Project no.: 512668

Project acronym: MULTISENS

Project title:

Cameras as Multifunctional Sensors for Automated Processes

Instrument: **CO-OPERATIVE RESEARCH PROJECT**

"PUBLISHABLE FINAL ACTIVITY REPORT"

Due date of deliverable: December 2006

Actual submission date: December 2006

Start date of project: 1.11.2004

Duration: 24 Month

Organisation name of lead contractor for this deliverable: Profactor GmbH

Revision [1]

Project co-funded by the European Commission within the Sixth Framework Programme		
	CO	
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Contents:

"PUBLISHABLE FINAL ACTIVITY REPORT"

December 2006

0 Summary description

Goal of the project was the development of a “smart” camera for process control and fault detection in automation. The camera should take the role of several sensors and thus reduce the setup time for machines substantially. Two prototypes were develop that are targeted at low-speed (40ms) as well as high-speed (1ms) applications.

In most automatic assembly machines a large number of (sometimes expensive) sensors are used to check whether the machine is still operating correctly or to avoid collisions. A typical situation is that a sensor has to make sure that a gripper is retracted, before the handled object moves on to the next station. The setup of these sensors and programming of the right timing in a PLC (programmable logic controller) program is a very time consuming process.

The proposed device is essentially a camera which is combined with a processing unit and is able to visually interpret image sequences of automated processes, report malfunctions and deviations in the process and assist the task of programming the right sequence of events.

Strategic Objectives:

- The project provides a prototype of a new product for SMEs working in the field of machine vision, which will lead to substantial growth of these SMEs.
- Based on this product SMEs in the field of machine building will increase their competitiveness, by reducing the costs for the setup of machines.
- International cooperation between the SMEs and the RTD performers will open new markets for the involved SMEs.

Project Objectives:

- The development of a combined camera/processing system for the control of automated processes. This includes:
    - Development of algorithms for high-speed analysis of moving objects for automated processes
    - Development of methods for visual interpretation of image sequences of automated processes
    - Construction of a prototype camera/processing system capable of processing up to 25 images/s
    - Construction of a prototype camera/processing system capable of processing up to 1000 images/s
    - Installation and tests on automated machines from the field of robotics, automation and assembly
    - Preparation of exploitation of results

Contractor List:

Participant name	Country	Logo
AnaLogic Computers Ltd. *http://www.analogic-computers.com*	*HUNGARY*	
HAGE Sondermaschinenbau GmbH & Co KG *www.hage.at*	*AUSTRIA*	
Maschinenbau Heinrich Hajek GmbH & Co KG	*AUSTRIA*	
Hochrainer GmbH *www.hochrainer.de*	*GERMANY*	
Profactor Produktionsforschungs GmbH *www.profactor.at*	*AUSTRIA*	
Foundation for Research and Technlogy – Hellas *www.ics.forth.gr*	*GREECE*	
Computer and Automation Research Insitute, Hungarian Academy of Sciences *www.sztaki.hu*	*HUNGARY*	

Coordinator:

Steyr Head Office	**Vorarlberg Office**	**Spain Office**
PROFACTOR Produktionsforschungs GmbH A-4400 Steyr-Gleink, Im Stadtgut A2 Phone: +43 7252 885-0 Telefax: +43 7252 885-101 Email: sekretariat(at)profactor.at	PROFACTOR Produktionsforschungs GmbH A-6850 Dornbirn, Competence Centre CCD Phone: +43 5572 398995 Mobile: +43 664 60 885 200	PROFACTOR Produktionsforschungs GmbH Edificio Centros Tecnológicos Parque Científico y Tecnológico E-33203 Gijón, Spain Phone: +34 984390063 Telefax: +34 984390061 Mobile: +34 630 185276 Email: steven.trogisch(at)profactor.at

1 Work performed:

To describe the work performed we can split it into three main topics:

- Analysis of moving objects
- Interpration of image sequences
- Smart Cameras

1.1 Analysis of moving objects

State of the art:

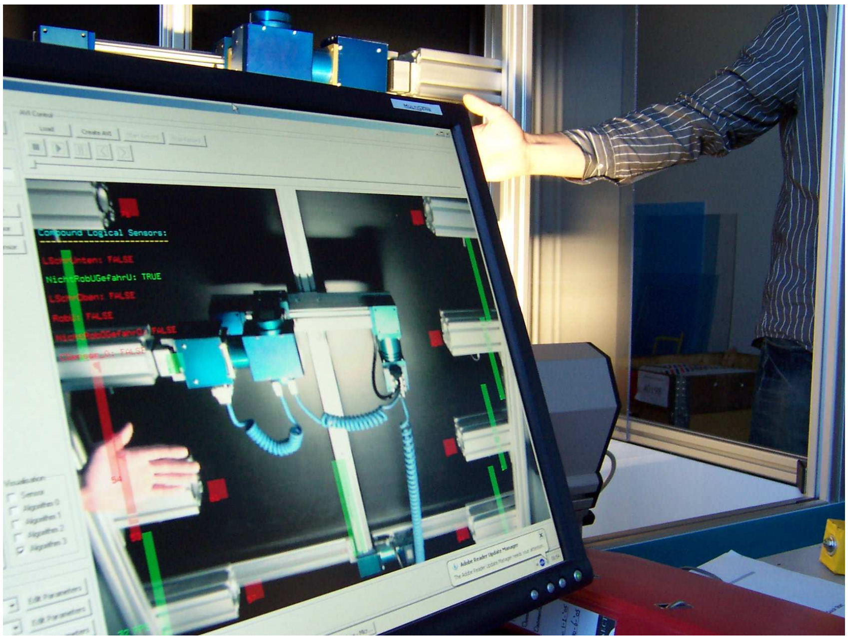
In the field of automation smart cameras are usually able to find known objects in an image. If, for example, a few screws are spread on a plane a camera system will be able to find the position of each screw and the angle of rotation of the screw at a speed suitable for automated processes. Some of the cameras can even deal with slightly overlapping objects. Such cameras are often connected to robots for pick-and-place tasks (e.g. the Adept Flexpicker).

These problems, however, are substantially different from the information that must be extracted out of the scene, where the shape and overall appearance of the object to be analysed depends on the distance of the object from the camera and their relative position. Another complicating factor is the nature of the object to be analysed (e.g. whether it is rigid or deformable), the presence of many similar objects in the same scene, the rate of change (e.g. the speed) and the possibility of occlusions, etc.

The approach taken in the project to tackle the analysis of moving objects is motivated by the observation that in most of the automated processes, things occur in a strict, timely and predetermined way, without considerable deviations. This means that knowledge of the current state of the viewed scene permits high-confidence predictions regarding the state of the scene at the immediate future.

Solution of Multisens - Methodology:

The proposed approach is based on what we call “Vision Based Logical Sensors” (VBLSs). It is assumed that during set-up time, Regions Of Interest (ROIs) of arbitrary shape in the image acquired by the camera can be defined. Moreover, a set of specific algorithms and the parameters governing their operation can be defined to each of the ROIs. The set of algorithms associated with each ROI is called Image Processing and Analysis (IPA) algorithms.



Screen with live image (operator putting hand into robot cell). Virtual sensor (red = on, green = off) detecting hand

Results:

Four different types of IPAs were implemented:

- Preprocessing algorithms (type 1)
- Core analysis algorithms (type 2)
- Post-processing algorithms (type 3)
- Decision algorithms (type 4)

Algorithms of these types were implemented in a low speed environment (low speed camera + PC) and a high speed environment (Bii-camera). The algorithms were recursively improved after various test runs in the laboratory as well as in real machine plants.

1.2 Interpretation of image sequences

State of the art:

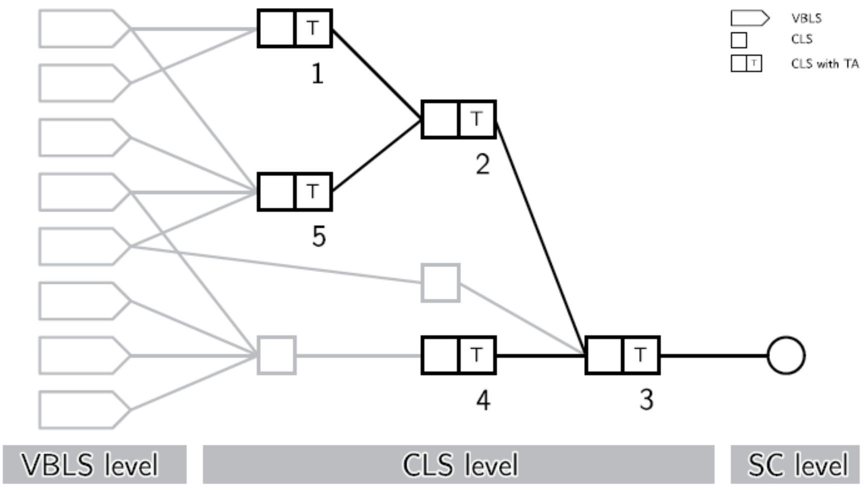
Up to now research in the domain of high level image sequence interpretation was mainly focused on the field of interpreting traffic scenes or human activities. In such systems complex vision algorithms are used to track the movements of vehicles in the scene. The extracted motion information is used to create a textual and understandable description of the activities observed in the scene.

PROFACTOR and FORTH have developing with other European partners a system for interpreting and understanding activities of expert operators. The results that have been achieved will be transferred to the industrial application of process control and fault detection. MULTISENS is focused on an industrial application for European machine builders that they can benefit from the capabilities of this new technology.

Image understanding is a technology that is not used in any available 'smart' camera. Consequently, no existing 'smart' camera is able to perform such complicated tasks.

Solution of Multisens - Methodology:

In the context of our VBLS approach the interpretation of the motion means a logical and temporal connection of the resulting signals of the VBLSs. These so called Compound Logical Sensors (CLSs) can then be built as predicates involving the values of LSs (or, recursively, other CLSs) at various moments in time. Using these fundamental building blocks, the system may detect important events occurring in the viewed scene. These CLSs can substitute complex tracking algorithms by providing comparable information and have a lot of advantages compared to general tracking algorithms.



The last step was the development and implementation of a high level software component, which contains the reasoning functionality to understand if the detected activities and extracted events are in a context, which describes a successful assembly / production process and if there are some detected deviations denoting an error during the process.

The mechanism to detect faulty situations is the so called “scenario”. The “scenarios” are mechanisms supported by the VBLS approach for monitoring the processes and verifying that events occur as they should (i.e. with the proper timing) and with the proper sequence. Therefore, a scenario is defined by a list of events, expressed by means of CLSs, and the time interval between each of them.

Graphical representation of the VBLS output as an input for the scenario module.

Results:

As a result, software components for defining CLSs and VBLSs were developed implemented and tested. The RTDs developed mathematical methods to setup scenarios and CLSs based on videos of faultless and faulty situations which were tested in the laboratory as well as in the production plants of the SME end users. A user interface was created to enable the user to set up the system manually or to modify the automatically adjusted system.

1.3 Smart cameras

For low-speed applications (25 frames per second) there is a wide range of ‘smart’ cameras available. The simplest cameras have a fixed functionality, e.g. reading a barcode or matrix code. More intelligent cameras are programmable based on scripts or on drag-and-drop interfaces that allow more complicated applications as e.g. measuring an object, finding objects in an image, or checking the presence or absence of objects. To add more flexibility to the camera the integration of C-functions is possible for some models. However, none of these ‘smart’ cameras has the potential to execute algorithms as complex as those that are designed in this project.

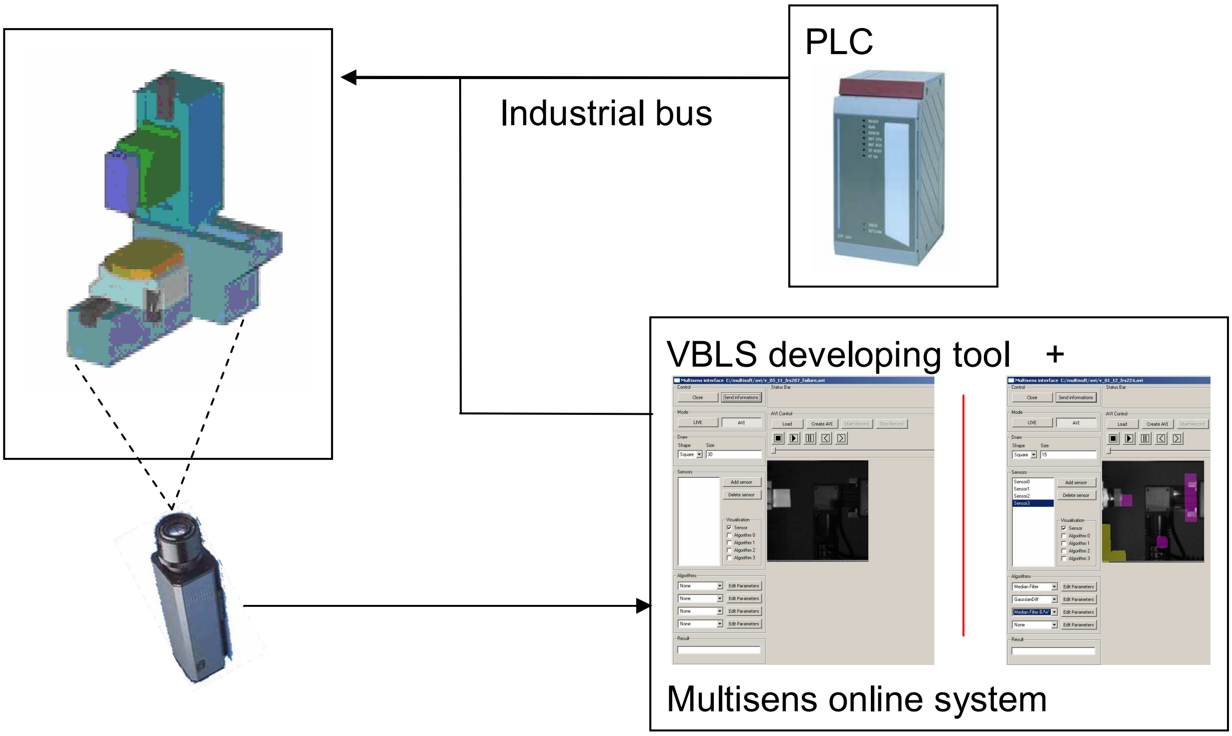
For high-speed applications the range of possible cameras is much more restricted. Standard CCD-cameras can reach up to 100 frames per second (resolution 768x582 pixels), CMOS cameras may provide even higher frame rates, if the number of pixels to be read out is reduced. Faster cameras are rare for two reasons: The data generated by the camera have to be transferred to the memory of a processing unit. If a PCI-bus is used (which is typical in standard PCs) the amount of data is limited to about 100-200 MB/s, which corresponds to about 200 frames/second as a theoretical upper limit. Even more importantly, the amount of data has to be processed and depending on the complexity of the algorithms standard PCs are limited to 40-60MB/s of image data.

During the runtime of the project the German company FESTO introduced a high speed diagnosis camera system. This camera system with the capability of acquiring frames up to 185 full-frames/second is appropriate for recording high speed videos in industrial environments. Furthermore a software tool for documentation and synchronization of video sequences is offered. The contents of Multisens exceeds this functionality by far, since Multisens includes the interpretation of the scene and the extraction of high-level events out of the video-sequences.

Solution of Multisens - Methodology:

The implemented system can be split into a development environment and a runtime system.

- In the development environment the user defines the IPAs, CLSs and LSs into a live image sequence or a recorded video. Furthermore the parameterization and optimization is done in this software component. The result is a configuration that is sent to the online system.
- The online system typically runs on an intelligent camera. The IPAs, CLSs and scenarios also run typically on this platform to guarantee real time behaviour. The produced signals are sent back to the development environment for visualization purposes and to the machine PLC to signal faults.



Block scheme of the running system

Results:

To sum up the resulting system-components are:

a) a programming environment for setting and parameterising complex logical sensors based on recorded sequences of a production task.

b) an online system to create process relevant events with special IPAs (image processing algorithms) operating in the logical sensors on a life image sequence of the production scene (e.g. mounting task, packaging task,…). These events are used to signal faults or deviations from the normal production to a PLC.

c) An online system implemented and tested on the high speed camera of the project partner Analogic computers as well as on a standard image processing PC with low-speed camera.

The development environment runs on standard PC while the online system is a general software library that can be integrated easily into most of the embedded system used for intelligent cameras. The project partner Analogic made an implementation on the Bii intelligent camera to test the functionality and to prove the concepts. With the Bii it was possible to detect faults with simple VBLS configurations up to 1000 frames per second.

Impact to the industry and research sector:

The project will significantly contribute to the competitiveness not only of the participating SMEs but of other SMEs active in the areas of mechanical engineering by providing a flexible, multifunctional camera system that speeds up the construction and setup of machines.

In Europe there are about 135000 SMEs working in the field of mechanical engineering. Their benefits from the project will be similar to those of the end-users in the project. They will reduce costs by applying a technology that allows a much faster setup of machines. SMEs working in the field of high-speed assembly automation will benefit most of the results, since the reduction of work-time for the setup of a machine will be significant in their case.

Producers of intelligent cameras can benefit from the project using this innovative product which ideally complements their product range. The consortium has developed a runtime system for high speed cameras that is either sold ‘as such’ to be programmed by some image processing expert or that is integrated into a machine-vision system . For both of these applications the market size is limited so far. This project will provide an easy-to-use application of the camera that can be sold to any machine-builder, who needs not be an image processing expert.

The results were and will further on be disseminated through the classical channels of technical papers in scientific journals, presentations, and demonstrations at exhibitions. A web-page has been prepared to present detailed information about the project:

www.multisens.org

2 Publishable results of the final plan for using and disseminating the knowledge

VBLS concept and its application to industrial automation

Description

A camera-based technology for creating virtual sensors has been developed. The technology enables the user to simply place sensors in the image of a camera and to use these sensors for various tasks of controlling automatic or semi-automatic processes. The virtual sensor is simply drawn into the image, it can be of any shape and offers a range of robust algorithms that can determine relevant events at very high speeds.

Market applications

The developed algorithms can be included in the proprietary software of smart cameras and also be used for machine vision software libraries.

Stage of development

The algorithms have been tested and can be demonstrated at any time.

Collaboration sought

Licensing agreement.

Collaborator details

Companies from the field of industrial sensors, smart cameras or developers of machine vision libraries that are interested in adapting the software to their products.

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A system for monitoring automatic processes with cameras

Description

A smart camera has been developed that can be used for monitoring automatic processes in assembly or handling machines. The camera will analyse the motions in the machine and check these motions against previously recorded motions. The technology is mainly based on generating events, that ahve to occur at a specific time and place in the video image. Events may be combined logically or temporally. The system will automatically adapt to typical variations in the automatic process and it is able to perform the monitoring task at different levels of detail.

Its main advantage is the ease of setting up a complicated automatic process, since programming the timing of the process takes place in video images on a very intuitive basis.

Market applications

The system can be applied in any kind of automation. Its benefits will be greatest for high-performance automated machinery.

Stage of development

The systems been tested and can be demonstrated at any time.

Collaboration sought

Licensing agreement.

Collaborator details

Companies from the field of industrial sensors, smart cameras or developers of machine vision libraries that are interested in adapting the software to their products.

Contact details

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2.1 Conclusion

All SMEs in the consortium are convinced that the results of MultiSens have a great market potential. They also realize the outcome of the project is a working prototype, which requires further effort for productization as well as marketing. It is acknowledged that all this will carry significant extra cost, and that funding must be sought otherwise the chances of exploitation will rapidly diminish.