VISUAL MONITORING OF WATER ORGANISMS FOR ECOTOXICOLOGY INSPECTION

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Abstract

The paper describes a visual system intended for an autonomous monitoring of biological organisms in the two water vessels. These two organisms named Lemna minor and Daphnia magna are sensitive to toxic substances in a water and so they are used as convenient detectors of such impurities. The both vessels are continuously scanned by industrial cameras and obtained images are then processed to achieve a result used to final water quality assessment.

1 Problem Definition

Water quality is a general term which refers to several basic attributes of the water. These attributes mean physical, biological and particularly chemical features of water. A crucial case is a drinking water which should be extremely pure especially from a toxicology point of view. The following text describes a visual system designed for an autonomous camera inspection of the water quality by means of the two known biological organisms sensitive to toxicity.

The first one is an aquatic plant named Lemna minor with up to three leaves on each one root. The main colour of Lemna is pure green in perfect condition (no toxicity) and other colours especially yellow and white in case of some kind of toxicity. Lemna has a weak immunity to toxic substances and slow response to their presence in a water vessel. The other one organism is a well-known water flea named Daphnia magna used in a lot of experiments since 1934 when discovered. Daphnia is live organism which has a weak immunity to toxic substances same as the Lemna but with fast response to their presence in a water. This is the reason why responses of these two organisms to the toxic substances are combined together to detect a potential problem with drinking water.

Figure 1: Examples of diagnostic organisms: Lemna minor (green) and Daphnia magna (brown)

The basic idea of the inspection task is to track current activity of the both bio-organisms by an autonomous camera system in time [1]. Because the organisms are sensitive to unnatural substances (especially chemical), each change in organisms’ behaviour means change in water quality from a standpoint of toxicology. It means we can use a visual data to detect toxic substances in water.

2 Technical Solution Design

The technical solution of the mentioned inspection task is formed by using industrial cameras connected to computer equipped with the Matlab development environment and Image Acquisition/Processing Toolbox. The inspection only needs two separated vessels with the same water on their inputs and the Lemna plants in the first vessel and the Daphnia fleas in the other one. The experimental workplace designated especially for image acquisition task is depicted in the next figure.

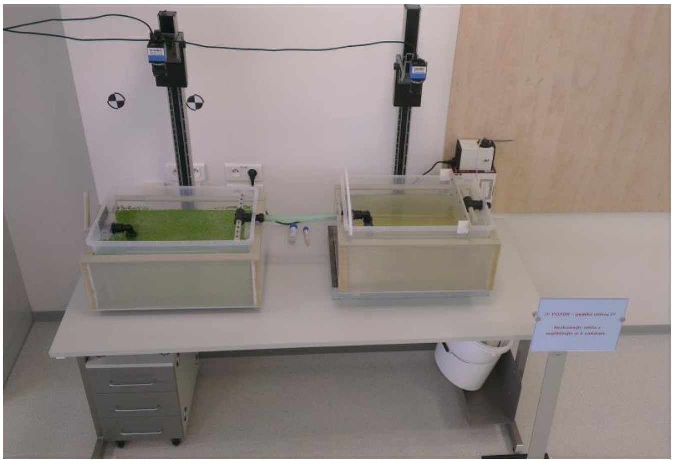

Figure 2: The isolated vessels containing different bio-organisms and a camera subsystem

As it was already mentioned, the first vessel contains the Lemna minor organism which is clearly green and grows broad if water conditions are perfect from a toxicity point of view. In an opposite conditions the Lemna degenerates in colour and surface. The other case of Daphnia magna is very similar to the first one. The only one difference is that vitality of Daphnia is not determined by colour and surface, but by moving speed of individual animals. In our design both the Lemna's vessel and Daphnia's vessel are viewed by two industrial cameras positioned above them [1].

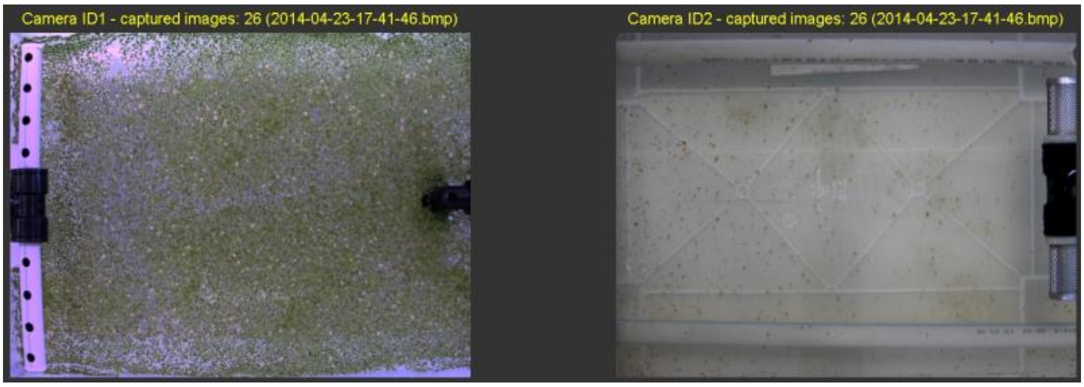

Figure 3: Input images from the colour CCD cameras: Lemna minor (left) and Daphnia magna (right)

Both vessels are scanned repeatedly after a predefined lapse of time. Each image is processed immediately and obtained results are added to the previous series. In the case of the Lemna organism the purity of green colour and the surface of green colour are the only two features extracted from the images. In the case of Daphnia a method of a difference between two or more images in sequence is employed to detect current activity of the fleas [3,4]. Lower activity fleas have more toxic the water is.

3 Image Acquisition and Processing in Matlab

The first step in the inspection task is to obtain images of both organisms in the vessels. To achieve this, two identical industrial USB cameras by Imaging Source Ltd. with resolution of 1280 by 960 pixels are used. For the reason of uniform and stable sequence of images a manual exposition mode has been chosen as a proper acquisition method [1]. In the case of Lemna exposition time is manually set to 1/20 s and to 1/30 s for the other case of Daphnia. An automatic white balance has been naturally switched off in the both cases.

Image processing in the both mentioned cases of the Lemna minor images and the Daphnia magna images respectively is relatively simple and only requires basic methods of image processing with straightforward implementation [5,6]. Lemna's images are processed by a method based on colour information in image data [4] and Daphnia's images are treated as a sequence of dynamical images and mutual motion is detected by means of the differentiation method [6].

3.1 Image Processing on Lemna Minor Images

The images delivered by a camera over the vessel with Lemna organism are in the RGB format. This native format of almost all colour industrial cameras is not precisely the one we need for colour analysis. To achieve exact and robust colour analysis and inspection the RGB colour space is transformed to an alternative colour space called YCbCr. These two colour spaces are mutually equivalent to each other and the only one difference is that the Y component of grey levels is given explicitly in the YCbCr format [4].

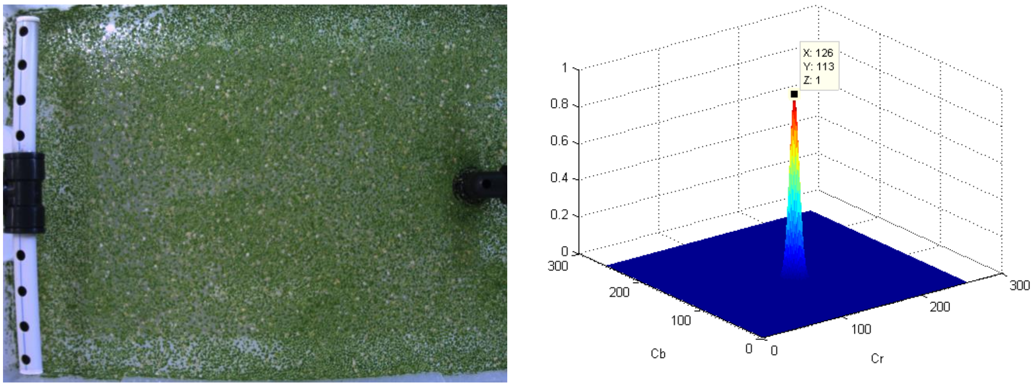

Figure 4: Image of healthy Lemna organism (on the left) and the probabilistic classification model

In case of Lemna’s colour and surface inspection we have used a simple method for classification of each pixel from an input image. A probabilistic model of healthy Lemna organism in the CbCr plane has been designed based on experimental set of images (see the previous figure). This model gives an unambiguous response to each pair of input pixel’s values CbCr. The response determines a likelihood how much the current pixel belongs to the pure green class and so a membership to the Lemna class.

As it was already mentioned in the text above, the healthy Lemna organism has pure green colour and so only G-channel (a complement of the CbCr plane) of the input image plays a role in a classification task. Vice versa unhealthy (i.e. toxic) Lemna organism differs in colour especially towards yellow and white and so information in R-channel (the Cr component) joins to the classification step. For this reason not only the probabilistic map related to green (G) colour is computed. The similar map related to yellow (RG) colour is obtained by the same technique and both these maps are combined into the one synoptic image.

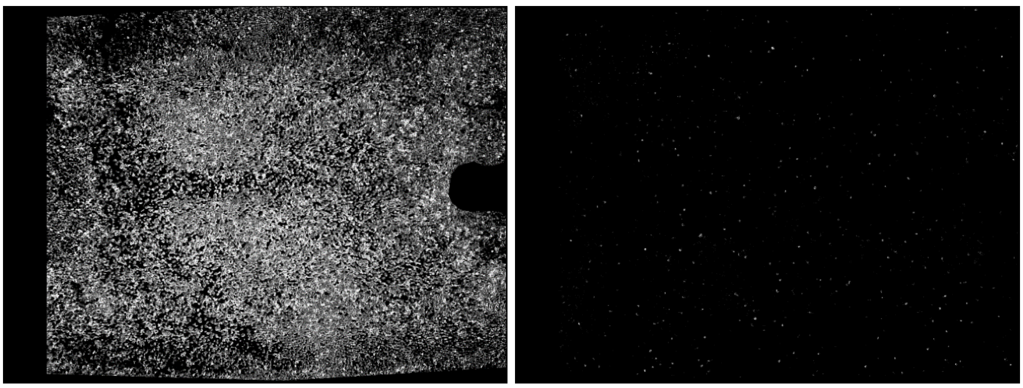

Figure 5: Images of the probabilistic distribution: green colour on the left and yellow on the right

An interpretation of these two images separately is intuitive and straight, unfortunately the same interpretation of the fusion of them is a little complicated problem [7]. See, the probabilistic map related to green colour simply expresses how much healthy the organism of Lemna is (see the image on the left on the previous figure). On the contrary the probabilistic map related to yellow colour expresses how much unhealthy the same organism is, but these two classes are not complementary. There is a large gap between healthy and unhealthy colours considered as neutral.

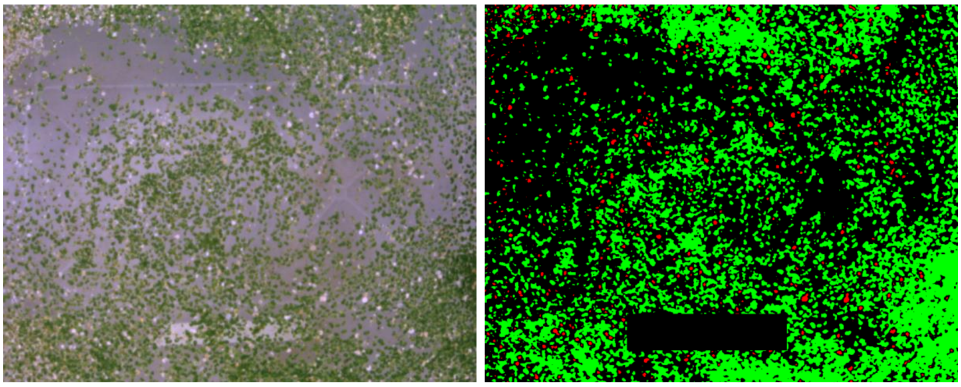

Figure 6: An input image of Lemna and relevant segmented healthy (G) and unhealthy (R) objects

Finally, the overall surface of the all green objects is the only one selected indicator for determination of water quality based on analysis of the Lemna organisms.

3.2 Image Processing on Daphnia Magna Images

On the opposite side a so-called method of difference of images is used for detection of current motion activity of the Daphnia organism. It is the simplest method for motion analysis suitable only for certain class of classification problems [5-8]. For a water quality assessment only absolute measure of current motion activity is necessary. As an input data for the evaluation of the current movement the sequence of images with Daphnia organisms is used.

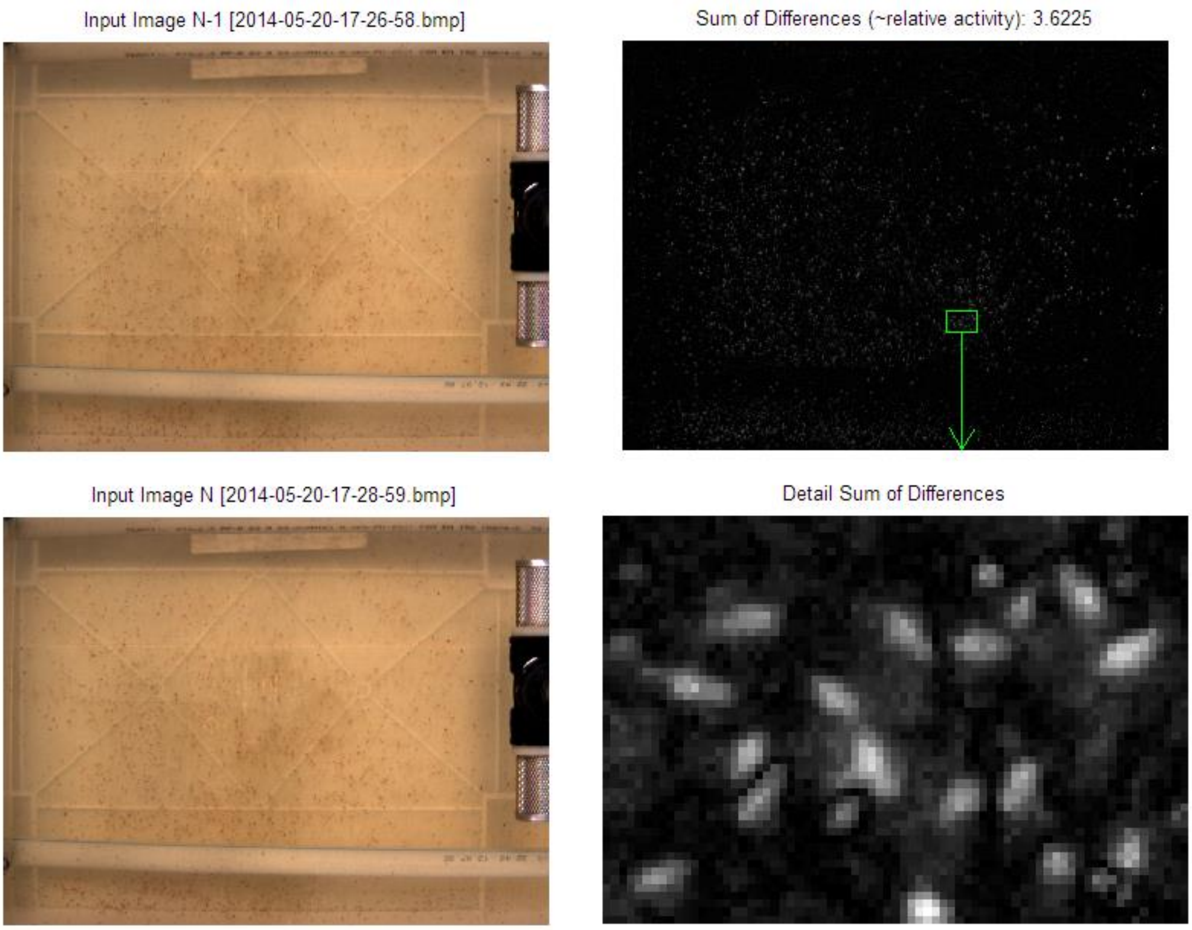

Figure 7: Pair of input images (left column) and the image of differences and its detail (right column)

Mentioned method of motion analysis is based on calculation of the difference between two or more images in an image sequence. The first image with index n is subtracted from the other one with index n+1 and result is treated as absolute value, because direction of a movement is not considered in general. The pixels with high values of brightness in the resulting image are those with significant movement and vice versa low values of brightness represent stable areas without motion (see detailed image at the bottom right corner of the previsou figure). Such kind of classification method takes into account only absolute changes in brightnesses levels between two images and individual objects are neither recognized nor labeled and tracked. The scalar value of sum of all single differences is only one indicator for water quality assesment based on the current movement of Daphnia organisms.

4 Results

Methods we have used for evaluation of water unwholesomeness are straightforward and so simple and fast to implementation. Unfortunately a non-contextual method [5-8] for motion detection of Daphnia organisms is very limited for the future needs and probably will be replaced by some kind of contextual segmentation method [8,9] capable of tracking the individual objects independently.

Acknowledgement

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