Analysis of Effective Methods for Identifying Selected Objects in Digital Images

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Summary of doctoral dissertation

Ensuring the safety and appropriate level of prevention related to citizens' risks are in recent years more and more important and up-to-date problem. For several years in common use are surveillance cameras that allow for continuous observation of many places. They are used on streets, in public and commercial buildings, public transport. The number of cameras in urban areas continues to grow. More and more extensive structure of the monitoring systems are being built. Examples could be London (UK), which has more than 4 million cameras and Warsaw, where the urban monitoring center has more than 13 thousands connected cameras (as at 01/22/2016).

The dissertation deals with the problem of image processing and analysis for the purpose of video monitoring systems. **The main goal of the dissertation is to develop effective methods for identifying objects in aspect of their use in intelligent monitoring systems. The proposed method will allow for detailed content analysis in the process of detection and identification of threats. Possibility of parameterization make the methods possible to improve in terms of quality and detection speed in the context of specific proposed uses.**

The dissertation consists of thematically coherent set of publications which includes the following papers:

1. Andrzej Matiolański, Aleksandra Maksimova, and Andrzej Dziech. CCTV object detection with fuzzy classification and image enhancement. *Multimedia Tools and Applications*, pages 1–16, 2015. ISSN 1380-7501. doi: 10.1007/s11042-015-2697-z. URL `http://dx.doi.org/10.1007/s11042-015-2697-z`

2. Michał Grega, Andrzej Matiolanski, Piotr Guzik, and Mikołaj Leszczuk. Automated detection of firearms and knives in the CCTV image. *Sensors*, 74(12):4437–4451, 2015. ISSN 1380-7501. doi: 10.1007/s11042-013-1544-3. URL `http://dx.doi.org/10.1007/s11042-013-1544-3`

3. Remigiusz Baran, Andrzej Glowacz, and Andrzej Matiolanski. The efficient real- and non-real-time make and model recognition of cars. *Multimedia Tools and Applications*, 74(12): 4269–4288, 2015. ISSN 1380-7501. doi: 10.1007/s11042-013-1545-2. URL `http://dx.doi.org/10.1007/s11042-013-1545-2`

4. Piotr Guzik, Andrzej Matiolanski, and Andrzej Dziech. Real data performance evaluation of CAISS watermarking scheme. *Multimedia Tools and Applications*, 74(12):4437–4451, 2015. ISSN 1380-7501. doi: 10.1007/s11042-013-1544-3. URL `http://dx.doi.org/10.1007/s11042-013-1544-3`

5. Andrzej Matiolański and Piotr Guzik. Automated optimization of object detection classifier using genetic algorithm. In Andrzej Dziech and Andrzej Czyżewski, editors, *Multimedia Communications, Services and Security*, volume 149 of *Communications in Computer and Information Science*, pages 158–164. Springer Berlin Heidelberg, 2011. ISBN 978-3-642-21511-7. doi: 10.1007/978-3-642-21512-4_19. URL `http://dx.doi.org/10.1007/978-3-642-21512-4_19`

6. Piotr Boryło, Andrzej Matiolański, and TomaszM. Orzechowski. Face occurrence verification using haar cascades - comparison of two approaches. In Andrzej Dziech and Andrzej Czyżewski, editors, *Multimedia Communications, Services and Security*, volume 149 of *Communications in Computer and Information Science*, pages 301–309. Springer Berlin Heidelberg, 2011. ISBN 978-3-642-21511-7. doi: 10.1007/978-3-642-21512-4_36. URL `http://dx.doi.org/10.1007/978-3-642-21512-4_36`

Research Motivation

Currently, there is a noticeable rapid growth of interest in technologies that may improve and increase the efficiency of CCTV systems. This is confirmed by numerous scientific publications, as well as a number of commercial products offering modern solutions for video surveillance systems. The proposed methods will deal with objects detection and recognition problem applicable in CCTV systems. The dissertation describes the possible modification of algorithms and their parameterization in order to improve the quality and speed of processing in the context of specific proposed uses. The current technical capabilities allow to use advanced algorithms for image processing and analysis. Hence they are more efficient and push to develop new functionalities. This set of functionalities can be seen as the introduction of a new type of video monitoring systems, so-called **intelligent monitoring of threats** , which allows you to:

- avoid the constant observation of the scene by system operator and notify only in case of danger by the system,
- maximize support for system operator with video surveillance,
- significant automate the process of urban monitoring, the system informs the operator on a regular basis,
- load transfer of man on the computer, avoiding the mistakes of human nature caused by fatigue and lack of concentration,
- process many video streams at the same time,
- constant supervision by a man, an algorithm does not respond to an event, but informs the operator as a result of image analysis.

These features, viewed from the perspective of monitoring system as a whole, allow to improve its effectiveness, reduce operating costs and provide a natural evolution of existing solutions. Worth mentioning is the social utility of the research. Efficient video surveillance systems are used to improve the security of citizens and which is especially important to protect privacy by avoiding the constant observation.

Intelligent monitoring threats is currently an active topic of research. This is evidenced by numerous publications in reputable journals and papers presented at leading conferences in this

area of science. Research is also conducted in many projects (among others, INDECT and Insigma projects in which author was involved). In the area of commercial solutions, companies introduce a single functionalities of intelligent solutions for their products. The systems' evolution develop the need for new functionality which certainly will present in the market for a long time.

Algorithms for Identifying Objects in Video Monitoring Systems

The dissertation discusses image analysis algorithms that can be used in intelligent monitoring systems. Among them are both my own solutions and existing ones, which were improved by me. During the research, I tried to keep in mind that the developed algorithms will work in the real CCTV systems. Significant factors that influence the effectiveness of a solution are processing speed, high efficiency, and the ability to adapt to changing conditions. Each of presented algorithms can be parameterized which means adaptation to the specific conditions of which is supposed to work. This ability is important because of the multitude of hardware solutions and the conditions in which monitoring system may work. With the parameterization, there is an optimal use of image recognition methods in collaboration with different models of cameras, the ability to adapt to changing weather conditions and implementation of dedicated usage scenarios. According to the assumptions of engineering it is crucial to maintain balance between the speed of processing, quality of the solutions and the expense of implementation (*ang. Engineering triangle*). Parameterization enhance the desirable features of the solutions. For instance it is possible to improve the speed at the expense of the quality of object recognition. Different usage scenarios presented algorithms may require different adjustment.

In this paper I consider some exemplary usage scenarios for developed algorithms. They are used to demonstrate the performance and capabilities of image processing methods. They do not exhaust all the possibilities of these solutions that can be adapted for other purposes. In the work the following use cases were considered on the basis of presented various image processing and analysis algorithms:

- detection of selected objects:
  - human face,
  - dangerous tools (based on knives),
  - vehicles (based on cars),
- cars' make and model recognition,
- embedding metadata into images using digital watermarks.

The effectiveness of the described algorithms has been proven on the basis of tests carried out. For this purpose a number of independent usage scenarios were selected. Validation was done on a significant number of samples from different datasets acquired under realistic conditions. Thus, there is no basis that proposed solutions could not be used in commercial video monitoring systems.

Own individual author's contribution to the state of the art made by the above thesis is to:

- propose an optimization algorithm for face detection using genetic algorithm,
- develop a method for the use of multiple parallel classifiers and combining their results, which resulted in an improvement in detection efficiency and shortening the processing time,

- develop an algorithm to identify objects using video descriptors to describe specific objects,
- propose the use of clustering on fuzzy sets and methods of machine learning in the process of identifying objects,
- development of a method for object identification allowing parameterization and use in various scenarios of use,
- validate the algorithms with large number of samples,
- propose an algorithm to embed digital watermark in the image, which allows for the lack of separation between the image and the metadata.

Some of the described solutions have been created in the national and international research and development projects. They have big potential for implementation in the real video monitoring and safety systems. Presented algorithms have become part of the prototype system INPROT, which was awarded the gold medal at 113th International Invention Fair „Concours Lépine" 30th April - 11th May 2014 in Paris and a silver medal for innovation at the 2015 Kaohsiung International Invention and Design EXPO, 4th - 6th December 2015., Kaohsiung, Taiwan.