# ESTIMATION OF THE INTELLIGENT CAMERA COMPUTING POWER FOR THE REAL-TIME IMAGE PREPROCESSING

**Janusz Szpytko, Paweł Hyla**

*AGH University of Science and Technology*
*Faculty of Mechanical Engineering*
*Mickiewicza Av.30, PL 30-059 Krakow, Poland*
*tel.: + 48 12 6173103, + 48 12 6173104, fax: + 48 12 6173531*
*e-mail: szpytko@agh.edu.pl, hyla@agh.edu.pl*

***Abstract***

*Advances development of visual sensor technology, digital communications and networking technique has enabled the deployment of a growing number of high-tech varied kind visual systems. One of this advances vision systems are smart cameras. Smart cameras refer to the new generation cameras with high capabilities. Image sensors combined with processors create a new vision solution of all-in-one type. The objects of statements were a test of intelligent camera functionality on the computing power benchmark. The authors tested other hardware pieces like a memory or storage functionality. All possesses results was compare with stand alone PC tower in variety kind. The piloted test may give answer about smart cameras suitability in application for material handling devices.*

*The tested SmartCam is ideal devices for built vision application for monitoring material handling devices or types non standard vision application or operation parameters. Small dimension (tested camera dimension is only 110 x 55 x 55 [mm] and low level of power consumption with relatively enough computing power are ideal for use with non standard vision application, especially for material handling devices in variety usage.*

*Small dimension (tested camera dimension is only110 x 55 x 55 mm) and low level of power consumption with relatively enough computing power are ideal for use with non standard vision application, especially for material handling devices in variety usage.*

***Keywords:*** *smart camera, vision systems, benchmark, transport application*

## 1. Introduction

It is not fully clear when the concept of smart cameras was introduced for the first time [1, 5]. The notion probably goes back to military and/or space applications motivated by having a stand-alone system for scene interpretation. The idea of projecting an imaging device with the processor unit, additionally capable of performing real-time scene interpretation can be traced back to the 1960s. In 1961 [7] was introduced at the annual convention of the American Rocket Society camera with mosaic arrays of photodetectors. The devices was projected for NASA and dedicated for *Manned mission on Mars* programme. This was an early concept of a smart camera [3, 5].

Today one of the most advance vision systems are intelligent camera or smart camera devices. A smart camera can be defined as a fully functional vision system which is capable to extracting specific information [5, 8] from the captured images in real time mode. Additionally this kind of devices enable generating event descriptions, making decisions or generating signals, that are used in an automated system. Summarize in this two words the smart camera, are hidden solutions integrating hardware and software for solving problems connected with autonomous stand alone device for preprocessing and interpreting captured images of the vision scene. Additionally the compact architecture [6, 13] of vision system based on the smart cameras functionality allow achieves lower cost in image processing in comparison with PC-based vision systems technique. With dedicated hardware architecture, each smart camera unit usually is not design for specific applications. The crucial part of each smart device (especially smartcam) is an embedded operation system [4, 11]. The used software determine smart cam functionality [11] or make possible co-operative mode, when several units must operate independently or/ and synchronously.

The object of statement is a SmartCam hardware test for draft knowledge about intelligent camera real computing power potential. All described tests was realized on the Sony XCI V3 intelligent camera model. Computing power was compare with stand alone PC or vision system based on standard PC architecture. Main approach of this type of test was motivated by the fact, that the smart camera vision application field are still growth. A volume of application based on machine vision technology (main idea of SmartCam use) potentially are limited only by the floating point computing power.

## 2. Vision system hardware architecture evolution

One of the first mile stones in vision system architecture was an implementing new kind of communication interface of IEEE-1394 type. This serial bus interface standard for high-speed communications and isochronous real-time data transfer enabling a direct connection between industrial cameras and standard PCs eliminating the need of use a frame grabber card. The IEEE-1394 communication interface (of type a) bandwidth limit was amount to 50MB/s [8]. Today PCI-X BUS bandwidth limit enable communication transfer at 1085 MB/s rate. Frame grabber elimination was a step in vision system general coast reduction.

*Tab. 1. Variety of communication interface type*

| Interface type | Bandwidth limit [MB/s] |
|---|---|
| IEEE-1394a | 50 |
| USB 2.0 | 60 |
| IEEE-1394b | 100 |
| GigE | 125 |
| PCI Bus | 125 |
| Camera Link | 400 |
| USB 3.0 | 640 |
| PCI-X Bus | 1085 |
| Light Peak (prototype version) | 1280 |

Today vision market is very different than in the late 1990s. Main vision providers offering a wide variety of products, including analog and digital cameras, simple vision sensors and smart cameras with complete built in computers. Presented application can be use in material handling devices for example in work space supervising [9, 10, 12] or crucial parameters monitoring.

### 2.1. Smart camera system architecture

Certain machine vision applications require, that every frame be transferred reliably and in assume time period to the host computer for processing [2]. To receive a real time vision signal in host machine, the data transfer with the reference to video signal frame rate is the most important parameter. Frame rate in conjunction with resolution and the number of bytes per pixel. These parameters determines the amount of data to transferred and processed. For example, a camera with a 1280x1024 resolution at 60 fps and 8 bits per pixel requires a data bandwidth of approximately 100 MB/s. If the same vision application needed 10 bits (more than one byte) per pixel, the bandwidth requirement will be increase to 200 MB/s. As a matter of fact reliable vision system with data transfer first priority use additional onboard memory buffers that guarantee lossless image transfer.

However, the vision system develop take effect in image processing with use more and more complicate algorithms used to perform specific tasks at the same time vision system should be reliable, flexible and cost-effective. This fact was a main source coming into existence the smart camera devices [3, 6, 13].

Smart cameras term has been marketed since the mid 1980s, but only in recent years have they reached widespread use, once technology allowed their size to be reduced while their processing power has reached several thousand of MIPS (Microprocessor Without Interlocked Piped Stages). The devices with 1 GHz processors and 8000 MIPS are available since of end 2006s. Image preprocessing directly on the device of interest determine the smartcam computer central unit specifications and other factors like a flash and RAM memory, display capabilities, communication interfaces and others. Modern smart cameras can rival PCs in terms of processing power and functionalities and even be better. In situations where very limited space (Fig. 1) is available for a PC tower in the vicinity of the vision system, a smart camera or an embedded vision PC appliance becomes an attractive option or even only solution.

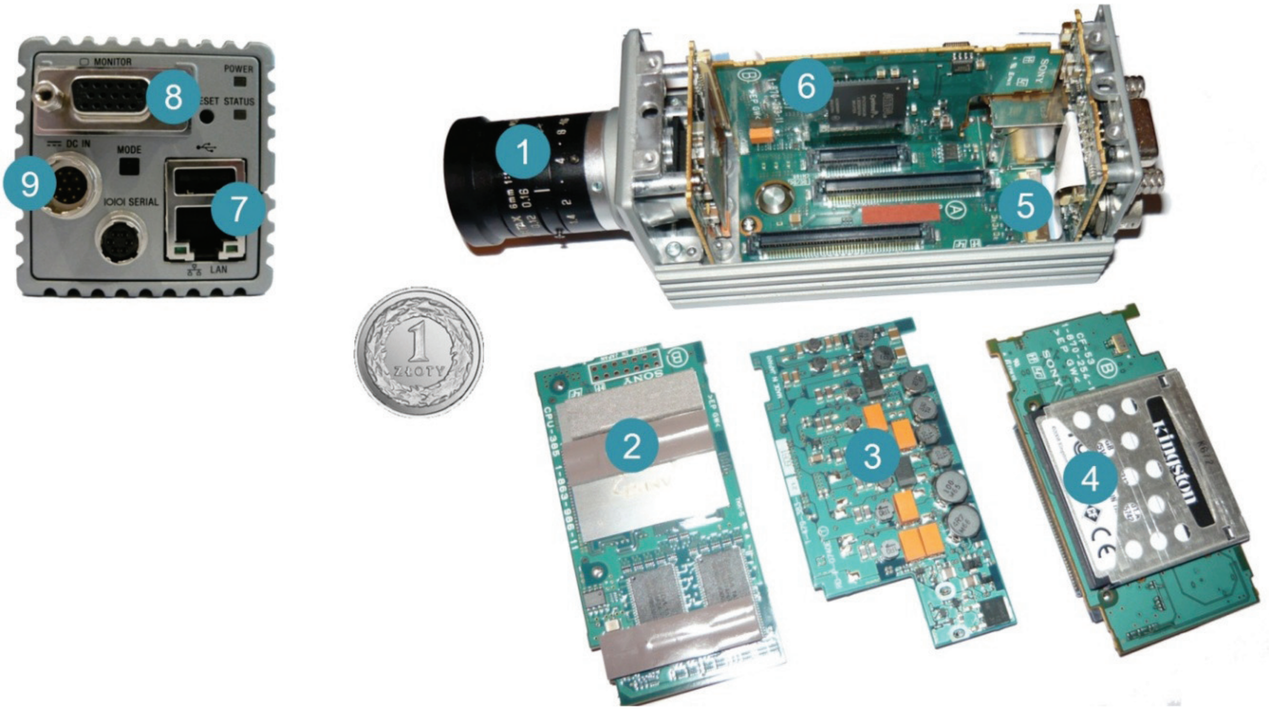


*Fig. 1. SmartCam Sony XCI V3: 1 – objective, 2 – CPU unit, 3 – ROM/ RAM memory module, 4 – Mass Storage unit (based on CF card type), 5 – motherboard, 6 – frame grabber, 7 – communication interface, 8 – display interface (D-Sub), 9 – Power Supply*

## 3. Benchmark

In computing language, a *benchmark* is the act of testing the performance of a device using one or more standard test programs. There are many CPU benchmark tests that are widely used, however to Sony XCI V3 test was use BenchMarX software in 4.1 version (also known as simply BMX). BMX is compact system information and benchmarking tool, that offers benchmarks for CPU, FPU, memory and hard drive, as well as detailed system information. With this all kind benefit, BMX software is available for free. Moreover the BMX software was chosen, because not required installation, includes "download and run" utility. All presented tests were run several times, to determine an average benchmark performance score, other machine with variety specification were tested too. All achievement was sorted and presented in three different groups diagram tests:

- CPU (ang. *Central Processor Unit*) with FPU (ang. *Floating-Point Unit*) efficiency (Fig. 2),
- memory and cache efficiency (Fig. 3),
- data storage time access in read and write mode (Fig. 4).

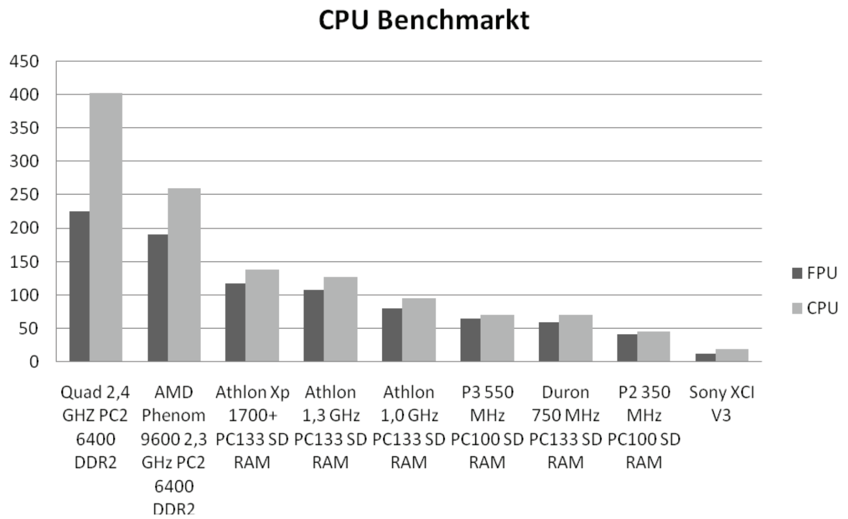


*Fig. 2. CPU Benchmark: more points=better score*

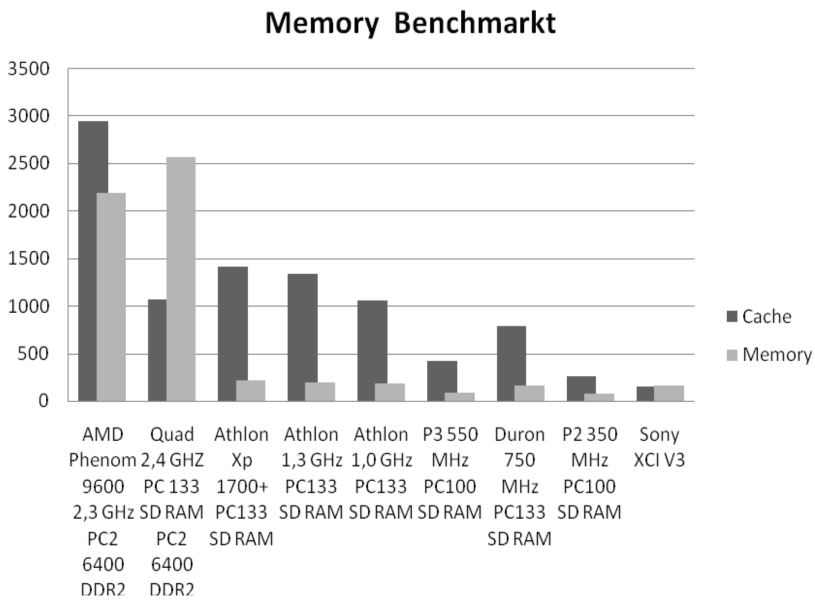


*Fig. 3. Cache and memory efficient tests: more points=better score*

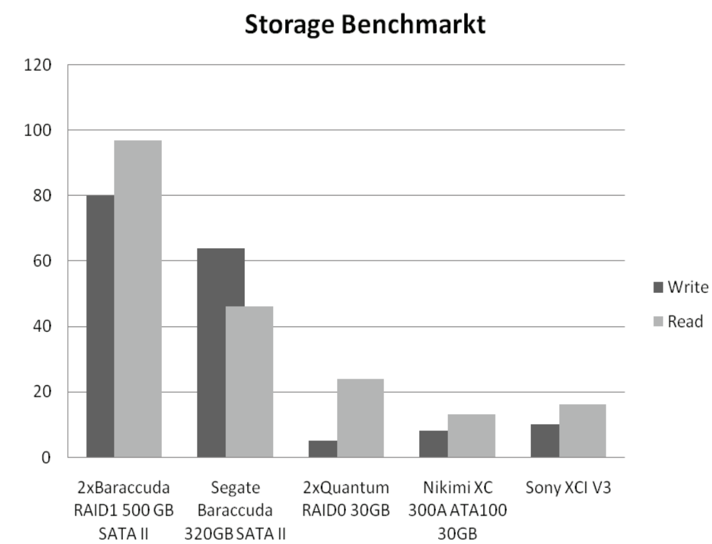


*Fig. 4. Average data time access in write and read mode: more points=shorter latency*

The results of the CPU benchmark test (Fig. 2) coefficient that the computing power of the XCI V3 processor (AMD Geode GX533) works with 400MHz clock, compared with the quad core processor (Intel Core 2 ATV 2.4) with frequency 2.4 GHz per core give the following results. The central processor unit computing power of XCI V3 comparison with quad core processor is only 4.7%, whereas math coprocessor floating-point operations give 12 points in benchmark test, what constitutes 5.3%.

On the Fig. 3 was presented a mass storage benchmark test relate to average read and write time latency. The total mass storage test of XCI V3 becomes very well. Te fastest mass storage tested by the BMX benchmark software was a disk array working under advanced functionality of RAID 1 (ang. Redundant Array of Independent *Disks*) with a separate controller for each disk (so called duplexing or mirroring mode). The tested RAID array write speed result was an eighty points, however CF (ang. *Compact Flash*) card use like a mass storage device in XCI V3 camera reach maximum value of 10 points what constitute 12.5% with reference to the array devices. Higher results were still achieved at the test of the read speed, which the intelligent camera achieved the 17.7% points with reference to the tested RAID 1 array.

Next graph (see Fig. 4) was presented of RAM (ang. Random Access Memory) test. The authoritative comparing in this special case isn't possible. Both the quantitative (capacity of installed memory) and qualitative (type of installed memory) criterion isn't the same in all tested machines. However the XCI V3 smart camera has 256 MB built in memory of the DDR-SDRAM type. In comparison with stand alone PC with 4 GB RAM memory of the PC2 6400 DDR2 type XCI V3 achieving the less efficiency about 93.5%.

RAM is general purpose memory, used to store programs, data, graphics, but the more specialized memory used by the CPU to speed up access to the RAM was a cache. It acts as a buffer „looking ahead" trying to anticipate the next item needed from RAM memory. In this case sony XCI V3 has result worse about of 86.3% in comparison with 4GB of RAM memory installed machine.

## 4. CPU power consumption and heat dissipation

Central processing unit power dissipation or CPU power dissipation is the process in which central processing units consume electrical energy, and dissipate this energy both by the action of the switching devices contained in the CPU and by the energy lost in the form of heat due to the impedance of the electronic circuits.

Power consumption and average heat emission was measured on the intelligent camera surface with the help of the digital multimeters and thermocouple wire connected directly to the multimeters. The thermocouple tip was put into intelligent camera casing, trough tripod fixture hole, after removing the screw cap (Fig. 5). Additionally the CPU and thermocouple tip was coated by the thermal gel layer.


*Fig. 5. Intelligent camera casing without fixture screw cap and thermocouple wire*

The whole test was conducted in two phases. In the first phase the smartcam was operating under open source embedded OS, dedicated for intelligent devices, after that was installed MS Windows XPe. During the experiment was measure smart camera power consumption [W] and processor temperature [$^{o}$C]. Both parameters was measure after device turn on (left side of the graph) and during normal operating (right side of the graph). The Fig. 6 and 7 present final effect of the experiment.

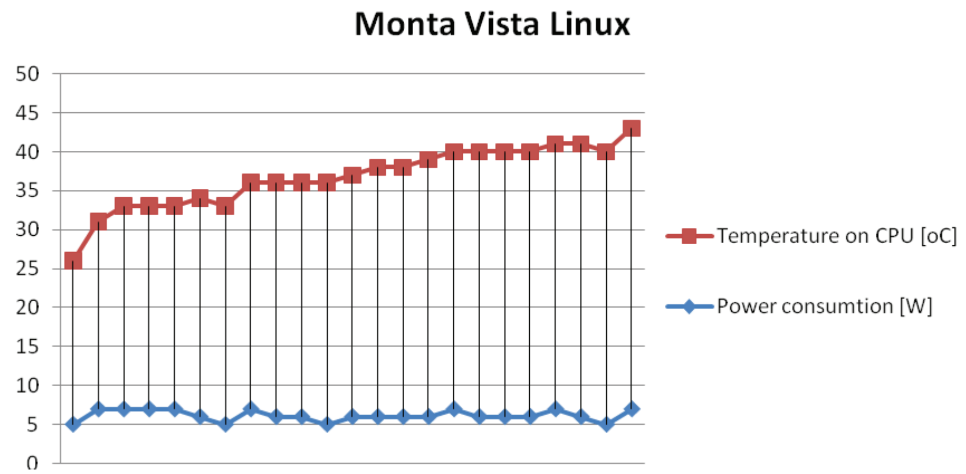


*Fig. 6. Heat growth progress linked with the average power consumption under Monta Vista Linux*

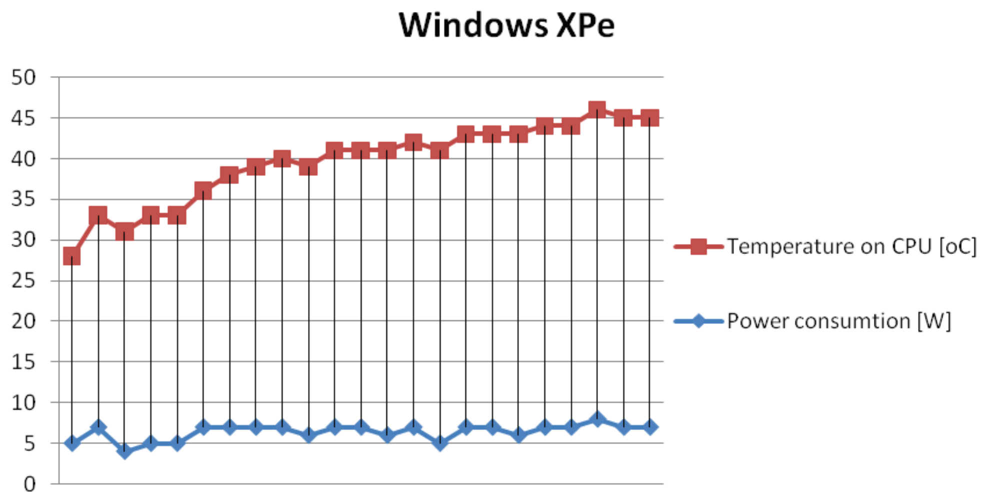


*Fig. 7. Heat growth progress linked with the average power consumption under MS Windows XP embedded*

The tested smart camera power consumption isn't reliant from operating system at al. Average power consumption between different operating class of embedded system oscillate between 5%, but the system temperature is visibly higher when the smartcam works under XPe embedded system.

## 5. Conclusion

The Sony XCI-V3 SmartCam are the perfect union of a high-end CCD camera with a complete PC functionality. These cameras eliminate the need for conventional PC based image processing systems and allows simply setup all kind of vision application with high flexibility. However, the tested SmartCam don't have great computing power both in FPU and CPU tests, but for preprocessing built in VGA (640 x 480) video source with progressive scan functionality is quite enough.

However, Sony XCi V3 SmartCam was designed in late 2006. In this same period of time, Intel share a new family of processor of Core 2 Duo type. The XCI V3 AMD GeodeTM GX533 processor computing power must be compare only with Core 2 Duo family.

Another advantage of the tested SmartCam is a high shock and vibration resistance (70G) with compact architecture (without lens the tested smartcam it is a rectangular box with 55x55x110 mm dimension) and lightweight (approximately 400 g).

It can be only one summarize conclusion, the tested smartcam is ideal devices for built vision application for monitoring material handling devices or types non standard vision application or operation parameters. Small dimension (tested camera dimension is only110 x 55 x 55 mm) and low level of power consumption with relatively enough computing power are ideal for use with non standard vision application, especially for material handling devices in variety usage.

## Acknowledgements

The research project is financed from the Polish Science budget for the years 2008-2011.

## References

[1] Blebachir, A. N. (ed.), *Smart Cameras,* Springer, ISBN 978-1-4419-0952-7, New York 2010.

[2] Bramberger, M., Pflugfelder, R. P., Maier, A., Rinner, B., Strobl, B., Schwabach, H., *A Smart Camera for Traffic Surveillance,* Proceedings of the first Workshop on Intelligent Solutions in Embedded Systems (WISES), pp.1-12, 2003.

[3] Broers, H., Caarls, W., Jonker, P., Kleihorst, R., *Architecture Study for Smart Cameras,* Proceedings EOS Conference on Industrial Imaging and Machine Vision European Optical Society, pp. 39-49, Munich, Germany 2005.

[4] de Sousa, A., *Smart Cameras as Embedded Systems,* Proceedings First International Conference On Computer Applications (ICCA2003), Session 4: Embedded Systems, pp. 105-112, 2003.

[5] Hornberg, A. (ed), *Handbook of Machine Vision,* WILEY-VCH Verlag GmbH & Co KGaA, ISBN 978-3-527-40584-8, Weinheim, 2006.

[6] Kleihorst, R., Broers, H., Abbo, A., Ebrahimmalek, H., Fatemi, H., Corporaal, H., Jonker, P., *An SIMD-VLIW smart camera architecture for real-time face recognition,* In proceedings of Research on Integrated Systems and Circuits (ProRISC '03), pp. 1-7, 2003.

[7] Lally, E. F., *Mosaic Guidance for Interplanetary Travel,* In: Space Flight Report to the Nation, American Rocket Society, pp. 2249-2261, 1961.

[8] Levis, I., *The Myths and Realities of Image Acquisition,* Photonics Spectra, ISSN: 0731-1230, pp. 70-72, November 2006.

[9] Szpytko, J., Hyla, P., *Material handling devices operation environment 3D-type presentation based on laser scanning systems,* Journal of KONES, Vol. 17, No. 2, pp.451-458, 2010.

[10] Szpytko, J., Hyla, P., *Odwzorowanie Przestrzeni Roboczej Środka Transportu Technologicznego z Użyciem Układu Wizyjnego,* Czasopismo Techniczne, Wydawnictwo Politechniki Krakowskiej, T. II, Z. 7, s. 505-514, Kraków 2011.

[11] Szpytko, J., Hyla, P., *Rola i funkcjonalność wbudowanych środowisk operacyjnych w systemach wizyjnych,* Logistyka, Nr 3, s. 2659–2670, 2011.

[12] Szpytko, J., Hyla, P., *Work space supervising for material handling devices with machine vision assistance***,** Journal of KONBiN, Safety and reliability systems, No. 3-4, pp. 7-16, Warsaw 2009.

[13] Wittke, M., Hoffmann, M., Hähner, J., Müller-Schloer, Ch., *MIDSCA: Towards a Smart Camera Architecture Of Mobile Internet Devices,* 2$^{nd}$ ACM/IEEE International Conference On Distributed Smart Cameras (ICDSC-08), pp. 1-10, Stanford University 2008.