

Dynamical Segmentation of Images for the Problems of Medical Diagnostics

Evgeny Maryaskin, Sergey A. Ivanovsky and Anatoly P. Nemirko

St. Petersburg Electrotechnical University "LETI", St. Petersburg, Russian Federation

Abstract. This article describes software realized method, suggested for the analysis of medical data. The methods are illustrated by the examples in the fields of echocardiography and angiography. Dynamic scenes segmentation and motion detection, based on optical flow calculation underlie this method. The description is illustrated by model and real medical data examples. The results may be used in applied tasks of dynamic segmentation of medical images.

1 Introduction

A number of actual problems of image processing add up to detection of moving objects, of objects' scope, of motion and of motion parameters [1], etc. Solution of these problems is based on image segmentation.

The prospects of one segmentation method developing, equally suitable for every task seems hardly realizable [2]. Nowadays problems of dynamic segmentation are not studied enough and there are no seriously studied computer-aided dynamic scenes segmentation methods. In spite of fair quantity of static segmentation methods in existence, nowadays the tendency to combining these areas is only appearing.

The goal of this work is to analyze the images segmentation method in medical diagnostics applications and to provide some ideas devoted to medical data analysis of echocardiography and angiography.

For the last 15-20 years echocardiography has been one of the main methods of heart visualization. One of the drawbacks of echocardiography is evident dependence on the researcher's qualification[4]. Echocardiography results research methods in existence do not imply using subsidiary computer-aided resources.

Angiography or arteriography is a medical imaging technique used to visualize the inside, or lumen, of blood vessels and organs of the body, with particular interest in the arteries, veins and the heart chambers. Angiographic methods are widely used in the pulmonary thromboembolism prevention in case of acute venous thrombosis

2 Motion Analysis

Motion analysis has long been a specialized subject area, which hasn't had much importance for the general theory of image processing [1]. But now because of the

general development in the field of image processing more advanced methods used in motion analysis. Rapid progress in hardware and algorithms make it now possible to analyze image sequences even on standard personal computers and workstations.

Nowadays there are no detailed systems, which make it possible to carry out dynamic segmentation of image sequence fully and well [1, 2]. Methods in existence, which are used for this come to the abstraction of optical flow and then to further pixels selection, which will be interpreted as moving. However this choice comes to the simple threshold filtration. This method appears to be extremely unsuccessful particularly for the scenes, in which objects themselves are changing, for example changing their irradiance, stretching, shrinking or interacting with each other.

It is necessary and, which is more important, possible to improve segmentation methods, which can be done on the basis of already utilized methods, algorithmic and software tools, for the improvement of final result of the operation.

2.1 Optical Flow Definition

Moving and intensity levels changing are not equivalent. In connection with this two terms are of great importance: motion field and optical flow. Motion field of the image is the real image in 3-D scene, adjusted to the image plane. Optical flow is defined as a "flow" of intensity levels on image plane. Optical flow and motion field are equal only for few restricted cases.

The notion of optical flow is taken from hydraulic gas dynamics. From the integrated form of equation:

$$\int_V \left(\frac{\partial \rho}{\partial \tau} + \nabla(u\rho) \right) dV = \frac{\partial}{\partial \tau} \int_V \rho dV + \oint_A \rho u da = 0 \quad (1)$$

The optical flow continuity equation results:

$$\frac{\partial g}{\partial \tau} + f^T \nabla g = 0 \quad (2)$$

where f refers to the flow vector and g – to the intensity level. The solution of this equation for a pair of frames is a vector field of four elements: two coordinates, velocity and the pixel shift direction, built in the frame[1]. Then we can rewrite the (2) equation for 25 pixels ($p1..p25$) of this neighborhood in matrix form:

$$\begin{pmatrix} Gx(p1) & Gy(p1) \\ \dots & \dots \\ Gx(p25) & Gy(p25) \end{pmatrix} \begin{pmatrix} \Delta x \\ \Delta y \end{pmatrix} = - \begin{pmatrix} Gt(p1) \\ \dots \\ Gt(p25) \end{pmatrix} \quad (3)$$

Let us designate the matrixes of this system as \mathbf{A} , \mathbf{d} , \mathbf{b} . Then we obtain the equation (3) in matrix form:

$$\mathbf{A} \mathbf{d} = \mathbf{b} \quad (4)$$

For optical flow calculation several algorithms are developed and implemented on basis of these equations. The method of solving the stated problem [3], first suggested by Lukas-Kanade in 1981, consist in the minimization of the following expression:

$$\|Ad - b\|^2 \quad (5)$$

The solution of this problem results in the following:

$$Ad = b \Leftrightarrow A^T Ad = A^T b \Leftrightarrow d = (A^T A)^{-1} A^T b \quad (6)$$

From the solution method several natural constraints on the source data arise:

1. $A^T A$ is reversible
2. proper values of $A^T A$ are congruous and negligible

As a result of the Lukas-Kanade method working a shift vector finds its positioning in every pixel of the frame.

3 Method Researching

Any video succession processing with allocation of information about motion consists of two parts: preprocessing and the optical flow calculation and postprocessing of the received flow data with the attempt to extract information from them. In this article modifications, suggested for both parts of the processing procedure, are described.

3.1 The First Processing Stage

Research showed, that even on the stage of optical flow calculation, some algorithmic modifications can be made, which will help to accelerate the calculation process without considerable lost of information. A special software tool was designed for quick flow calculation and for the demonstration of its structure. Flow vector field calculation is performed on basis of Lukas-Kanade method and it has some peculiarities:

- Vectors are calculated separately in every pixel, none of the calculations being performed twice. That means, firstly, that it is possible to calculate optical flow vectors only in the pixels, in which it is necessary, and secondly, it gives us a chance of parallel vector field calculation.
- The direction, assigned by a vector is calculated not absolutely, but accurately within $\pi/4$, which, firstly, can be done very fast, secondly, does not reduce accuracy, because for every pixel of the image this vector sets the neighboring pixel, in direction of which it is moving, and thirdly, it considerably simplifies the flow postprocessing and flow vectors classification.

The important advantage of this development is the possibility of real-time calculating, even using non-specialized equipment.

On the illustration there are screenshot of the program in the process of angiography data researching. It may be noticed, that with the similarity of the two sequenced frames, the calculated vector field follows the real sanguimotion, happening at the time of filming.

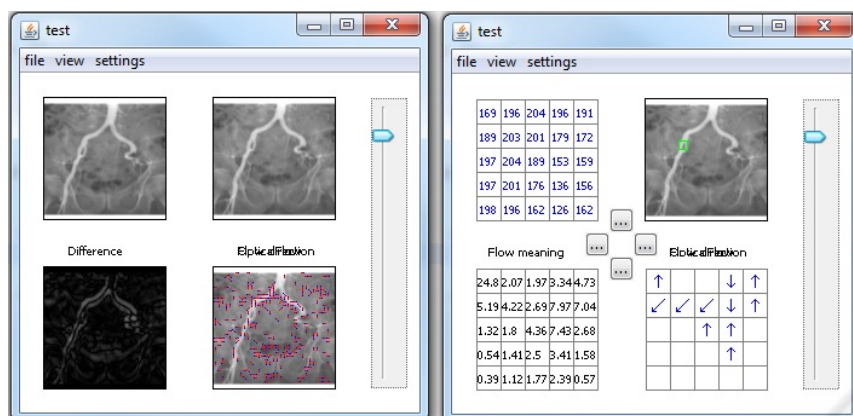


Fig. 1. Demonstration of the developed optical flow calculation and researching software. Angiography proceeding sample.

3.2 The Second Processing Stage

The presented method differs greatly from methods, common for images processing, firstly as it does not confine itself only to sifting short flow vectors, but take into account both vector components and secondly as it does not end with receiving vector field of the flow, but works with it as with new three-dimensional signal, subject to segmentation.

Key stages of the method are the following:

- Clustering. The clustering result is a vector field, divided into clusters of similar vectors, every cluster being a noise vectors package or a part of a real object.
- Filtration. Filters are in the large based on the statistic image processing methods.
- Characteristics calculation. Detection of characteristics, allowing us to determine the best moment for terminating the iterative process. Characteristics reproduce the main properties: shape, size, location, dispersion, distribution inside the clusters, etc.
- Postprocessing. On this stage final forming of objects from clusters with postfiltration and form accentuation takes place.
- Transition to a new iteration. This repeats until required characteristics are achieved.

For realization of operation with calculated flows a special software tool was developed, which makes it possible both to apply ready flow data postprocessing algorithms, read from dynamic scenes and to manually combine any variants of suggested filters, handlings and settings for research purposes.

The main advantage of this method is that it makes it possible to solve segmentation problems, which have no solution for static images and to identify complex configurations at the expense of usage of four-dimensional flow vectors.

4 Scenes Modeling

The possibility of inclusion independently modeled scenes into the research methodology allows us to achieve two significant for the whole development results

1. The possibility of investigating some particular cases, which are especially interesting in the scope of the investigation.
2. The possibility of constructing the whole processing quality characteristic estimation, based on the comparison of the result of the methodic operation and initially known model characteristics.

For the estimation of algorithm operation quality we need the possibility to create input dataflows with the following settings:

- Image mask specifying
- Noise of arbitrary intensity and distribution.
- Arbitrary quantity of objects
- Adjustable motion settings
- Adjustable changes of object's sizes

In the course of research a special video successions modeler was developed, which answers these demands and considerations.

5 Segmentation Characteristics

While considering possible quantitative estimation characteristics, we can come to a conclusion, that the comparison of the idealized model and the algorithm operation result induces a multitude of possible quality criteria. As the criteria of quality the following is chosen:

1. The ratio of the number of pixels having been treated as moving both in the model and at the algorithm to the number of pixels, treated as moving by the algorithm. It shows the percent of pixels, treated as moving, were identified correctly.
2. The ratio of the number of pixels having been treated as moving both in the model and at the algorithm to the total number of pixels, treated as moving in the model. It shows, what percent of actually moving pixels were identified correctly.

6 Experiments

6.1 The Model Scenes

The first model scene is destined to estimate cases, which answer the optical flow equation, because the scene does not enclose objects which change their form or their own intensity. However, images of 3x objects present in the tangent plane intersect one another twice during the observation and every image is very noisy.

The second model scene is the most important, as it is destined for the estimation of cases, not answering the optical flow equation. In this example the scene contains an object with variable intensity, an object with changing size and the intersection of

objects. Each image is very noisy.

On the illustration 2 there is an image at the moment of the software operation, which allows us to observe moving path, drawn for every object, which assists in segmentation and tracing.

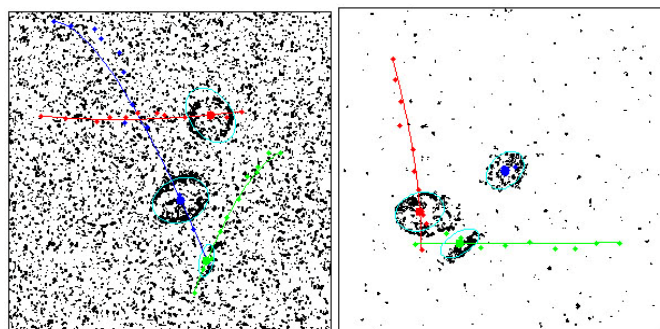


Fig. 2. Model scene 1(left) and 2(right) proceeding.

After applying the developed software package we succeed in highlighting and tracing the three indicated objects. Then the characteristics calculation stage is performed, which can be supplement with the meanings of characteristics for the same cases, which, however, are calculated in the traditional method of threshold segmentation.

Table 1. The results of characteristics calculation for the traditional and for the developed segmentation methods. The first model scene.

	1 st characteristics	2 nd characteristics
Object #1	0.0430 / 0.7456	0,4297 / 0.7060
Object #2	0.0684 / 0.8493	0,3999 / 0.7518
Object #3	0.0405 / 0.2111	0.2411 / 0.6388

Table 2. The results of characteristics calculation for the traditional and for the developed segmentation methods. The second model scene.

	1 st characteristics	2 nd characteristics
Object #1	0.0498 / 0.5811	0,3967 / 0.9254
Object #2	0.0382 / 0.7561	0,2873 / 0.8379
Object #3	0.0487 / 0.3008	0.2386 / 0.6132

Where the first characteristics is the ratio of right-detected moving pixels and the second characteristics is the ratio of right-detected found pixels. The calculation results are shown for the traditional/developed method.

6.2 The Real Scene

The results of echocardiography were taken for testing on real scenes. The main peculiarities of these sequences are the following:

- intense noisiness
- lack of pronounced movements trajectories
- constant size changing
- lack of proper intensity change

Segmentation in each of these frames is very complicated, and only experienced specialist can draw conclusions about the object of observation. Then, to estimate the result it takes to overlap cluster boundaries, exposed by the algorithm and the initial image in order to state the efficiency of method operation.

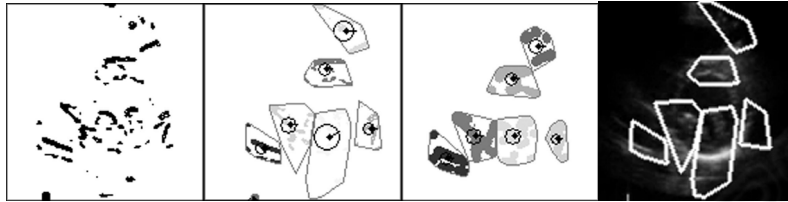


Fig. 3. Real scene proceeding and result(the right one).

Image is now segmental on basis of jointly moving sections and it appears to be much more convenient for understanding by a non-specialist in ultrasonic diagnostics.

7 Conclusions

In this work the existing methods of dynamic segmentation in the problems of medical diagnostics illustrated by echocardiography and angiography were analyzed and the new methods, based on the calculation of optical flow were developed. Most attention was devoted to the critical for flow calculation cases.

A comparative survey of existing methods and the developed method of dynamic scenes segmentation was conducted, which showed significant comparative effectiveness of the development up to a 40 times.

References

1. Jahne, B.: Digital Image Processing. 6th revised and extended edn, Vol. 583. Springer-Verlag, Berlin Heidelberg (2005)
2. Ballard, D, Brown C.: Computer Vision, Vol. 573. Department of computer science, University of Rochester, New York (2006)
3. Baker, S., Matthews, I.: Lucas-Kanade 20 Years On: A Unified Framework, Vol. 30. The Robotics Institute Carnegie Mellon University, Pittsburg(2002)
4. Ribakova, M.: Practical Guide In Ultrasound Diagnostics. Echocardiography, Vol. 544. Vidar-M, Moscow (2008)