Cost-effective fault detection with the application of web cameras

Streszczenie
Artykuł przedstawia zagadnienia dotyczące budowy systemów wizji maszynowej, wykorzystywanych w diagnoce przemysłowej i zadaniami wykrywania błędów. Szczególna uwaga poświęcona jest możliwości wykorzystania tych komponentów – kamer internetowych, a także oprogramowania typu open source.

Abstract
This paper concentrates on the topic of machine vision systems for the tasks of industrial diagnosis and fault detection. The main attention is devoted to the possibility of using low-cost components – standard web cameras and the open source software.

Słowa kluczowe: Detekcja uszkodzeń, diagnostyka, teleservice, kamery internetowe, systemy wizji maszynowej.

Keywords: Fault detection, diagnosis, teleservice, web cameras, machine vision.

Tytuł: Zastosowanie kamer internetowych w tanich systemach wykrywania błędów.

1. Introduction
The meaning of machine vision systems in all fields of modern industry still grows. This is caused by the increasing capabilities of such systems and decreasing cost of them. However, the cost is still considerable. Lot of manufacturers, to lower the price of their solutions, produce bundled complete vision systems or specialized sub-components for building such systems. But still the majority of applications is built on the base of standard PC with multi-purpose operation system, so the main part of the cost is the price of cameras (and frame-grabbers) and software.

Although the high price of cameras is undoubtedly a big drawback, it is justified by the conditions which they meet. It is possible to choose a camera, which exactly addresses the needs of user in the field of performance, durability, size, etc. The requirement of applying specialized cameras in highly sophisticated tasks is undeniable. However, for applications in which it is not necessary to use devices with high accuracy and performance, the possibility of lowering the cost of solution by replacing industrial cameras with common and cheap components – web cameras – should be investigated.

Also the price of commercial computer vision software is still crucial. First – the price of operating system. The most common choice is Windows family, because majority of available software and hardware drivers exist in versions for this system and often manufacturers give no alternative for that. On the other hand the growing tendency to migrate towards other, especially free Linux systems is noticeable. Also the commercial vision software can be replaced by programs created basing on the open source libraries.

In this paper we want to propose cheap machine vision solution built upon the base of standard PC platform with Linux operation system, web cameras and free open source software.

2. Camera
Capabilities and popularity of webcams have been rising for recent several years. Comparing the speed and quality of image produced by first internet cameras and modern solutions, it is easy to see the great improvement of these factors. At the same time the price of webcams drastically decreased. Currently there are two interfaces used for connecting this type of cameras to PC – USB, in versions 1.1 and 2.0 of different speed, and FireWire, which is de facto industrial standard. Although USB interface exists in two versions, the majority of webcams use slow 1.1 protocol, so it is necessary to compress the video stream (in case of FireWire and USB 2.0 it is possible to transmit VGA stream at 30 fps). Another issue is that different manufacturers use their own protocols for the devices which they produce, so various cameras are not compatible with each other. FireWire interface is standardised, so different devices may work with generic drivers and they can operate virtually with any professional machine vision software which provide driver compliant with IEEE 1394 IIDC specification.

Most of available web cameras with FireWire interface has similar characteristics. Our choice was Fire-i webcam from Unibrain. Table 1 shows main specification of this device. It exists also in OEM version without plastic housing, as subassembly for creating custom solutions, in both color and monochrome versions and the manufacturer offers several types of lens for it.

<table>
<thead>
<tr>
<th>Camera Type</th>
<th>Sensor Type</th>
<th>Resolution</th>
<th>Optics</th>
<th>Video Modes</th>
<th>Frame Rates</th>
<th>Gain</th>
<th>Shutter</th>
<th>Gamma</th>
<th>White Balance</th>
<th>Saturation</th>
<th>Backlight</th>
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Web cameras are based on a single CCD array sensor with Bayer pattern, so they are exposed to problem common for all single chip cameras known as color aliasing. This occurs when a region of sharp contrast is imaged with a color mosaic CCD array. This problem influences other factor – feature resolution, which is the smallest feature reliable imaged by the system [1,2]. According to Shannon's sampling theorem it is necessary to use at least 2 pixels to represent an object on the image. Practically, due to the inaccuracy of devices, for good contrast and low noise images it is assumed that objects are reliably represented usually by 4-5 pixels, but for images with lower quality it is necessary to assume more pixels. Feature resolution is given by the formula:

\[
R_f = F_p \times \frac{FOV}{R_i}
\]

where \(R_f\) – feature resolution, \(F_p\) – number of pixels that represents a feature of minimum size, \(FOV\) – field of view, \(R_i\) – image resolution. For Unibrain Fire-i camera the maximum image resolution is 640\*480. Taking into consideration some problems with color aliasing and the quality of optics of the device, it would be necessary to assume number of pixels that will span an object of minimum size at the level of at least 6 pixels. For the field of view 12cm\*8cm (these are the dimensions for our system), the resulting feature resolution is 1,07mm. This quantity is important mainly for the inspecting camera and say how big defects can the system detect.

3. Software
The software part of application consist of two parts – operating system and a program created with the usage of computer vision library with some additional packages which are necessary for the correct work of the application.
3.1. Operating system

The applied operating system is standard distribution of Linux – Slackware 10.1. The system must be installed with X Window System (X11R6). The version of kernel is 2.6.11 compiled with IEEE1394 card and additional USB support.

3.2. OpenCV – Open Source Computer Vision Library

OpenCV is an open source computer vision library created by Intel and it is mainly aimed at real time computer vision [3]. It is a collection of high-performance and low-overhead operations on digital images. It consists of primitives such as binarization, image statistics, filtering, pyramids, as well as of high-level library implementing algorithms for calibration techniques, feature detection and tracking, shape analysis, motion analysis, 3D reconstruction, object segmentation and recognition.

3.3. Additional packages

There are several additional open source packages which need to be installed in order to make the whole system work properly. These are:
- libenc1394 – a library which provides a high level programming interface to control IEEE1394 based cameras that conform 1394-based Digital Camera Specification
- libraw1394 – a library which provides access to 1394 bus
- ffmpeg – an audio/video conversion tool
- GTK+ – a multi-platform toolkit for creating graphical user interfaces

4. System description

Our system (Fig.1) was built on the base of production line model. It is a set of conveyors and pneumatic devices built of Fischer technics blocks. The whole application is controlled by SPS which drives all motors and pneumatic devices basing on the informations from sensors on the production line. The SPS is equipped with an ethernet interface, so it is possible to connect it to the network. Our aim was to create a system, equipped with two cameras, which would be able to inspect goods on the production line and which would perform a teleservice – observation of the whole system by the second camera.

4.1. Core system

The main part of application includes two basic parts. First is the vision system, which deals with inspection of products and teleservice. And the second part is communication with SPS, which is necessary to receive information about critical events on the production line and about the presence of goods under the inspecting camera (information from sensors).

The operation principle of teleservice is simple. The camera instantly captures video sequence to the buffer, which always stores frames from last 20 seconds (or other arbitrary chosen time) of system activity. After receiving an information from SPS about some critical event in the production process, the camera continues to capture the video stream through 10 seconds. After that time the content of the buffer is compressed and sent through e-mail with appropriate information to the remote operator.

The inspection camera can perform various tasks, for example: measurements, presence detection, completeness checking, counting, color and shape recognition, etc. After receiving the message from the SPS about the presence of an object under the camera, the system can perform given image processing tasks to determinate characteristics of it. Next it can return information to SPS whether to continue the production process or to dispose the product of.

4.2. Optional components

There are several possibilities of other components, which complement the system and however they are not directly connected with machine vision and image processing, they add functionality mainly to the teleservice part of application.

Database can store the images of all faulty products, what may be helpful in verifying the correctness of the system work and in improvement of the production process. It can also store all the video sequences which show all the critical situations on the production line.

In case of error occurrence in the production line the system can automatically send SMS with the description of the problem to the remote operator. It can also send an image information in the form of MMS.

Internet connection in the same manner as the GSM connection – to send e-mail messages with the information (text and video) related to the critical situations on the production line. Except form that it can be used normally for remote administration of the system.

5. Conclusions

It seems that systems built one the base of web cameras and free software can be an attractive alternative to applications consisting of professional devices and commercial software, especially in not complicated tasks, which do not require superior image quality and performance. Although the results of tests of the system which we have created were promising, we need to remember that it is only a model and its operation was not examined in real industrial conditions, so its hard to determinate its usefulness.

Also, we have to remember, that despite the fact that we have access to the whole source code, and we can benefit from that, not being dependant to manufactures, we have to deal with all the problems ourselves, without any support.

6. References