IoT gateway and industrial safety with computer vision

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***Abstract* — Despite of automation and security in plants, industrial environment is still dangerous for humans and machines. This work deals with a safety in industrial condition. We designed and built a system to detect dangerous situations and help to avoid them. In our solution, we created a method to detect dangerous situations. We created safety scenes and situations to verify our algorithms, too. The first algorithm is designed to protect a human. This algorithm detects dangerous collisions of human and thermally dangerous areas. Our algorithm and experiments are based on thermal camera. We created a graphical interface to our method, which allows better configuration for more scenes. Reached result will be implemented in designed IoT gateway, to improve industrial implementation with scalability.**

***Keywords* — Computer vision, Safety, Security, Industry, Detection, IoT gateway**

I. INTRODUCTION

Safety is one of the most important thing in industry. New trends depicted a computer vision like a big approach in safety.

Computer vision is a scientific discipline, increasingly infiltrates new areas. It finds it´s implementation even in the industry, nor in untraditional areas such as safety in industrial conditions. In this article, we are focusing on design and verification the methods for detection of dangerous areas and presence of persons in these areas. An asset of this work is the exploitation of described methods for increasing the safety of people in the industry.

This work focuses on the design of computer vision methods, which will be applicable in industrial conditions. Computer vision focuses more and more on new areas of application. It integrates into various structures and it brings benefits like higher safety or security. However, it is not only depending on camera. Therefore, camera systems are supplemented by intelligent software-programs that covers computer vision as a science. Our aim is to create a method that allows machine to see. Under the vision is understood primarily scene understanding and use of the knowledge that offers us the very scene.

In practice, we met with a large number of methods that focus on safety. The idea arose to ensure the safety of people in carrying out work with a higher risk of injury. Man is often distracted and in cases of fatigue or overwork it is doubly true. We can follow the work of man, and if a dangerous situation to intervene in time. The method, which was designed follows the movement of persons. In case, that a human is moving inside a zone, which is dangerous for him, the method detects this and highlights the area of red. Simulation of such a situation and proposed control method was implemented in MATLAB programming. The application is useful to analyze situations, which could lead to an unsafe condition and will provide information, why not originated and what to do to avoid repeating such states. To protect human, we can look also from a technical standpoint machines, because they should be in good condition as not to endanger workers' health. We deal with human protection by using computer vision in our second proposed method. The method is able to control the technical condition of the machine in terms of their thermal load. The method is able to define the warmest region, what can be evaluated like a dangerous zone for human or production. Early diagnosis are one of the important operations in enterprises.

This paper describe computer vision from complex view in the beginning of paper (chapter II). We described safety and security in industry in chapter III. Analysis of current state related to our work in industry is described in chapter IV. Our designed solution and implementation is described in chapter V. We designed our solution not for real-time use yet. We recorded video and then we used these records in our method. However, we want to optimize and improve our method to be implemented in real time and in industrial conditions.

II. COMPUTER VISION AND SAFETY IN INDUSTRY

A. Computer vision and behaviour based system like an aproach

The main aim of computer vision and safety is to find a way, to connect vision and safety rules to create safe industrial environment [1].

Computer vision is trying to resemble human vision. However, computer vision is trying to learn a system to pick what should be zone of interest, how to understand the objects and how the machine should be thinking. It can be said, that this is a command-control based approach. In the meaning of a command based approach, we can find out some constrains, exactly implemented human's constrains into system. On the other hand, the technological implementation of computer vision system is better than biological in many ways. For example, a camera can detect movements faster than human eye. However, command-control based system can only react on present situation. One of emergence field is behavior

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based safety [2]. It uses psychology to prevent injuries. Behavior based safety (BBS) is not only based on safety rules on machine side to monitor any intervention. BBS involves human's behavior into safety system. Therefore, it can evaluate more safety situation and avoid more dangerous situations.

B. *Computer vision and image processing division*

Computer vision is based on the image processing, which is divided into two levels. We can divide image processing to the lower and the higher level.

The lower level uses a little knowledge about the image content. It works with methods for image compression, pre-processing, filtering, tracking, segmentation [3],[4].

The higher level is based on the knowledge and plans to achieve the objectives. It uses low level routines for further object or motion description and analyses. Also the artificial intelligence methods are applicable. This layer´s task is to describe and understand the objects on the image [4].

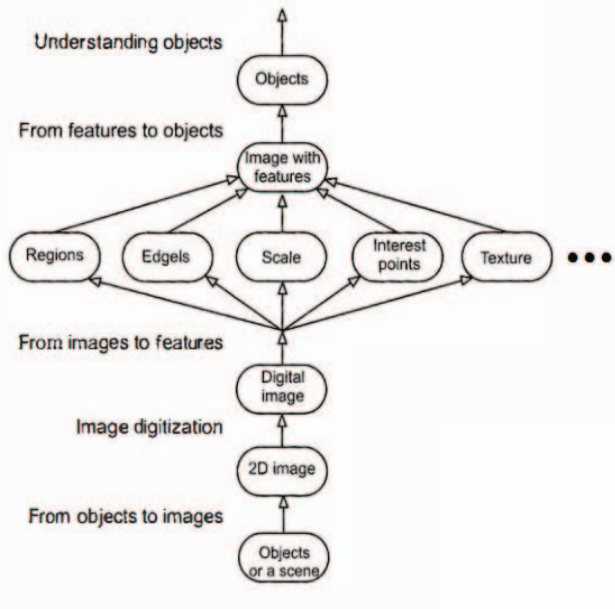

Figure 1. Levels of image representation [4]

Global view on the low level and high level description of image processing is described in the Figure 1.The high level of image processing if depicted above the step *From image to feature*. Our work begins in low level image processing and overlays with high level processing. We are mainly concentrating on low level part with description of high level in this paper.

III. SECURITY AND SAFETY STATE IN INDUSTRY

Some industrial system can be based on the cooperation with the camera system and can be divided into two basic groups according role, too. The roles are: safety and security. Some applications cannot be exactly classified under one of the stated groups, because by their functionality they cover both groups. In the reference [5] is defined a difference between the safety and security.

A. *Safety role systems*

Employees are often exposed to increased demands, when performing their work and their reaction time decreases due to overwork or fatigue, what can lead to an injury. These systems should pay attention to human health protection during performance of work with an increased risk of injury with their activity.

B. *Security systems*

The group of these systems is formed by those applications in practice, which supervise our objects and property protection. Application in practice is wide, beginning with tracking the unwelcomed movement in private areas, through fire-fighting measures, to monitoring the operational temperature of machines and the maintenance resulting from it.

IV. ANALYSIS AND DEFINITION OF SAFETY SYSTEM

Two types of systems ensure the human's safety in the industry. We selected safety systems as the area of interest.

A. *Safety systems analyse and proposal*

Safety is protection against random incidents. Random incidents are unwanted incidents that happen because of one or more coincidences.

This type of system is represented in the industry by optical latches, scanners, pressure mats, and similar safety elements. Applications are using the computer vision to protect the human health during work. For example, using a camera, which is able to detect a gas leaking from a big distance can help to protect humans in the gas industry.

In industry, a camera placed on the electric locomotives avoids dangerous collisions with obstacles or workers [5],[6].

Our intention is to use thermal camera and computer vision to create a system, which will not only be a command-control system, but BBS, too. The result will be implemented into our IoT gateway, which is described in reference [7]. In the Figure 2., we are already designed method represented in red-yellow-blue circle, which represents analytic block.

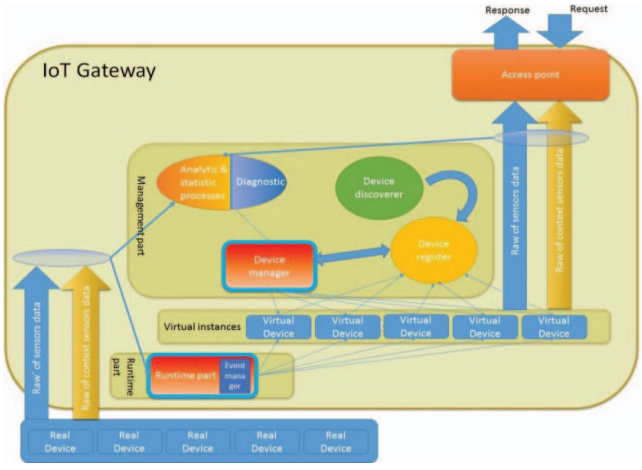

Figure 2. IoT gateway functional description [7]

Goal and advantages to implement this solution into gateway is in a better exchange of reached analyses from monitored environment and business, control or emergency systems.

V. DESIGNED SOLUTION

Our solution is divided in low level and high level implementation. In this paper, we are concentrating on low level implementation.

The low level implementation is based on image processing. This begins with grabbing an image and ends with extracted features, which are important to defined objects. Our implemented method is based on finding area of interest, which represents a potentially dangerous situation.

In the higher level, we are focusing on evaluation of dangerous situations. We designed a method to avoid incidents. We are concentrating on cases when a person is in a dangerous area and it is important to detect the hottest spot in the Matlab programming environment. Designed solutions serve as backward analysis and for situation evaluation yet. Our intention was to create a solution, which will help to analyze and create methods for a protection from incidents in the industry. We would like to optimize and use this method in real time in the future. However, we designed a concept of industrial gateway, where will be this safety feature implemented and will use the BBS.

We designed and created a graphical user interface (GUI), which is described in chapter VI.

A. Camera and experimental's conditions

We used Fluke Ti200 Thermal Imaging Camera in our experiments. It is a thermal camera. Camera has two modes:

- Automatic – LaserSharp TM I. allows fast and automated focusing.
- Manual – allows manual focusing, in our condition manual focusing. We did not reach good results whit manual focusing.

The camera has other good features, but we did not used them in our experiments.

We used this camera in home conditions, where we simulated process in industry. We created scenes and simulated collisions. There are two types of scenes in our experiment:

- Scenes for detecting human in dangerous zones – this allows to detect dangerous situation for human. For example, if human is in dangerous zone. These situations were only simulated with not extremely hot objects. We simulated real conditions with help of laboratory and office equipment. We would like to test our methods in true industrial conditions in the future work.
- Scenes for detecting dangerous zones - in these scenes are not only human the main objects. Machines, wares, components and other things in production are getting hot and starting to be dangerous for human.

We want to simulate industrial conditions, where are many vibrations caused by working machines. Therefore, we did not used stand. The video processing were harder, but we wanted to create methods that are more robust.

Figure 3. Fluke Ti200 Thermal Imaging Camera [9]

B. Detection of person in a dangerous area

The objective of this method is to identify a human, which moves to the static background. To achieve the objectives, we use a line of commands from the image processing toolbox. During the pre-processing we transfer the individual images to the palate of grey shades and adjust their brightness. Subsequently, we convert the images into a binary form and after smaller adjustments we create a difference between the background and the individual images from the video.

We applied morphological operations on the resulting image. The outcome of such processing is a person´s silhouette. We determine 3 straight lines that delimit the prohibited area using the Hough transformation from the binary image of the background. At the end of the method, we check, if the person´s silhouette is beyond the straight lines´ boundary. If so, we mark the silhouette by red color. The output of this method is also the person´s outline, drawn by a green color.

Figure 4. Detection of person in not dangerous zone

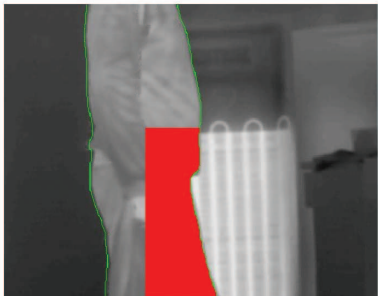

Figure 5. Detection of person in dangerous zone

C. Hottest spot detection

This method is already popular, but in our way. Hottest spot detection is used to detect damages on machines. For example, hottest spot detection is used to find damages on furnace.

Method is similar to the previous case, but it´s more simple. It´s simplicity lies in the fact that we don´t have to look for various objects, but only one hottest spot. Uploaded images are transferred to the pallet of grey shades. We threshold this image by large value, therefore getting the brightest spot on the image, which matches the hottest spot. From such a transferred image, we create an outline of the hottest spots, which we draw on the original image.

We used only two types of scenes:

- Electric engine – temperature of engine is getting up during his workload. The other constriction parts connected with engine can be dangerous for human.
- Hot water – hot water simulates a hot liquids that can be dangerous for human, especially if are inside tanks or pipes, which are very close to human working area.

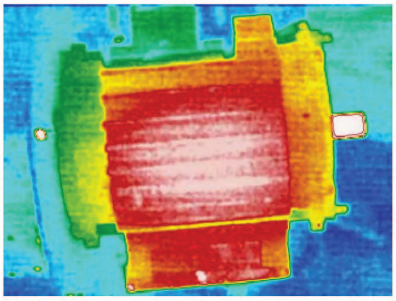

Figure 6. Example of zone, which can cause an injury

VI. Implemented Solution

We wanted to create a solution, which will be easy to use. Therefore, we created a graphic user interface (Figure 7). It allows easy configuration of methods' parameters. In the application, it can be picked one of these two methods, videos, working are to reduce computing and frame rate. We created application in Matlab. BBS allows saving data and analyzing further templates from data. These templates will be analyzed from psychological view. In this point, we will be able to say if human behavior is dangerous and evaluate situations. Gateway implementation will offer wider data acquisition and control over plant [8].

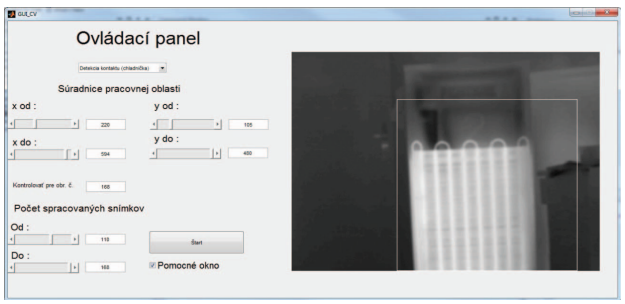

Figure 7. Frame from thermal camera

VII. Future Work

We would like to test our methods in the industrial conditions. Next, we would like to optimize and use this method in real time, to not only analyze what creates incidents, but we want to create alarms if the incidents will appear. At last, we want to implement this solution in designed industrial gateway, where will be implemented the BBS.

VIII. Conclusion

This paper is focusing on human safety. We designed a solution, which will be a part of our IoT gateway. Designed method can be used to improve safety in the industry. The solution allows identifying and avoiding incidents. Improving these methods and their shift to real-time tracking level can find wide utilization in practice. With help of this solution will be able to improve safety. It is a more space to improve implementation of BBS in industrial safety, which is intention of our future work.

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