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Advanced System for Consumption Meters with Recognition of Video Camera Signal

Z. Machacek[1], R. Slaby[1], R. Hercik[1], J. Koziorek[1]
[1]*VSB Technical University of Ostrava,*
17.listopadu 15, Ostrava, 70833, phone: +420 597 323 497
zdenek.machacek@vsb.cz

***Abstract*—This paper focuses on the design and realization of the advanced system for consumption meters state recognition. In this context, it means a variable volume flow meter, which shows the consumption of the value. The developed advanced system is based on the image signal recognition, thus display status reading of the consumption meters by the camera. There is described a unique solution that was given to the Patent Office of the Czech Republic. The specific structure of the hardware solutions and implemented recognition algorithms enables to realize extremely low cost device, with wireless connection to the user interface implemented on the cell phone platform with SMS text messages and personal computer application.**

***Index Terms*—Image sensors, image recognition, energy consumption, data visualisation.**

I. INTRODUCTION

Developed advanced system for consumption meters is designed for searching sections containing detectable data that is analyzed, stored and transmitted as recognized numerical values. The advanced recognition system is based on the input signal from the camera chip, which scans the monitored consumption meter. The basic parameters of the system are particularly the minimum cost of the used functional components with minimum power consumption. These limitations determine a design of hardware and algorithms structure for identifying the scanned image signal.

Today there are common the power meters, which contain additional elements for detecting the state by electronic means, for example they are equipped with the pulse output, the magnetic sensors. However, the consumption meters with analog numerical display are currently more widespread compare to the expensive digital meters with peripheries. The developed advanced system is based on an innovative method of using video signal for the autonomous data collection in comparison with the expensive and less efficient collection by staff. The system is designed with the need to protect against unauthorized manipulation of the advanced device by protective casing fixed to the monitored consumption meter.

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II. STRUCTURE OF ADVANCED RECOGNITION SYSTEM

Advanced recognition system structure (Fig. 1) consists of low-power microprocessor with control and recognition algorithms, the external FLASH memory for saving parameter settings and processed data, the camera module for scanning video signal, the communication module for connection to a service device with a measured consumption database and user interface.

There is used microcontroller ATmega 1284p as control module with regard to the requirements of the processed application focused to recognition system. Basically, this low-power microprocessor is not suitable for image processing with respect to frequency and internal memory size, but with specific modifications of the video signal scanning and its non-standard processing, it can be applied to the developing advanced system.

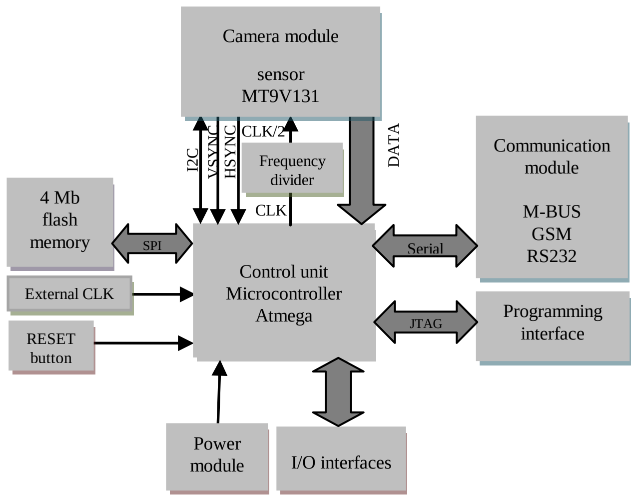

Fig. 1. Structure of developed advanced recognition system.

The scanned and processed video signal parts are sequentially saved and conversely loaded via SPI interface to FLASH memory AT45DB. The basic parameter is 4Mbit data capacity organized in 8192 pages of 512 bytes with two input SRAM buffers with 512 bytes capacity enable simultaneously reading and writing from different parts of the FLASH memory. Selection of memory has focused on the minimum requirements of consumption, sufficient size and frequency of data rate, because of minimal time delay between the microprocessor and camera sensor cooperation. There are sequentially in functional blocks saved and used the data of particular results, the scanned image in a luminance form, the image patterns of possible objects respectively digits from consumption meter, the final results of the recognition algorithm, the position data of the detected area, the recognition system parameters.

Scanning video signal is realized by the image sensor MT9V131 based on CMOS technology with a resolution of 640 x 480 pixels, thus it contains 101,376 pixels, which are transmitted and processed by the parallel data interface to the microprocessor. The I2C interface is necessary to set the white balance, exposure, gamma correction and gain. The sensor is powered by a DC power supply with a constant value of 2.8 V with the consumption of 20 mA in the active state and 2.5 μA in standby mode. There are transmitted the data by 8-bit parallel interface, where the new frame is activated by VSYNC pulse on the output. The output HREF is set to logical 1, when is the row sending operation done. The image pixel information is synchronized by the signal at pin PCLK [1].

The communication module provides the connection with the user interface that can be used for monitoring the actual state of consumption meters, to setting of the serial communication channel, for setting the point coordinates of detected sections, and for parameters setting of recognition algorithms. The user interface is applicable on a standard PC with Microsoft Windows operating system or it is possible to operate on the cell phone as the SMS messages containing the state recognition results. Data communication is created with regard to a minimum information flow of the detected consumption value inside analysed image signal. Data transfer is realized in communication standards for wired and wireless communication. The communication is based on the serial communication interface with optional GSM standards, M-BUS, RS232, which define the content and structure of a sending data message. Asynchronous serial communication is set in the bit rate $v_T = 115200$ kb/s, thus there is necessary to set the divider register r_{div}, which is given by the oscillator frequency and presented functional relation

$$r_{div} = \frac{f_{osc}}{16 \cdot v_T} - 1 . \qquad (1)$$

Power supply of developed system is implemented using batteries. There is expected battery lifetime same as meters calibration lifetime with respect to minimum consumption of functional components.

III. ALGORITHMS FOR PROCESS AND DETECTION OF ACTUAL CONSUMPTION METER STATE

Scanned data sensed by the image sensor must be saved for next usage within the limited capacity in the external FLASH memory. The proposed compression algorithm allows storing the entire one pattern of the digit only to a one memory page. In implementing process the algorithm was designed based on the lossless compression method, RLE (Run Length Encoding), which is a simple compression technique, which is based on reduce repeated sequence of pixel values. The principles of this method (Fig. 2) are implemented using a single byte, where the first part of the 7 bits indicates the number of repetitions and the second part of the 1 bit indicates the current white or black colour.

The compression method may be ineffective for inadequate data, because the current pixel values size from the RLE encoder can have up to twice the size compared to the input. The modified method RLE is effective in the case of digits compression, because the images with a small number of colour changes in the line have the minimum of bytes after compression.

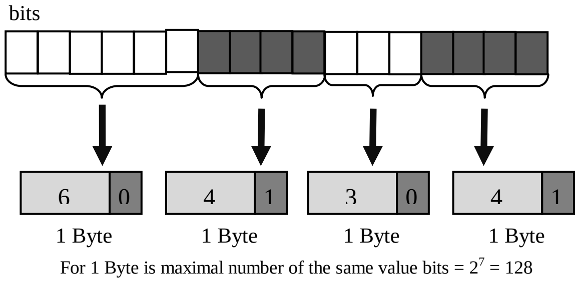

Fig. 2. Structure compression algorithm reset structure.

Detection method of consumption measurement consists of the following sequential steps, where first step is loading of the input image and its transforming into binary matrix.

These operations are performed only on a limited user-defined work area, where are placed the consumption state digits. The solution procedure is shown graphically in Fig. 3.

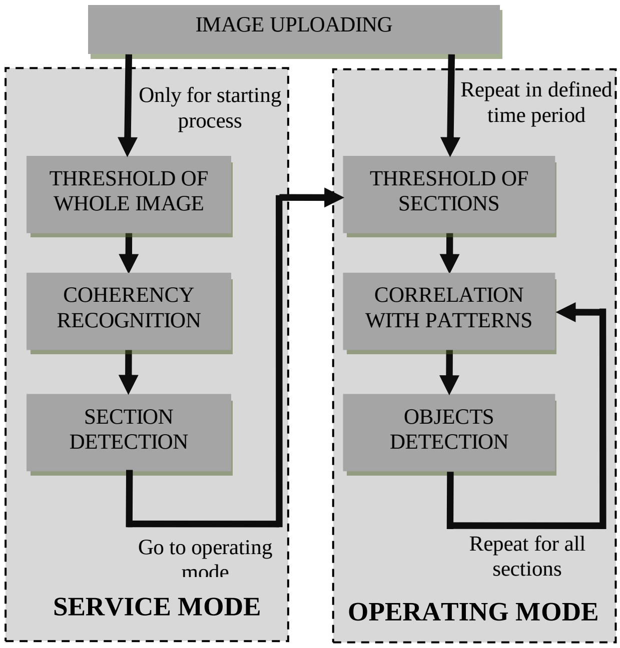

Fig. 3. Block diagram of chosen and modified method for actual measured values recognition.

Because of different lighting of each digit, there is processed a separation of digits areas in manually or automatically manner in the service mode. This is necessary for the correct threshold detection in various conditions. In standard operating mode, there are detected threshold levels of the scanned images accurately in such defined separated digits areas, which can be set by the user or automatically selected according to the method based on separation of background and objects called the Otsu method. Optimum threshold detection algorithm is evaluated from the histogram (Fig. 4), where the result of external variances $r_{S,N}$ for the background and objects must be maximal [2], [3], [4], [5].

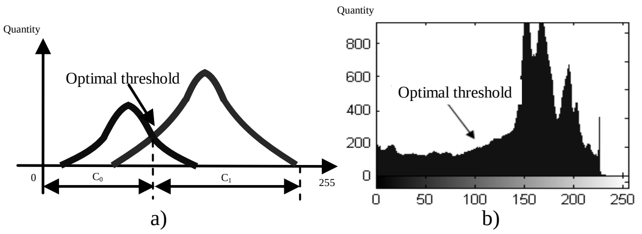

Fig. 4. Graphical view of histogram with optimal threshold.

Absolute histogram is divided into two classes, where the boundaries between the classes are gradually moved in the interval from 1 to 255 and for each division are processed described algorithms. The external variance $r_{S,N}$ is compared with other values $r_{S,\langle 1,N-1\rangle}$. Calculation of the external variance $r_{S,N}$ is based on background probability occurrence $q_0(N)$ computation and probability object probability $q_1(N)$ computation and it is given by presented algorithms

$$q_0(N) = \frac{1}{H}\sum_{i=1}^{N} P(i) \tag{2}$$

and

$$q_1(N) = \frac{1}{H}\sum_{j=N+1}^{M} P(j), \tag{3}$$

where H is the number of pixels and brightness component rate, which are contained in the parameter $P(x)$. At the same time there is given equation for all brightness component levels

$$q_0(N) + q_1(N) = 1, \tag{4}$$

There is necessary to calculate the mean value of the background occurrence $\mu_0(N)$ and probability of the object occurrence $\mu_1(N)$ by given algorithms

$$\mu_0(N) = \sum_{i=1}^{N} \frac{i \cdot P(i)}{q_0(N)} \tag{5}$$

and

$$\mu_1(N) = \sum_{j=N+1}^{M} \frac{j \cdot P(j)}{q_1(N)}. \tag{6}$$

Calculation of maximum external variance $r_{S,\langle 1,M\rangle}$ gives the optimal threshold. There is presented relation equal to

$$r_{S,N} = q_0(N)\cdot\left[1-q_0(N)\right]\cdot\left[\mu_0(N)-\mu_1(N)\right]^2. \tag{7}$$

Automatic digit sections detection is processed identically in service mode as described above in the text, but threshold algorithms are applied to the entire area. After the threshold detection, there are searching all continuous areas representing individual separated digits. The searching method of continuous areas is designed to sufficiently simple and fast evaluation of the matrix pixel elements inherent to the given area. There was chosen method based on the principle of two-pass, where the pixels assignment to objects is made in two cycles. In the first cycle, there is assigned to pixels the temporary class and in the following cycle, these temporary classes are replacing to the final marks, which are representing the object.

In operation mode, each work area with the separated continuous areas is compared with the digit patterns stored in the database using a method based on the correlation function. There is obtained the compliance rate of the digit pattern and scanned object with digit by the final evaluation of the correlation function.

IV. Properties of the User Interface for Service Purposes and Verification of Recognition System

The user interface is developed in C# for the Microsoft Windows operating system. The intuitive user interface is connected with recognition system by serial communication standard. The user interface is primarily intended for service purposes (Fig. 5), thus it is to set the basic parameters of the recognition system [6], [7].

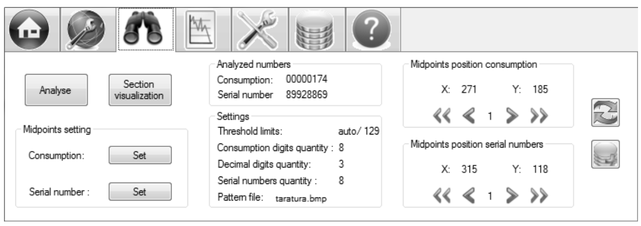

Fig. 5. User interface window for parameters setting.

The basic parameters and possibility of the developed service user application are the automatic identification of areas coordinates for the consumption state detection, setting of the section coordinates for recognition system, setting of the digits patterns for recognition system, setting of the size and the number of patterns, setting of the digits number representing the sections, manual setting of threshold limits and additional parameters, reading of the scanned image from the recognition system, reading of the actual detected sections with detectable data from the recognition system, reading of the basic parameters form the recognition system.

There is graphically presented the original scanned image and processed image in microprocessor with detected separated sections and the threshold distribution of objects and background as the example of application user interface shown in Fig. 6.

The various already presented computational methods were verified and the basic results are presented in the following Table I.

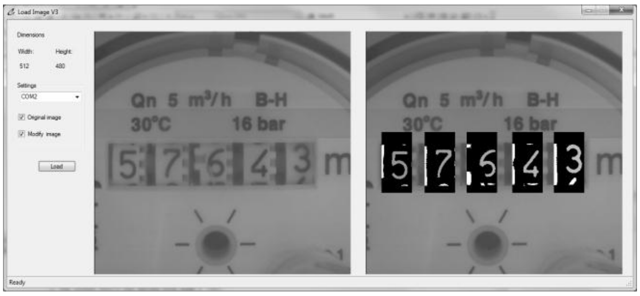

Fig. 6. User interface window with original measured image and with processed image with separated sections results.

There was applied detection in three different luminaires. On the left side, there are given examples and the average of detected threshold levels N for dividing objects and backgrounds. On the right side, there are presented examples and the averages of the calculated coincidence level R of objects and digit patterns, where the marked fields with numbers of inverse colour are faulty detected. In the right column, there is list of the detected digits percentage success rate, which represents actual measured consumption. There were performed 20 measurements in each type of lighting for verification.

TABLE I. EXAMPLE OF RESULTS FROM AUTONOMOUS RECOGNITION OF DIGITS 5,7,6,4,3 FROM ACTUAL MEASURED STATE.

Detected objekt		N - treshold levels					R - object identity ration					T from 20 measurements
		5	7	6	4	3	5	7	6	4	3	
ILLUMINATION	Dark	71	73	76	81	77	81	85	63	90	85	82%
		71	78	79	81	79	79	88	81	90	85	
		73	75	80	78	76	78	87	76	88	86	
		68	78	78	82	78	53	67	60	77	76	
		72	74	81	79	77	79	87	79	91	84	
		Ø71	Ø76	Ø79	Ø80	Ø77	Ø74	Ø83	Ø72	Ø87	Ø83	
	Normal	92	89	87	89	91	79	89	80	90	87	89%
		95	90	80	89	91	82	90	63	91	87	
		89	89	88	90	89	85	92	80	90	90	
		90	88	87	91	88	85	92	81	90	91	
		87	85	90	87	90	85	93	91	92	91	
		Ø91	Ø88	Ø86	Ø89	Ø90	Ø83	Ø91	Ø79	Ø91	Ø89	
	Light	99	103	102	103	104	85	89	81	90	91	94%
		102	99	100	100	102	83	90	80	92	91	
		102	103	99	105	100	84	89	78	92	92	
		100	101	101	107	105	75	66	67	58	68	
		101	103	101	101	102	84	89	78	93	89	
		Ø101	Ø102	Ø101	Ø103	Ø103	Ø82	Ø85	Ø77	Ø85	Ø86	

V. CONCLUSIONS

The purpose of the paper was to verify the possibility of recognition parameters in the developed advanced autonomous recognition system for consumption meters. The specific realization is usable for measurement and other applications with using video signal recognition methods. The structure and used sequence of algorithms were developed in theoretical knowledge base. The main goal of this paper is to show development of autonomous advanced system for actual state recognition. The basic system architecture and algorithms are presented here. The service application as the user interface for parameters setting and verification was explained.

The results in Table I show the increasing threshold object level with increasing illumination. The marked cells in Table 1 represent individual non-correctly recognized digits because of low illumination and protective glass scratch above the digit 6. The recognition advanced system was verified in 20 samples for each illumination and there was measured successful recognition from 82-92 % depending on the illumination confirming usable application for practice usage. The system realization has been developed for the industrial partner for domestic water flow, gas, and electricity meters.

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