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APPLICATION PROCESS CONTROL COMPUTER VISION AND METHODS OF MAKING A DECISION ABOUT SUITABILITY REGENERATION OF WASTE OIL

Summary. The paper describes a new technological process enabling automatic evaluation of the quality of waste oil. The evaluation concerning the color and viscosity of the product is conducted with the use of computer vision methods, which ensures the stability and recurrence of the parameters of the product. The described system, already applied in an company dealing with collection and treatment of industrial waste, is being expanded to incorporate remote monitoring and management of technological processes in an oil refinery.

Keywords: industrial automation, ERP, industrial waste treatment, computer vision, image processing

ZASTOSOWANIE PROCESÓW STEROWANIA ORAZ METOD KOMPUTEROWEJ WIZJI PRZY PODEJMOWANIU DECYZJI O ZDATNOŚCI REGENEROWANYCH OLEJÓW ODPADOWYCH

Streszczenie. W przedstawionym artykule omówiono nowy proces technologiczny umożliwiający automatyczną ocenę jakości produktu. Opisywany projekt rozbudowy systemu w już istniejącym przedsiębiorstwie, działającym w branży zbiórki i przetwarzania odpadów przemysłowych, jest rozbudowywany o moduły realizujące zdalny monitoring i zarządzanie procesami technologicznymi w Zakładzie Rafinacji, przyłączonym do istniejącej już sieci przedsiębiorstw działających w systemie ERP.

Słowa kluczowe: automatyka przemysłowa, ERP, przetwarzanie odpadów przemysłowych

1. Introduction

New IT technologies are increasingly facilitating the integration and centralization of management processes in network-structured companies. For over 10 years this has been particularly observed in various fields of the service sector, such as banking, telecommunications, postal services and transport services. In large enterprises the integration and centralization of management is usually based on special telecommunications and computer networks (belonging to the company or on lease), often comprising an area beyond the country, or even the continent. The process of integration and centralization of management processes helps these enterprises to improve the quality of their services and to significantly reduce the operating costs.

Eurobac Sp z o.o. (Ltd.), based in Paterek is one of few companies which fulfill the legal responsibility for collection and recycling of waste oil (R9 process) imposed on producers and importers of lubricating oil (according to Article 3 of The Act of 11 May 2001 on the Obligations of Businesses Regarding the Management of Certain Types of Waste, and on Product and Deposit Fees). In the company's branch in Trzebinia a modern installation for regenerating waste oil has been built. The waste oil distillation system was put into operation in 2008. The production capacity of this installation is estimated at 6,600 tons a year. The complexity of processing and manufacturing system makes it necessary to customize the tools and their software, which, in turn, increases the costs of such an installation. Modern measuring instruments, IT and computer vision tools allow companies to break the economic barrier, even in the case of a network of medium-sized or small companies.

The main object of this paper is to present the possibilities of applying a hybrid system for controlling the installation of processing waste oil, consisting of integrated ERP modules, visualization and control system, which enables automatic evaluation of the product quality. At present, the decision about the termination of the refining process is made on the basis of periodic sampling in a laboratory and requires stoppages, which reduces the efficiency and has a negative impact on maintaining the parameters of the product. In order to improve the parameters of the product, the filtration of base oil from receivers was established in a mixture of diatomaceous earth. The automatic evaluation of the quality of the color and viscosity of the product was applied to ensure the stability and recurrence, repeatability of the parameters of the product.

2. General description of the system

Rapid development of information and telecommunications technologies enables optimization of business activity of plants re-refining used oil. This offers an opportunity to improve the quality of processing and in the long run will have a positive impact on the protection of the environment. The security of the technological process is a very important aspect. Thus, the introduction of continuous monitoring and control of the installation is, from an economic point of view, one of the most essential elements in the evaluation of quality and quantity standards of the production process. The presented solution comprises latest developments in the fields of information and telecommunications technology, business management and automation.

The system comprises collection, refining, storage and drain of used oils in a company involved in re-refining of used oils. Thanks to combining these three things (ERP, visualization and control) it is possible to carry out an analysis at any stage of the technological process and introduce necessary changes. The described application of modern technological tools in monitoring and management of technological processes concerns the network of companies consisting of:

- headquarters based in Paterek near Nakło (27 km from Bydgoszcz),
- a branch in Bydgoszcz,
- a branch in Szczecin (in the north-west of Poland),
- a refinery In Trzebinia (in the south of Poland).

Figure 1 shows a general diagram of the activities carried out by the described network. In the course of the development of the network i.e. establishing new branches and joining them to the headquarters, the priorities concerning the computerization of the technological processes were changing. At the beginning, the biggest problem was the online connection of all branches with the headquarters and the complete computerization of transport and logistics, which was described in previous articles [1-4]. This resulted in significant positive economic results.

The expansion of the network – as part of the integration of companies dealing with collection and treatment of industrial waste – to incorporate the Refining Plant (re-refing used oil) in Trzebinia meant that a company with a completely different profile (production of base oil of low viscosity and components of heating oil) had to be connected to the existing ERP system.

A general scheme of one of the stages in the technological process is shown in figure 2. It is noticeable that automation and computerization of the technological process requires application of solutions specially designed for that purpose. The preliminary analysis of the

possibility of applying already existing monitoring and production control systems in the oil refining plant showed them to be unsatisfactory for a complete IT integration of the plant with the headquarters [5].

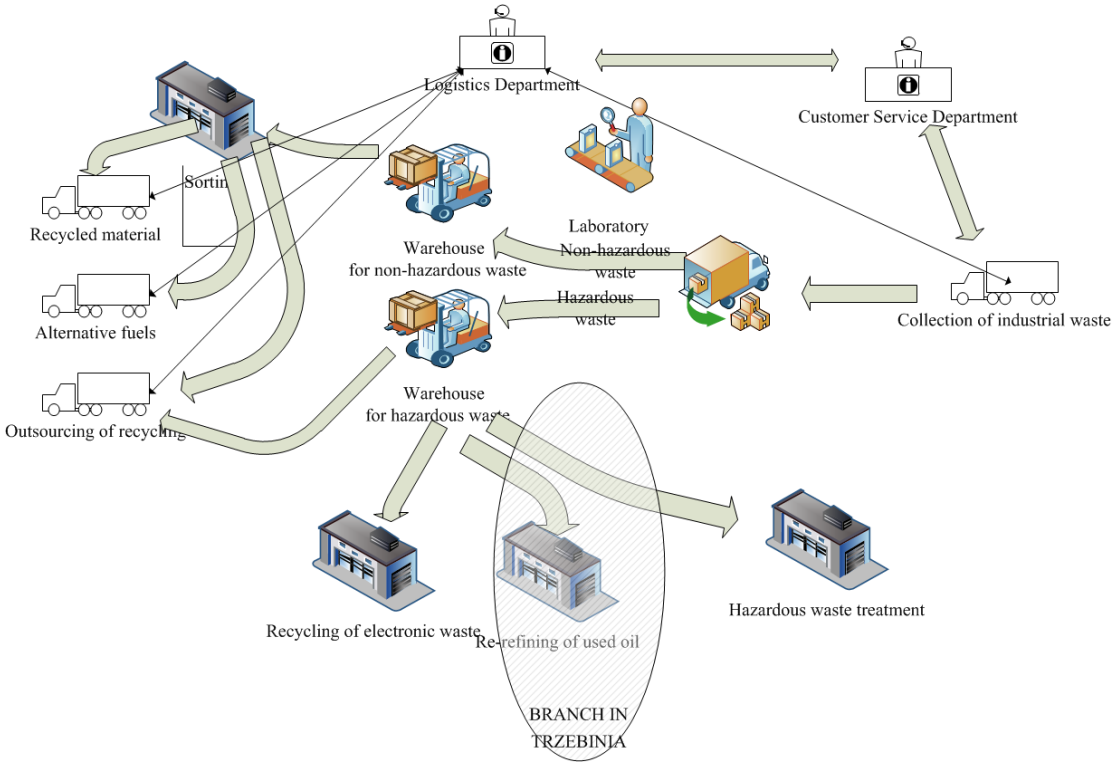

Fig. 1. General scheme of the areas concerned branch; source: developed own
Rys. 1. Ogólny schemat obszarów działania rozpatrywanego oddziału; źródło: opracowanie własne

Thus, a decision was made to create a new system of monitoring and control of technological processes in the oil refining plant. The new system was based on the application of modern SAIA drivers [10] and development of the IT and telecommunications infrastructure, which allow this plant to be incorporated into the integrated remote-controlled monitoring system as well as the management system of the refining plant in a relatively easy and economical way.

During the automation and computerization of technological processes there appeared a possibility and a need for modification of the technological processes in order to improve the quality of these processes and the economic performance of the company.

The computer vision method is used to evaluate the suitability of oil. The application of video-acquisition module allows continuous monitoring of oil parameters. In the developed method a lot of parameters connected with visual evaluation of the processed product are taken into consideration (e.g. transparency).

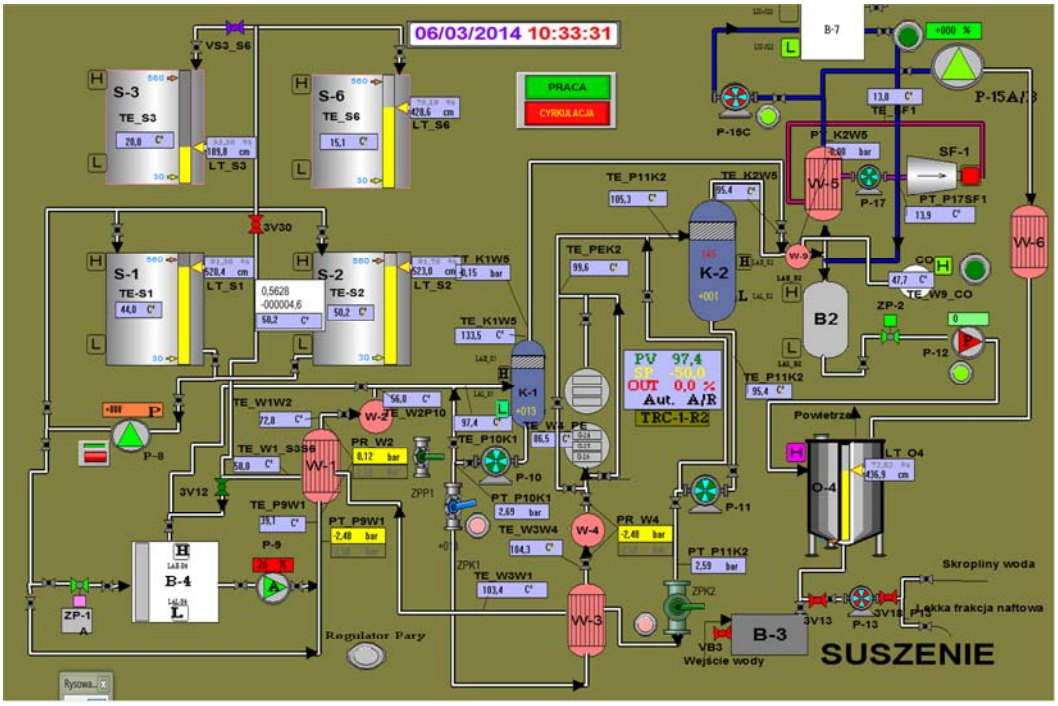

Fig. 2. Visualization stage "Evaporation" in the Department of Refining; source: developed using SCADA

Rys. 2. Wizualizacja etapu „Suszenie" w Zakładzie Rafinacji; źródło: opracowane przy użyciu SCADA

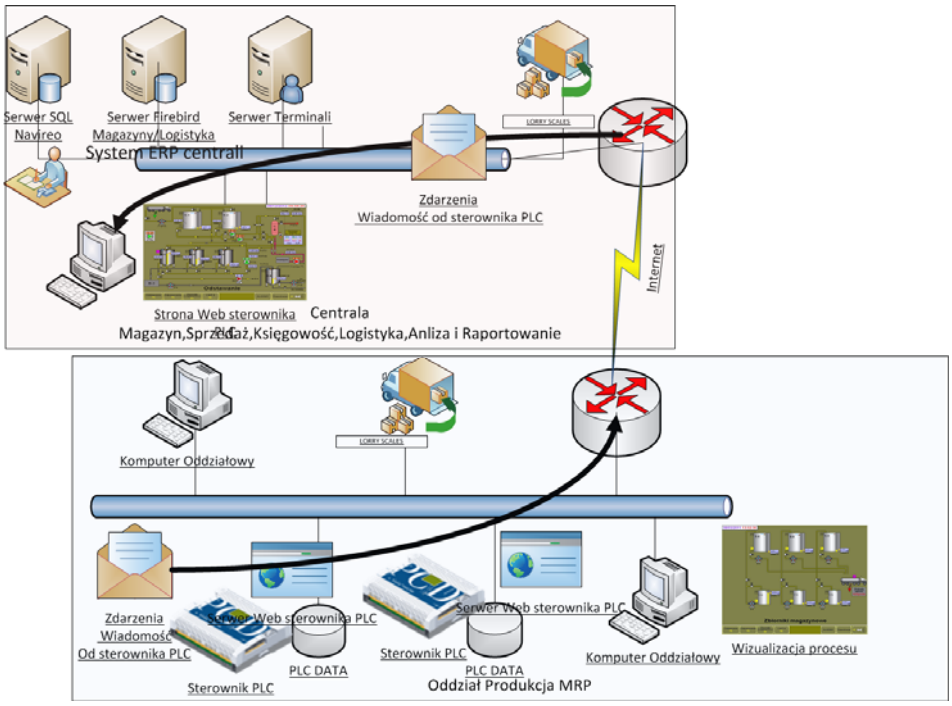

Fig. 3. Schematic diagram of the ERP system in the Department of Refining at all levels and areas of management; source: developed own

Rys. 3. Schemat poglądowy działania systemu ERP w Zakładzie Rafinacji na wszystkich szczeblach i we wszystkich obszarach zarządzania; źródło: opracowanie własne

The system of automatic parameterization of the end product consists of the acquisition stage, the preliminary processing including digital filtration, image conversion into luminance and chrominance space, the selection stage and the decision-making stage. At the stage when the suitability of the product is determined, the decision will be taken on the basis of visual parameters of the substance, fulfilling the criteria of base oil.

Preliminary research has shown an estimated 20% energy saving for the whole process, which will considerably reduce the time and the cost of re-refining used oil. A more detailed discussion of these issues is beyond the scope of this paper. Figure 3 gives an overall view of how the system works in the refining plant.

3. Tools used in monitoring and management of the company's branches

As has been mentioned before, after the analysis of a number of software offered by companies like Siemens, Mitsubishi, Saia, the tools of Saia-burgess [10] company were chosen due to their unique features. The most important characteristics of the SAIA's PLC driver that substantially improve integration with the ERP system are as follows:

- Saia S-Net is an elastic tool of network communication developed by Saia-Burgess Controls, based on open Profibus and Ethernet standards. The drivers implement standards and functionalities from the world of IT (The Internet, websites and e-mail).
- Saia S-Web is a unique functionality integrated with PLC SAIA platform (PCD and PCS) allowing control and monitoring process, presented in the form of HTML pages. SAIA offers a solution which does not require any runtime licenses, keys or additional dedicated modules. The connection with the server, implemented in the firmware of the basic model of a driver, is made though various communications channels (standard series ports RS232 i RS485, Profi-S-Net, Ethernet, modem, USB).

Saia S-Web technology is an alternative to SCADA (Supervisory control and data acquisition), it optimizes the system with regard to management and security, as well as implementation and maintenance costs. This is especially noticeable in case of simple systems of diagnosis, control and monitoring, where SCADA is too expensive. S-Web does not require dedicated software. It uses widely available Web browsers, such as Windows Internet Explorer, so the end user does not need an additional license or a key (dongle) Saia S-Web technology enables easy integration with the ERP system used at the headquarters, which will allow efficient management of the warehouses and will also lead to improvement of economic parameters of the company.

The applied solution enables direct usage of the information derived from the object by means of PLC drivers in the accounting process of the company. The connection with the server can be made using communications channels (RS232, RS485, Profi-S-Net, Ethernet, modem, USB). HTML pages are created with the help of Web Editor, which enables creating pages for viewing process variables and the status of the driver's activity.

Communications interface is divided into two areas: the file system is located in the driver while the part supporting the protocol is in the PC computer. Commands from the web browser are decoded into a protocol connected with PCD and sent to the driver. The reply from PCD is converted into TCP/IP protocol and sent to the web browser. Thanks to this, the time of data transmission is shorter and it is possible to maintain the drivers' working cycle in the real-time regime. Process data from the driver is identified on the basis of the PDP key (PCD data point) connecting the key with an appropriate element in the driver memory (register, flag, input, output, timer, counter, Data Block, text, PCD status). There is a possibility of storing the elements of the application (image, Java classes) directly on the PC hard disk, which enhances the communication with the driver.

The most frequently used channel of communication id a direct connection through so called Gateway, TCP/IP connection and a modem connection. The read-out and generation of web pages situated in the driver memory consists of four stages. Firstly, the pages generated by WebEditor are read, then the source code is created with the use of WebBuilder, which in the stage is processed by means of PG5 into the compiled version, and finally this is loaded into the driver. S-web does not require dedicated software, and so the end user does not need any extra licenses and is not dependent on a specific operating system or a web browser. This is of crucial importance in the measurement of the most important parameters of the installation because of the presence of a tax warehouse on the premises of the refining plant.

4. The use of computer vision methods in decision-making about the suitability of the product in the process of regeneration of waste oils

Image processing to determine the suitability of the product includes the operations of a number of methods for image processing of the product, including algorithms for color space conversion, digital image filtering, normalization and the calculation of the feature vector, based on which the final decision will be taken.

The whole process is divided into a pre-treatment step, consisting of the image acquisition operations, filtering and color space conversion, and wherein the step of extracting features based on the chrominance coefficients *Cr* and *Cb* is formed for the image

feature vector of the product. The last part of the second stage is to decide on the suitability of the product, where the criterion is the distance of the feature vector with the limits prescribed under the standards PN-80/C-04034. Proposed image processing scheme is shown in figure 4.

Fig. 4. Diagram of the steps of image processing; source: developed own
Rys. 4. Etapy przetwarzania obrazu; źródło: opracowanie własne

The first step of the image processing is image transformation. The 24 bit colorful image represented by 3 coefficients Red, Green and Blue from the acquisition unit must be converted to the *YCrCb* color space. The image can be represented in a three-dimensional coordinate system in form three matrices. The *Y* component represents the gray scale image, the other two matrices are chrominance components. By applying the *YCrCb* model it is possible to eliminate the impact of changes in lighting color components. Color space conversion is performed using the following transformations:

$$\begin{aligned} Y' &= 16 + (65.481 * R' + 128.553 * G' + 24.966 * B') \\ Cb &= 128 + (-37.797 * R' - 74.203 * G' + 112.0 * B') \\ Cr &= 128 + (112.0 * R' - 93.786 * G' - 18.214 * B') \end{aligned} \tag{1}$$

The next step of processing of the image is digital filtration. The filtration is used for improving the quality of the image, emphasizing details and making processing of the image easier. The filtration of digital images is obtained by convolution operation. The new value of point of image is counted on the basis of neighbouring points value. Every value is classified and it has influence on new value of point of the image after filtration [6-8]. The advantage of this filter is no effect of blurring and low computational complexity. Optional image processing steps include operations performed on the histogram of the image. This group includes operations: histogram alignment and modification of the brightness range.

In the creating of the feature vector step, a feature vector is formed, which is based on the coefficients *CrCb*:

$$FV = \{Cr, Cb\} \tag{2}$$

The classification in the recognition module compared features from the pattern to model features sets obtained during the learning process. Based on the feature vector *FV* recognition, the classification attempts to identify the image based on the calculation of Euclidean distance [9] between the features of the character and of the character models. It is planned to test the algorithms by using, the following distance measure:

$$D(C_i, C_r) = \sum_{j-1}^{N} \left| R(j) - A(j) \right|^2 \tag{3}$$

where: *Ci* is the predefined character, *Cr* is the character to be recognized, *R*(*j*) is the feature vector of the predefined character, *R*(*j*) is the feature vector of the character to be recognized, *N* is the number of features.

5. Conclusion and future work

Based on the evaluation of the effectiveness of the proposed method for recognition will be able to determine the suitability of the distance methods. The present project is currently (January 2014) in the implementation phase. It is planned that all implementation work will be completed in the first half of this year. In the presented paper discusses the implemented ERP system expansion project in the already existing network of companies operating in the collection and processing of industrial waste, modules implementing remote monitoring and management of technological processes in the Department of Refining, attached to the existing network of companies operating in the ERP system. Subsequently, it is planned to use the monitoring system to extend the functionality of other modules increasing the scope of vertical integration of processes.

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Omówienie

W przedstawionym artykule omówiono nowy proces technologiczny umożliwiający automatyczną ocenę jakości produktu. Opisywany projekt rozbudowy systemu w już istniejącym przedsiębiorstwie, działającym w branży zbiórki i przetwarzania odpadów przemysłowych, jest rozbudowywany o moduły realizujące zdalny monitoring i zarządzanie procesami technologicznymi w Zakładzie Rafinacji, przyłączonym do istniejącej już sieci przedsiębiorstw działających w systemie ERP.

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