ISSN 2409-9066. Science and Innovation. 2014. V. 10. No. 6. P. 17—23 doi: http://dx.doi.org/10.15407/scine10.06.017

Boyun, V., Sabelnikov, P., and Sabelnikov, Yu.
V.M. Glushkov Institute of Cybernetics, NASU, Kyiv

ALGORITHMS FOR ANALYSIS OF TELEVISION AND THERMAL IMAGES IN SPECIAL-PURPOSE VIDEO DEVICES AND SYSTEMS

The results of the research project «Development of Algorithms and Program Models for the Analysis of Television and Thermal Images» (code VC 200.16.13) have been presented. The existing methods and algorithms for processing the television and thermal video images have been analyzed and the new techniques that will allow the researchers to create more effective video devices and systems for special purposes have been offered.

Key words: image, thermal imager, filtration, contour, comparison of objects, and real-time systems.

Nowadays, for the military operations in the daytime and at night, the crucial factor is to be the first who discovers the enemy object against any natural background using automated surveillance systems and to give the operator the image of better quality. This is achieved by improving the quality of television and thermal vision cameras and by using algorithms and technical means for image processing.

The aim of research project implemented at the V.M. Glushkov Institute of Cybernetics of NASU was to enhance the efficiency video equipment for weaponry systems (particularly, for armored vehicles) through the development of algorithms for processing images in visible and infrared bands, which will provide the operator with necessary comprehensive information.

Recently, many methods for image processing have been developed. Among them, there are digital filters that can significantly reduce the impact of noise and blur and, provided they improve their contrast, can increase the detecting ability of TV and thermal monitoring channels.

There is no general theory of image enhancement. When the image is processed for visual interpretation, the ultimate judge of how good is a particular method is the observer. Visual assessment of image quality is a very subjective process that makes the image quality an elusive standard that is used to assess the algorithm effectiveness.

The authors have reviewed and elaborated methods and algorithms that can be a basis for developing a set of software tools for video devices and systems. The operator can select out of them those necessary to address major challenges in particular situation.

Filtering and segmentation make it possible to get an improved image or to highlight individual objects. The algorithms for detection of contours and comparison of them or their individual sections allows the users to recognize objects by shape regardless of shift, rotation, and scale in the presence of noises of different nature. Also, they can be used to adjust the television and thermal images, if not for their matching then, at least, for marking masked thermal objects on the TV images. Panning can improve the reliability of observations with PZT camera. The tracking algorithms will make it possible to track automatically any objects in the image specified by the operator and to feed the coordinates of objects to the actuators.

In addition, the Glushkov Institute of Cybernetics has developed programs to test the proposed algorithms and the architecture of promising calculators and sensor devices for implementation of labor-intensive algorithms in real time. At the same time, the researchers of V.E. Lashkarev Institute of Semiconductor Physics of NASU have analyzed errors affecting the quality of thermal images and the specific features of image processing. They have developed technical and design decisions related to thermal surveillance devices to increase their apparent ability, reliability, and survivability.

Herein, there are some results of research on how to speed up the algorithms for primary image processing in the video devices built on the basis of signal processors, as well as the proposed method and algorithm for image object comparison.

PRIMARY IMAGE PROCESSING

The important point for ensuring the real-time operation of specialized image processing devices is to accelerate video processing and to reduce the control signal delays in the feedback loop. This can be done by combining the input and processing of video information through using the smaller portions such as the lines as substitute for the frames, when inputting the image [1—4].

Modern signal processors underlying the majority of SIPD make it possible to organize a computational process using the direct memory access channels, which provides the input of new pieces of information from video sensor while the processor handles a portion of the previous data. In this case, the processor is largely released from the input process, with its internal resources being used sparingly for handling of information. This means that for processing video data it is enough to hold a regular portion instead of the whole image in memory. The processor internal memory that is much faster than the external one is sufficient for this purpose. For example, the Blecfin processors manufactured by *Analog Devices* (with a clock speed of 600—800 MHz) read the internal RAM for 1.7—1.3 ns, while the external devices like SDRAM (with a clock speed 133 MHz) to be connected to these processors can read data for a period of 22 ns and more, which is much slower (by an order of magnitude).

In this context, it is necessary to adapt or to develop new algorithms that make it possible to implement the serial input and processing of individual lines of video image.

From the technical point of view, the image analysis is processing of image accompanied with separation of individual objects, calculation of their parameters, and logical conclusions on the number, quality, and other characteristics of the selected objects. The task is usually divided into several stages, one of which is the primary image processing. As a rule, it includes:

- Image filtering;
- Segmentation;
- Selection and conversion to other representations of object contours;
- Calculation of initial parameters of image objects and so on.

Image filtering implies the removal of «noise», so the image becomes more «clean». Segmentation is division of the image into parts with similar properties, each representing a separate element or group of elements. After the segmentation, the object contours are selected and transformed to other representations, with the characteristics of objects calculated for subsequent analysis.

The mentioned methods and algorithms of filtering are referred to the window techniques of image processing. These methods are based on sampling of individual pixels with surroundings within a specified window and doing operations with selected values of pixels, as a result of which, a new pixel value is obtained. Masks with different coefficients may be involved. The processing of this type can be done in two ways, in parallel with the input of video data:

1) To organize the storage of several input lines of image in the memory and to generate the results for further steps of processing;

2) To input video data sequentially and to accumulate a few lines of processing results in the memory for subsequent steps of processing.

Number of video data lines to be stored in the memory and the time delay in generation of the results are determined by the mask size in vertical direction.

Image segmentation by texture and color features can be divided into 2 groups:

1) Segmenting by known features and characteristics of zones or areas identified in the image;

2) Segmentation based on the pre-determined image characteristics.

For the first group of algorithms, the typical way is either the image analysis through its scanning by a sliding window or the analysis of individual pixel in the case of some problems of color segmentation. Therefore, for this group of algorithms it is expedient to do processing by inputting image lines in subsequent manner keeping in the memory the number of lines that match the vertical size of sliding window.

For the second group of algorithms, firstly, it is necessary to define the characteristics of the entire image (histograms, statistical parameters, spectral characteristics, etc.), therefore the formation of characteristics and the very segmentation are impossible unless the entire image is obtained and the required characteristics are calculated. When processing the video sequences, the majority of characteristics (e.g., histograms, statistical parameters) certainly can be calculated while inputting the next image. These characteristics can be used for processing the next images.

The authors of [5] have proposed an algorithm that makes it possible to process video data obtained at the previous stages when coding, transforming the contours, and calculating some primary characteristics of objects, without waiting until the entire image frame is input. This is possible because the algorithms of the previous stages (filtering and segmentation) also allow the users to implement image processing and to get results while inputting and processing video data simultaneously.

Thus, obtaining the primary characteristics of objects required for the further analysis with minimal delay with respect to the last line of input video frame is of particular importance for surveillance systems operating in real-time mode.

IDENTIFICATION OF OBJECTS BY CONTOUR SHAPE

The authors hereof have proposed a method and an algorithm for comparing the geometric object contours (with accurate definition of scale and orientation) by characteristics of undistorted segments and more accurate numerical estimate of comparison results [6].

Having processed the image and converted it to binary form, the procedure for selecting the contours of analyzed objects and comparing them with the standards is initiated. The procedure is performed in four stages:

1) The contours of analyzed binary objects are separated and converted to the vector form, with their primary parameters such as length of contours, momentums, and coordinates of the centers of gravity calculated. At this stage, one or several selected contours with primary parameters can be saved as standards for the database. The contour is divided (manually or automatically) into several segments. The coordinates of boundary points of the segments are stored;

2) The candidate pairs (the object and the standard) are selected by the characteristics calculated on the basis of initial parameters by comparison with similar geometric standards for the further comparison. It should be noted that several standards can fit one analyzed object by their characteristics. The approximate scaling relations and approximate mutual orientation are calculated for each selected pair;

3) All selected pairs are sorted. The identical segments of the object contour (of the selected pair) are searched for each segment of the standard contour allowing for approximate scale and orientation, as well as the criteria. In other words, there is a search of the start and the end points of the segment. The criteria of segment identity are approximately equal (with a certain error) lengths

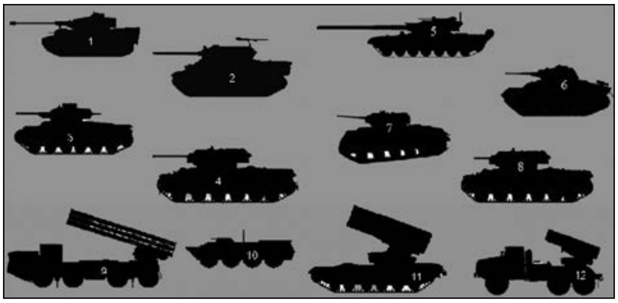
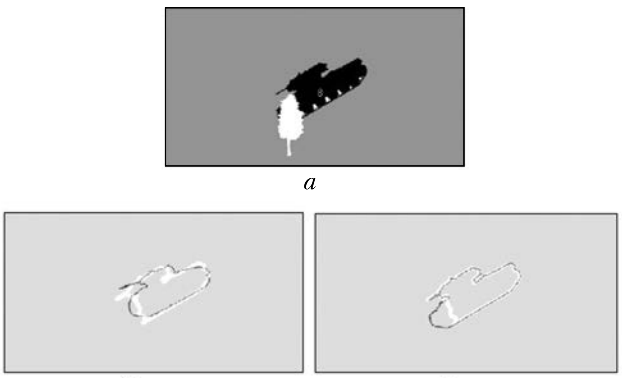


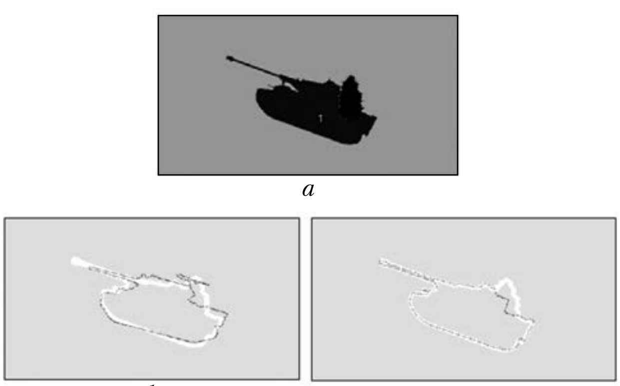
Fig. 1. Snapshots constituting the database of military equipment standards. The database consists of 12 objects



a

b *c*

Fig. 2. Comparison of objects and standards (noise type 1): *a*) silhouette of military equipment to be compared; *b*) result of comparison by the traditional method; *c*) result of comparison by the proposed method



a

b *c*

Fig. 3. Comparison of objects and standards (noise type 2): *a*) silhouette of military equipment to be compared; *b*) result of comparison by the traditional method; *c*) result of comparison by the proposed method

of contour segments of the object and the standard, and the ratio of the distance between the end points to the length of each segment. When comparing the lengths an approximate scale is taken into account, with the ratios being invariant to shift, rotation, and scale;

4) The likely scale, shift, and mutual orientation of objects are estimated on the basis of characteristics of identical contour segments. Thereafter, the standard contour is superimposed on the object contour, with degree of their coincidence calculated. The superimposition with the best estimate is deemed the result for approval of decision or further processing. It is assumed that it is a result of the undistorted segment of object contour identical to the corresponding segment of the standard contour. Accordingly, the parameters obtained as a result of superimposition, i.e. scale, shift, and mutual orientation, are deemed accurate and used for the further analysis.

It is possible to reduce the number of superimpositions and, consequently, the time required to get the final result provided the mutual orientation and scaling relations of the object and the standard are defined approximately (insofar as this narrows the area of searching the identical contour segments) and each superimposition procedure for the current selected segment is checked for its feasibility and is either confirmed or denied depending on result of the check-up. This is possible provided the binary image moments of the objects [7, 8] are used, for which, unlike the contours, the number of pixels does not depend on the orientation.

Fig. 1 shows the snapshots constituting the database of military equipment standards, which consist of 12 objects. In Fig. 2, *a*, there is a silhouette of military equipment object in the case of noise type 1 (a part of the image is cut) to be compared with the standards from the database.

The object and the standards are compared by two methods:

1) *The traditional method* (Fig. 2, *b*) when the objects are superimposed by the centers of gravity (the mutual orientation is calculated by the

second-order moments; the scaling relations are computed by moments of zeroth order);

2) *The proposed method* (Fig. 2, (*a*)) when the standard contour is divided into 4 segments and the identical segments of the test object contour are searched.

Fig. 2b shows that the comparison by the existing method gives a misleading result as the test object is identified with a completely different standard (number 7). The comparison based on the proposed method identifies the object with the adequate standard (number 8), as showed in Fig. 2(*c*).

Fig. 3 shows a military equipment silhouette in the case of noise type 2 (the image of other object overlaps that of object to be identified).

The objects were compared with the standards by the same techniques as mentioned above: the existing method (Fig. 3, *b*) and the proposed method (Fig. 3, *c*).

Like in the previous case, the comparison by the existing method gives a misleading result. The object is identified with inappropriate standard 2 (Fig. 3, *b*). In contrast, the comparison by the proposed method identifies the object correctly with standard 1 (Fig. 3, *c*).

The proposed method implies the analysis of four segments into which the standard contours are randomly divided. The comparison based on identical segments works well even for significantly distorted object contours.

CONCLUSIONS

The following results of R&D project have been obtained:

1) The errors affecting the quality of thermal images have been analyzed; the peculiarities of using algorithms for processing thermal images have been considered; recommendations for their use have been proposed; the use of color schemes (especially, the high-contrast ones) to improve thermal image recognition has been proposed and justified;

2) The algorithms for primary image processing (oversampling and filtering, segmentation according to various criteria, selection and coding of object contours and calculation of their original characteristics) have been considered; techniques to reduce time and to raise effectiveness of the algorithms due to simultaneously input and processing of information using only the internal storage of video device signal processor have been proposed;

3) An original method and algorithms for geometric comparison of partly distorted object contours have been proposed; techniques for the separation of areas where the object and the standard do not match and for the numerical evaluation of comparison with the standard, as well as a technique to speed up the comparison with the standard by calculating and using the moments of inertia of object binary image have been developed. These solutions allow the users to identify the objects by shape regardless of shift, rotation, and scale in the cases of noises of different nature. With the help of these techniques it is possible to adjust television and thermal vision images for marking masked thermal objects on the TV images;

4) Algorithms for creating panoramic images from video sequence, which increases reliability of observation with the help of PTZ camera;

5) The proposed surveillance algorithms can be basis for the systems of surveillance of moving objects (in addition, they ensure significant video compression). The proposed ways to improve computing algorithms can significantly reduce the number of operations required for searching moving objects. The surveillance algorithms make it possible to track automatically the position of object images specified by the operator and transmit their coordinates to the actuators;

6) Design solutions to improve the quality of thermal images have been developed. In particular, a dual channel system of thermal surveillance (the first channel for the range of 3—5 microns and the second one for the range of 8—14 microns) has been proposed to be used. This improves and facilitates the detection, identification, and monitoring of image objects. The stabilization of aperture temperature has been showed to be among the design solutions that can reduce the error;

7) A parallel multiprocessor architecture that can be implemented on serial programmable logic integrated circuits and structures of promising sensor devices [9, 10, 11] with parallel processing of video data directly on the touch matrix (including binarization and separation of image, identification of original characteristics, moments of inertia, etc.) have been offered. These solutions will make it possible to create video devices for real time processing of images.

The development of algorithms for image processing and analysis allowing for their specificity will facilitate the creation of modern, higher-quality video devices and systems for providing the national defense industry with Ukrainian-made visual media. These devices for digital image processing can be used in many other areas, such as industry, transportation, robotics, medical, biological, and other scientific research.

Three patents and eight papers have been published upon the results of this research; the results have been reported at three international conferences.

The project was carried out by V.M. Glushkov Institute of Cybernetics and V.E. Lashkarev Institute of Semiconductor Physics of NASU within the framework of the Program for Support of R&D Projects (Order of the NASU Presidium of 27.02.2013 no. 133) and the project «Development of Algorithms and Software Models for Analyzing TV and Thermal Images» (code VK 200.16.13). The project partner was Fotopylad Scientific and Production Complex, state-owned enterprise," Cherkasy.

REFERENCES

1. Boyun, V.P.: Perception and Processing of Images by Real-Time Systems. *Artificial Intelligence*, 3(61), 114—125 (2013) (in Ukrainian).
2. Boyun, V.P.: Specific Features of Processing of Signals and Images by Real-Time Systems. *Proceedings of International Scientific Conference on Modern Information Technologies: Problems, Achievements, and Prospects for Development*, 298—299 (2013) (in Ukrainian).
3. Boyun, V.P. and Sabelnikov, P.Yu.: Systemic Approach to Optimization of Input, Perception, and Processing of Signals and Images. *Proceedings of International Sscientific Conference on Issues of Optimization of Calculations*, 43—44 (2013) (in Ukrainian).
4. Boyun, V.P.: Intelligent Real-Time Video Systems. Proceedings of International Conference Ukraine – Russia – Skolkovo: United Innovation Environment, 54 (2013) (in Russian).
5. Sabelnikov, P.Yu.: Alignment of Input and Processing of Images in Intelligent Videocamera. *Proceedings of International Scientific Conference on Modern Information Technologies: Problems, Achievements, and Prospects of Development*, 286—288 (2013) (in Ukrainian).
6. Sabelnikov, P.Yu.: Comparison of Contours of Objects with Partially Distorted Shape. *J. of Qafqaz University. Mathematics and Computer Science*, 34, 47—58 (2012) (in Russian).
7. Sabelnikov, P.Yu.: Computation and Use of Binary Image Moments for Geometric Comparison of Objects. *Artificial Intelligence* Scientific and Theoretical Journal, 3(61), 223—232 (2013) (in Russian).
8. Sabelnikov, P.Yu.: Computation and Use of Binary Image Moments for Geometric Comparison of Objects. *Proceedings of International Scientific Conference on Artificial Intelligence and Intelligence System*, 124—127 (2013) (in Russian).
9. Boyun, V.P.: Device for Determining the Location and Parameters of Image Objects. Patent of Ukraine no. 104347. *Bulletin*, 2 (2014) (in Ukrainian).
10. Boyun, V.P.: Sensor Device for Determining the Object Location and Center of Mass. Patent for Useful Model no. 81142. *Bulletin*, 12 (2013) (in Ukrainian).
11. Boyun, V.P.: Sensor Device for Determining the Object Location and Moment of Inertia. Patent for Useful Model no. 82936. *Bulletin*, 16 (2013) (in Ukrainian).

В.П. Боюн, П.Ю. Сабельніков, Ю.А. Сабельніков

Інститут кібернетики
ім. В.М. Глушкова НАН України, Київ

АЛГОРИТМИ АНАЛІЗУ ТЕЛЕВІЗІЙНИХ І ТЕПЛОВІЗІЙНИХ ЗОБРАЖЕНЬ У ВІДЕОПРИСТРОЯХ ТА СИСТЕМАХ СПЕЦПРИЗНАЧЕННЯ

Наведено результати виконання проекту «Розробка алгоритмів та програмних моделей для аналізу телевізійних та тепловізійних зображень» (шифр ВК 200.16.13). Проаналізовано відомі та запропоновано нові методи і алгоритми для обробки телевізійних та тепловізійних відеозображень, які дозволять створювати більш ефективні відеопристрої та відеосистеми спеціального призначення.

Ключові слова: зображення, тепловізор, фільтрація, контур, порівняння об'єктів, системи реального часу.

В.П. Боюн, П.Ю. Сабельников, Ю.А. Сабельников

Институт кибернетики
им. В.М. Глушкова НАН Украины, Киев

АЛГОРИТМЫ АНАЛИЗА ТЕЛЕВИЗИОННЫХ И ТЕПЛОВИЗИОННЫХ ИЗОБРАЖЕНИЙ В ВИДЕОУСТРОЙСТВАХ И СИСТЕМАХ СПЕЦНАЗНАЧЕНИЯ

Представлены результаты выполнения проекта «Разработка алгоритмов и программных моделей для анализа телевизионных и тепловизионных изображений» (шифр ВК 200.16.13). Проанализированы известные и предложены новые методы и алгоритмы для обработки телевизионных и тепловизионных видеоизображений, которые позволят создавать более эффективные видеоустройства и видеосистемы специального назначения.

Ключевые слова: изображение, тепловизор, фильтрация, контур, сравнение объектов, системы реального времени.

Received 06.06.14