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COMPUTER IMAGE ANALYSIS IN MEDICINE AND ENVIRONMENTAL ENGINEERING

Стаття представляє декілька прикладів звернення аналізу комп'ютерного зображення в медицині і екологічної розробки. Додатки в медицині, щоб діагностувати патологічні зміни на шкірі і діагноз биття серця були представлені також як і в екологічній розробці - в біотестах (Дафнія magna і підліток Lemna) для водної якісної оцінки.

Статья представляет несколько примеров обращения анализа компьютерного изображения в медицине и экологической разработки. Приложения в медицине, чтобы диагностировать патологические изменения на коже и диагноз биения сердца были представлены также как и в экологической разработке - в биотестах (Дафния magna и подросток Lemna) для водной качественной оценки.

The article presents several examples of applying computer image analysis in medicine and environmental engineering. The applications in medicine to diagnose pathologic changes on skin and heart beating diagnosis were presented as well as in environmental engineering – in biotests (Daphnia magna and Lemna minor) for the water quality assessment.

1. Introduction

One of human senses is sight. Not only does it make possible to register images, but also allows their continuous, resulting in their recognition, assessment and classification. Starting from the very early times sight has made one of the most important research tools and even now many phenomena are described using this sense. However, the development of technology, especially observed in recent decades allows constructing and practical applications of instruments that could successfully replace sight observations.

All the devices registering image are constructed based on the structure and similarity to human – or more generally – animal sight organ. The equivalent of the brain area where images are remembered is mass memory in the form of a disc or different types of cards. The equivalent of the lens and eye muscles (enabling proper focus and accommodation) and pupil (regulating the intensity of the light passing to the eye) consists of the system of lenses and diaphragms making the camera objective. The equivalent of the retina in the eye, thus a converter and image recorder is – in the cameras used at present (digital cameras) – a charge-coupled device (CCD), the elements of this device play the same role as receptor cells in retina: cones and rods. The obtained with these devices image can be then made a subject of interpretation to get interesting for us information. This is a subject of a scientific discipline called computer image analysis. Its purpose is to enhance and extract interesting for the researcher objects in the image and to measure them [12,13].

Enhancement involves a range of procedures aimed at the improvement of the quality of input image such as focus, normalization, shade correction etc. Then by the application of adequate procedures such as filtering, verge detection etc., the objects are extracted from the image often containing many details irrelevant to the specific research. Then, by the application of one of segmentation procedures, a binary image is obtained. If necessary, it can be further modified by different morphological, arithmetic or logical transformations. The result of the described procedures is a binary image containing only the studied objects. At this point it is possible to make measurements of definite geometric values. Moreover, which is not less important, by the application of a proper procedure, it is possible to make outlines of the extracted objects, which, after putting on an input image allow their visualization and identification. It is particularly important when the input image is, for some reasons, unclear and the interesting objects – poorly visible.

2. The application of computer image analysis in medicine and ecology

Computer image analysis makes a very effective research tool. As it has already been mentioned, it is a separate scientific discipline itself, but also an auxiliary tool, referring to other scientific disciplines such as material science, medicine or biology. Particularly spectacular achievements made due to its application are seen in medicine and biology. In these areas sight observations of some phenomena are not very efficient – if ever possible – and applied so far description methods are not sufficient in their explanation. Computer image analysis allows the collection of incomparably more information of quantitative character.

An example of using computer image analysis in dermatology can be computer analysis of the character of skin changes [7,8]. The diagnosis lasts several minutes: after taking a photograph, with the use of an ordinary digital camera, the image of skin changes is recorded on the disc. Then the program, after the recording, makes a few measurements of geometric values. These values are used to determine certain parameters based on the earlier made algorithm. Based on these parameters it is possible to answer the question about the character of the analysed change and the degree of threat connected with it. Although the authors of the program emphasise that the answer can only make an indicator and the final diagnose is only possible after making standard histopathological examinations, the image analysis makes a useful diagnostic tool allowing quick preliminary diagnose.

Another example of the application of computer image analysis in medicine is a diagnostic method using the image analysis in heart beating diagnosis [3,13]. Unlike the previous example, this method allows the observation of dynamic changes in the real time. It is aimed at seeking the mechanism disrupting heart function and choosing a proper therapy. During a standard diagnostic procedure the cardiologist observes the image of heart beating (coming from the ultrasonograph) on the screen and makes a diagnosis. Due to a complex character of the phenomenon and poor quality of the image, its proper interpretation requires great specialist knowledge and long-time experience. This significantly reduces the number of cardiologists able to use the instruments effectively. Moreover, by principle, the observation result is qualitative and subjective. The proposed method allows automatic detection of the work disturbance of left heart chamber – the work of this chamber is crucial for the whole organ. A visual effect of the detection is the outline of the heart chamber on the echocardiographic image – Fig. 1. This way the objectified image of chamber work is obtained. It can be interpreted by less experienced specialists and makes it easier for them to make a proper diagnosis. The work on clinical application of this method has been continued. Its implementation would make an alternative for the ventriculographic method – strenuous and even dangerous for the patient.

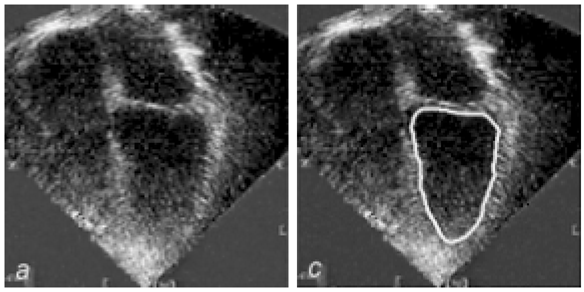

Fig. 1 The image of heart echocardiogram – left; right – the same image with the automatically detected outline of the left chamber

Another discipline, where computer image analysis can be applied is environmental engineering. Problems connected with the pollution of natural environment becomes more and more important. It is particularly important to take care of water cleanness by the monitoring of water composition aimed at the detection of toxic substances [5,6].

One of bioindicators (indicators sensitive to the presence of harmful substances in water, used in biotests, because of their sensitivity to the presence of a wide spectrum of toxic substances) are crustaceans *Daphnia magna*. They are applied in numerous laboratory biotests to find the level of toxicity of many substances. The *Daphnia* are put for a definite period of time (e.g. 24 hours) in a water solution of the toxin and their survival is observed by counting the survived specimens. Based on this one can assess which solution of the toxic substance causes a defined level of mortality. A similar effect during the biomonitoring of water informs on the level of water pollution [9,10,11]. The drawback of this type of biotests is the fact that they inform on the incidence of water pollution with a considerable delay. A significant progress would be a method informing quickly on the incidence of harmful substance in water.

The attempt was made to invent such a method that would base on the phenomenon that *Daphnia* react to the appearance of toxins changing the speed of swimming. Visual assessment of this phenomenon can only have a qualitative character and in no way can be used in its objective description. With the computer image analysis an algorithm was made that allowed the measurement of the *Daphnia* speed and then study the dynamics of changes after applying toxin. This method is very simple and involves recording every minute, with the proper speed several images of the *Daphnia* swimming in a dish and then, by a proper data processing, determining the situation of their centres and comparing with the situation on the subsequent image. This way the translocations of the *Daphnia* can be determined, and knowing the frequency of image capture, one can determine their speed, as in Fig. 2a and b, presenting the fragment of the observed area with the visible *Daphnia* in time t and t+0.2 s, and in Fig. 2c and d – the same images after processing and binarisation. The image visible in Fig. 2e was made by the overlapping two images and their magnification. The outlines also marked five intermediate situations taken by the organisms during that time and their mass centres were marked.

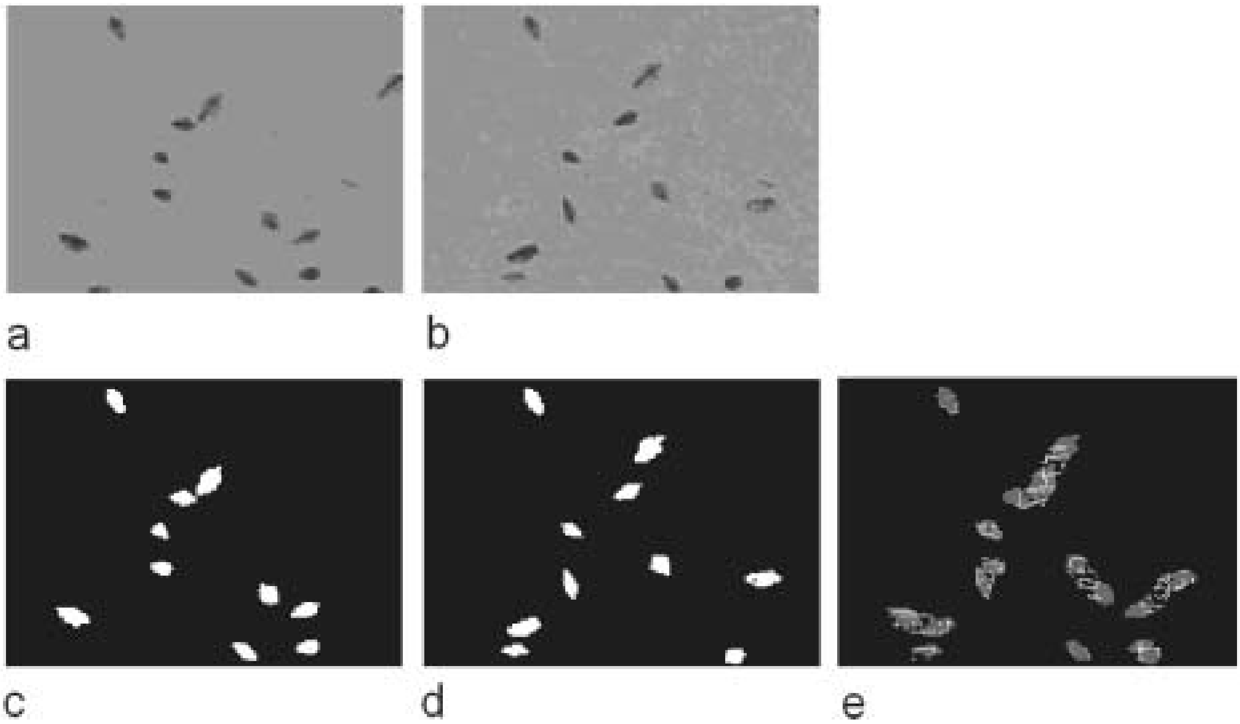

Fig. 2 The photographs of the same fragment of the image field in time t and t+0.2 [s]. Description in the text

The results of one of carried out studies were shown in Fig. 3, where one can see the course of the *Daphnia*'s momentary speeds in unpolluted water and its rapid change by the toxin added in the 60th minute.

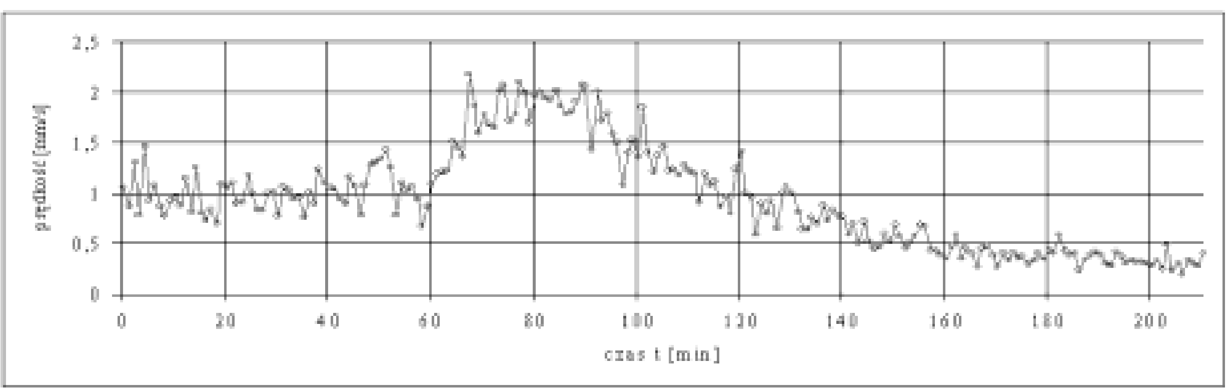

Fig. 3 The course of momentary changes in the speed of *Daphnia*. Description in the text

Based on the information obtained in the mentioned above experiments, a mathematic model of the observed phenomenon was proposed: the change of speed of the *Daphnia* specimens, measures from the moment of adding the toxin, is described with the equation:

$$v(t) = e^{t*b} \cdot c \cdot t^{a} \tag{1.1}$$

where coefficients a, b and c probably depend (in the way that has not been clearly defined yet) on the concentration and kind of toxin. The research is planned to verify this assumption.

For the course of the changes visible in Fig. 3, counted from the moment of adding the toxin, i.e. from the time t = 60 [min], the presented above equation makes a mathematic model that can be graphically illustrated by the curve presented in Fig. 4

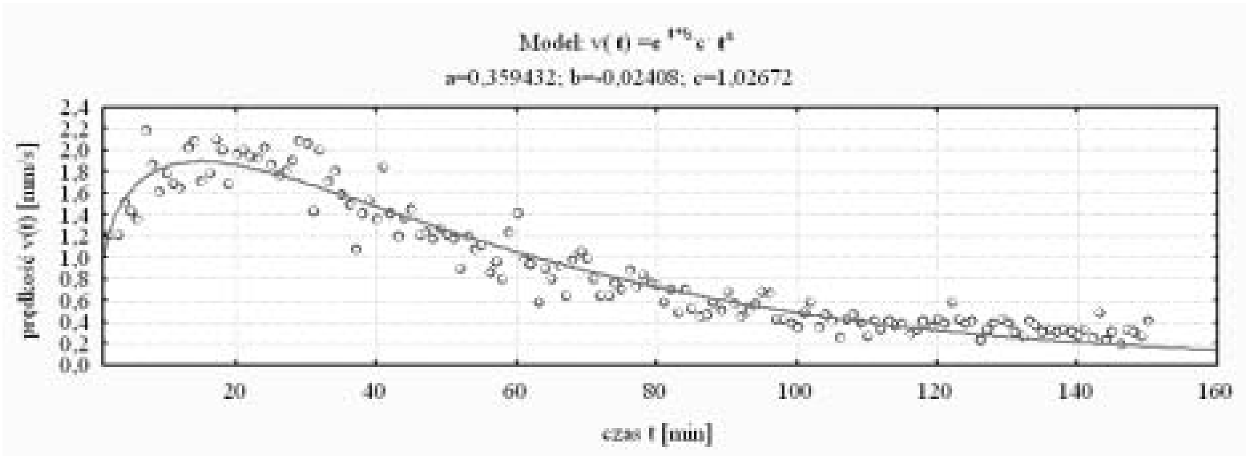

Fig. 4 The mathematic model describing the kinetic reaction of *Daphnia* due to the occurence of toxin

Differentiation of the given above equation allows determining the acceleration a (t),

$$a\,(t) = dv/dt = b \cdot e^{bt} \cdot c \cdot t^{a} + e^{bt} \cdot c \cdot t^{a} \cdot a \cdot t^{-1} \qquad (1.2)$$

the course of which is described by the curve presented in Fig. 5

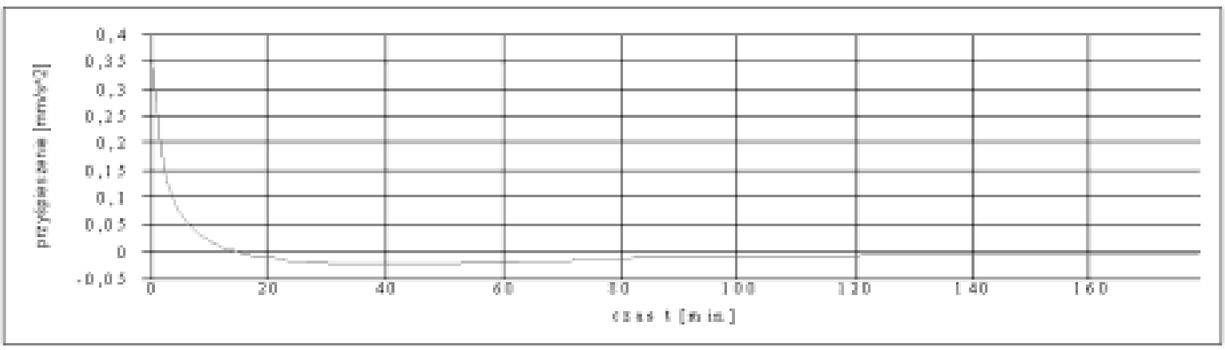

Fig. 5 The acceleration of *Daphnia* caused by the application of toxin

Analysing the values of velocities and accelerations obtained during the studies with the use of different concentrations of toxin, in the function of time, the conclusion can be made that the *Daphnia's* reaction for the toxin is the growth of velocity in the initial phase (in the later phase the speed of swimming gets reduced, up to the immobilization). The greater dynamics of this growth, measured with the acceleration is – the higher is toxin concentration. This allows much earlier detection of the harmful factor than in a classical survival test. Moreover, the observed sublethal effects, such as changes of swimming speed, which is not defined in a classic survival method, allow the detection of the amount of toxin that do not cause lethal effects. The application of computer methods increases the sensitivity, compared to classical methods.

Obviously, to make the final conclusions further studies are required. However, the obtained results provide good prospects for the use of the presented method in laboratory studies and on-line monitoring (early detection of toxic substances).

The next example of the application of the methods of the computer image analysis in environmental engineering is their application in the biotest based on the common duckweed *Lemna minor*.

The common duckweed – *Lemna minor* is a small perennial water plant having flat leathery leaf-like thalli, with one root each. It usually reproduces in a vegetative way – sometimes completely covering the water surface. It grows in ponds, lakes and also rivers with a slow flow, in particular in waters of a large content of biogenic elements N and P.

It is often used in hydrobotanic wastewater treatment stations, due to the increased degree of the adsorption of mineral compounds (containing N and P). Small size and easiness of cultivation, short reproduction time (doubling occurs after c.a. 1 – 4 days) encouraged applying this species for the purpose of the biotest. The biotest with the application of *Lemna minor* is widely applied to detect the occurrence of toxic substances in water. In Poland the duckweed biotest is legally confirmed and recommended in the enactment by the Minister of Environment of 13th May 2004.

Companies and institutes dealing with biomonitoring often introduce modifications of the *Lemna minor* tests. In classical biotests the growth of mass is measured by comparing the dry mass of duckweed in the control and experimental group, which is an invasive method and prevents the continuation of the experiment. Another method is "manual" counting thalli despite their size. The more reliable and accurate method of measuring the biomass growth is the measurement of the area of thalli in the experimental and control samples. This is a non-invasive method allowing the continuation of the experiment. For this purpose the attempt to construct the measurement tool based on computer image analysis method was made [4,5].

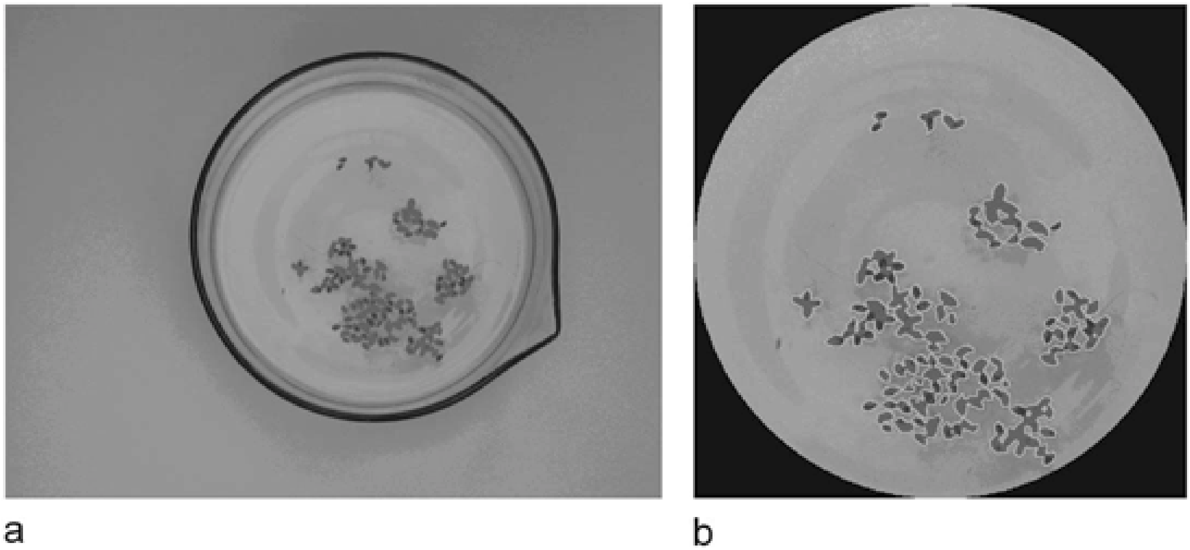

Fig. 6 a) The duckweed in the beaker, b) recognized objects taken for the analysis

The constructed tool using computer image analysis techniques meets all the expectations. It returns a repeatable result, the measurement error does not exceed 4.4 % of the measured value (interpretation in the categories of the relative error), which makes this tool useful in a non-invasive measurement of the biomass growth in the biotest based on the common duckweed *Lemna minor*. As a „side-effect" a full photographic documentation of the experiment is made.

3. Conclusions

Computer image analysis makes one of the most effective tools, and also most spectacular computer techniques used in different areas of science, especially those where only qualitative assessment has been possible so far. It is particularly visible in the presented examples, where alternative methods can be used. Computer image analysis enables carrying out many observations, for different reasons, impossible to be made with classical methods. The information on these phenomena and their applications allow their full description and understanding. The set of image acquisition techniques and the procedures for the processing of the data, implemented in a specialist program for the image analysis, make a useful and multifaceted tool able to be applied in such different disciplines as medicine or environmental engineering. Wide use of computer image analysis in different scientific disciplines proves its interdisciplinary character.

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