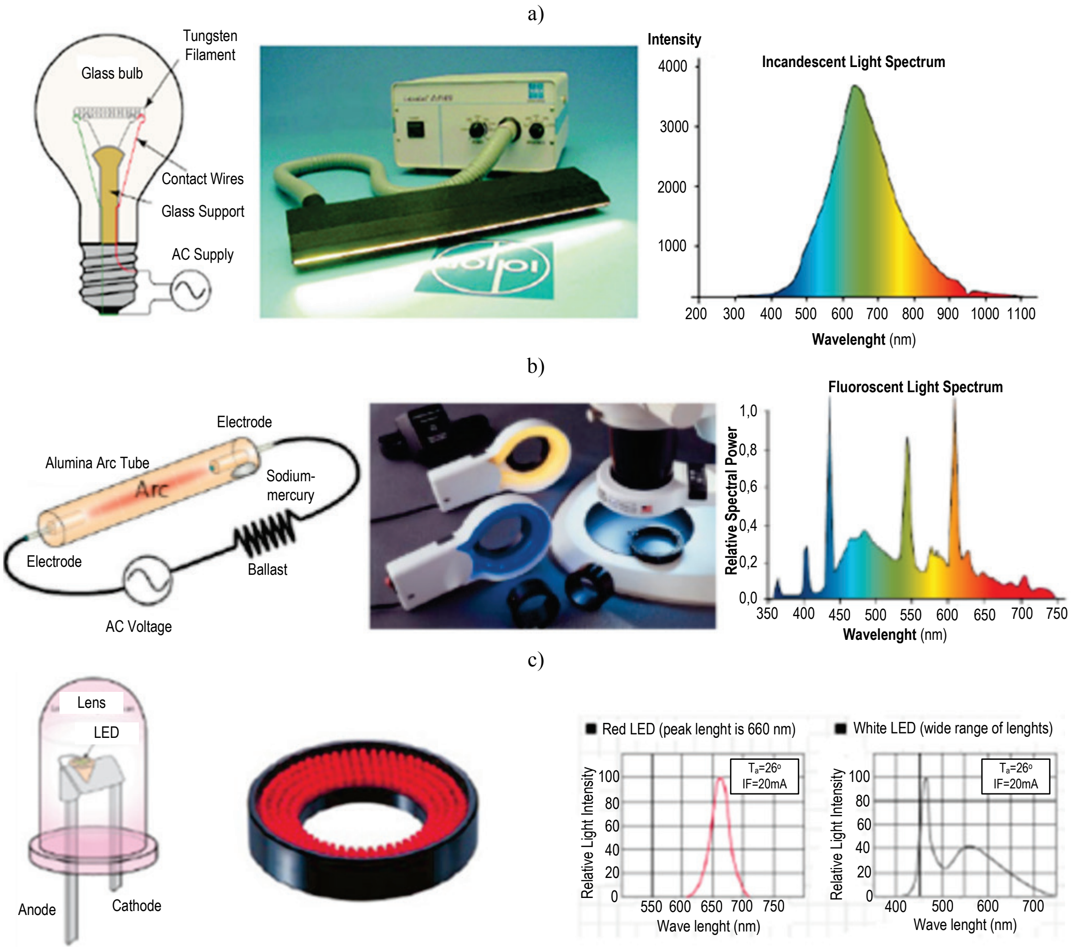

Figure 3 Types of light source use in machine vision: a) incandescent bulb, b) fluorescent tube, c) LED [3]

The output spectrum for LED light sources is a narrow band for single wave lengths LEDs, careful thermal management, small size – these advantages have made LEDs the light source of choice in most applications, from factory to traffic camera systems.

5 Sensors, cameras and interfaces

There are many cameras available for machine vision. They incorporate different sensors, different interface electronics, and they come in many sizes. Together, the camera and lens determine the field of view, resolution, and other properties of the image. There are many cameras designed specifically for machine vision applications (Fig. 4).

Most machine vision cameras use Charge-Coupled Device (CCD) image sensors. Charge from each line of pixels is transferred down the line, pixel by pixel and row by row, to an amplifier where the video signal is formed. CCD cameras are available in a wide variety of formats, resolutions, and sensitivities. They provide the best performance for most applications.

Complementary Metal-Oxide Semiconductor (CMOS) sensors are becoming available for some applications. Because they are made using the same processes used to fabricate computer chips, they can be produced very inexpensively. Low-cost CMOS cameras are already used in toys and in webcams. Unlike CCD sensors, which must be read out one full line at a time, CMOS sensors can be read pixel by pixel, in any order. This is useful for time-critical applications where only part of the image is of interest. At present, the noise performance of CMOS sensors is inferior to CCDs.

There are two types of camera interfaces in use, analogue and digital. In an analogue camera (Fig. 5), the signal from the sensor is turned into an analogue voltage and sent to the frame-grabber board in the vision-system computer. EIA, RS-170, NTSC, CCIR and PAL are all common analogue interface standards. Analogue cameras are inexpensive, but subject to noise and timing problems.

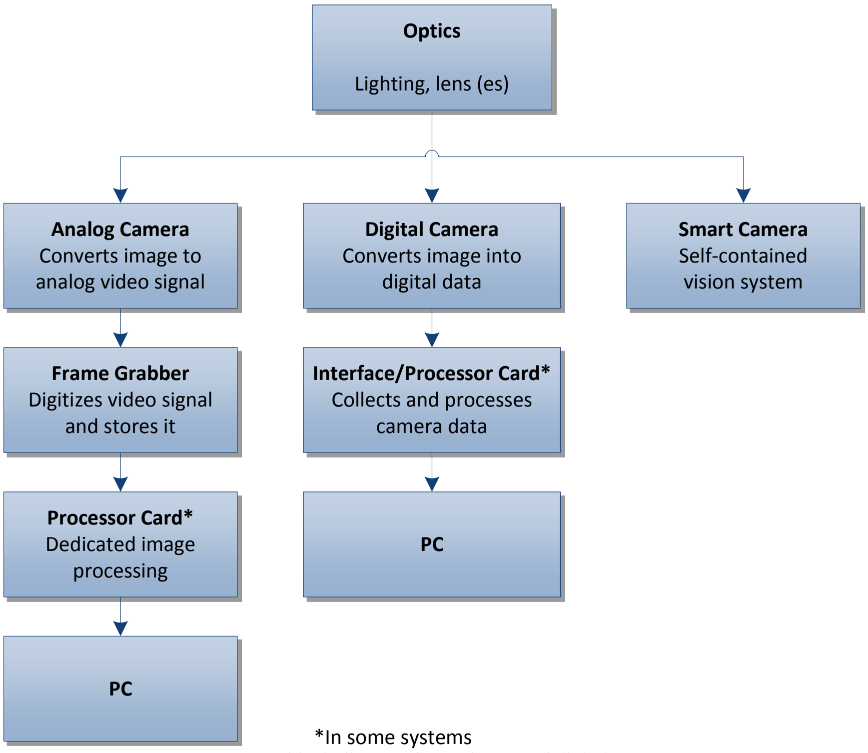

Figure 4 A block diagram for analogue and digital cameras

Figure 5 Sample of analogue camera named *"guppy"*produced by Allied Vision Technologies GmbH [4]

Most new machine vision cameras use a digital interface (Fig. 6). The signal from each pixel is digitized by the camera and the data sent in digital form directly to the computer. CameraLink, Firewire and GigaEthernet are three popular digital interface standards. The digital signal is not subject to noise and there is a perfect correspondence between each pixel on the sensor and in the image. Digital cameras support a wide variety of image resolutions and frame rates. Since the signal is already digitized, a simple interface board replaces the frame-grabber.

a) b)

Figure 6 Digital camera *In-Sight* (a) and a sample of self-contained vision system *Checker 3G* (b) – Cognex products [5]

6 Methods for image processing

Software machine vision system for both commercial and open-source consists of many different image processing techniques, such as:

- counting pixels (counting the light and dark pixels),
- binarization (colour conversion from the shades of gray in two colours: white and black,
- segmentation (used to locate and/or counting objects,
- "hard" to identify the image (to locate an object that can be rotated, partially hidden by another object or change its size),
- barcode reading (decoding of bar codes, read or scanned by machines),
- text recognition (automatic reading of text - letters and numbers, such as serial numbers),
- measurement (measuring the size of the object),
- edge detection (edge detection object),
- template matching (finding, matching, and/or counting specific patterns),
- others.

In most cases, the machine vision system uses a combination of these processing techniques in order to perform a complete inspection. For example, a system that reads bar codes can also check the surface of an object to detect scratches or other damage, and to measure the length and width of the manufactured component (Fig.

7). Increasingly, neural networks are used to calibrate the measuring system [6].

7 Application of machine vision

Machine vision systems are widely used in the manufacture of semiconductors, where these systems are carrying out an inspection of silicon wafers, microchips, components such as resistors, capacitors and lead frames [7].

In the automotive machine vision systems are used in control systems for industrial robots, inspection of painted surfaces, welding quality control [8, 9], rapid-prototyping [10, 11], checking the engine block [12] or detect defects of various components. Checking products and quality control procedures may include the following: the presence of parts (screws, cables, suspension), regularity of assembly, of the proper execution and location of holes and shapes (curves [13], circular area [14], perpendicular surfaces, etc.), correct selection of equipment options for the implementation of the quality of surface markings (manufacturer's numbers and geographical detail), geometrical dimensions (with an accuracy of a single micron) [2, 15, 16,] the quality of printing (location and colour).

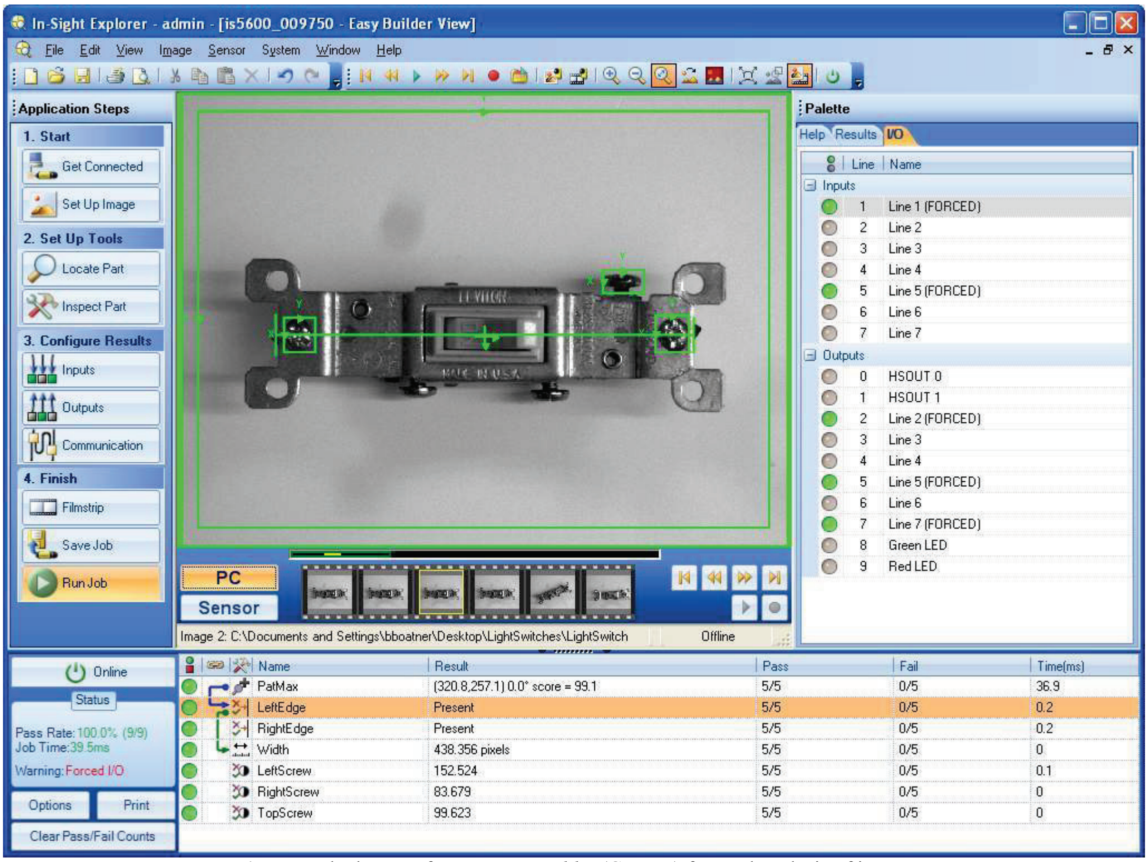

Figure 7 The latest software *Easy Builder* (Cognex) for total analysis of image

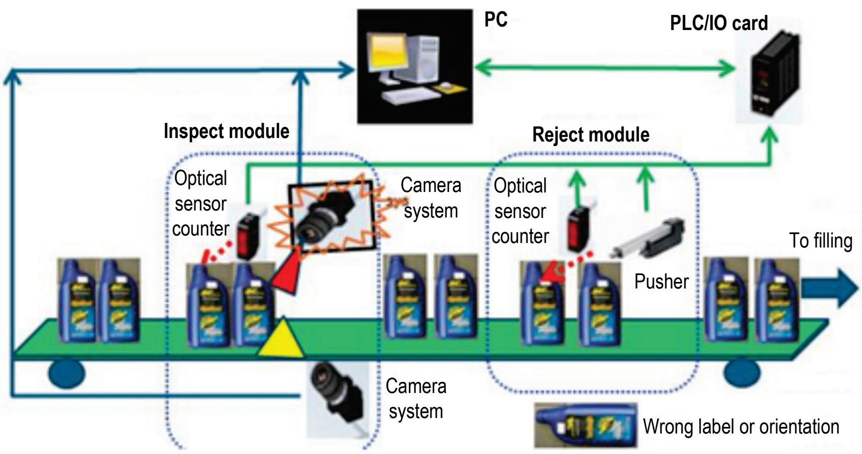

Figure 8 The simplest arrangement of the machine vision measuring olive oil bottles on production lines [18]

Beside listed above are other areas to implement machine vision. Fig. 8 shows the simplest arrangement of the machine vision measuring olive oil bottles on production lines. The online defect inspection method based on machine vision for float glass fabrication is shown in Fig. 9. This method realizes the defect detection exactly and settles the problem of miss-detection under curviness's fabricating circumstance. Several digital line-scan monochrome cameras are laid above float glass to capture the glass image. The red LED light source laid under the glass provides illumination for grabbing the image. High performance computers are used to complete the inspection task based on image processing [19].

Another interesting proposition is using the machine vision system for validation of vehicle instrument cluster [20]. The machine vision system (Fig. 10) consists of a camera, lighting, optics and image processing software. A Cognex In-sight CCD vision sensor was selected for image acquisition and processing, which offers a resolution of 1600 × 1200 pixels and 64 MB flash memory. The acquisition rate of the vision sensor is 15 full frames per second. The image acquisition is through progressive scanning. The camera can work in a partial image acquisition mode, which provides flexibility for selecting image resolution and acquisition rate. The image processing software provides a wide library of vision tools for feature identification, verification, measurement and testing applications.

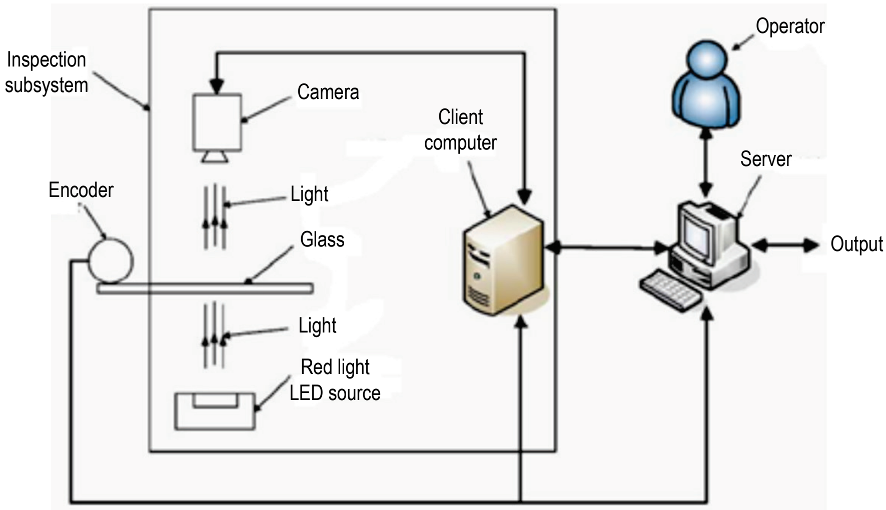

Figure 9 Float glass inspection system [19]

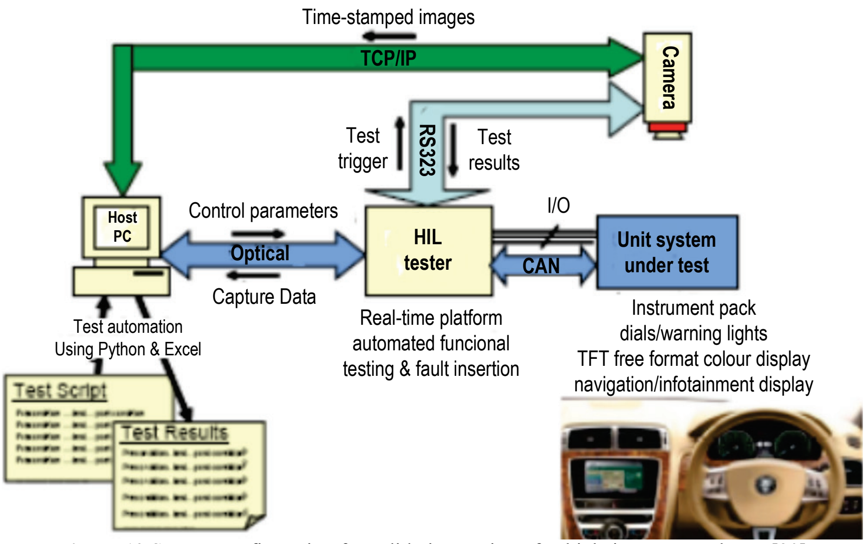

Figure 10 System configuration for validation testing of vehicle instrument cluster [20]

The PatMax™ technology for part fixturing and advanced OCR/OCV tools for reading texts are available within the software. The primary source of illumination is from LED ring lights with directional front lighting, which provides high contrast between the object and background. The selection of optical lens depends on the field of view and the working distance. In this setting, a lens with a focal length of 12 mm is used.

8 Conclusions

Application of machine vision is different and wide, such as in:

- biometrics,
- positioning [21, 22],
- industrial production on a large scale,
- small-lot production of unique objects [23],
- safety systems in industrial environments,
- intermediate inspection (e.g. quality control),
- visual control of inventory in the warehouse and management systems (counting, reading bar codes, storage interfaces for digital systems),
- control of autonomous mobile robots, industrial (AGV) [24],
- quality control and purity of food products,
- exploitation of bridges [25],

- retail automation[26],
- agriculture [27],
- exploitation of railways [28],
- vision systems for blind people (Artificial Visual Sensing) (e.g. Super Vision System, Artificial Eye System).

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