THE USE OF IMAGE PROCESSING METHODS TO IMPROVE THE DETECTION OF USER'S HAND IN VISION BASED GAMES USED IN NEUROLOGICAL REHABILITATION

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Abstract. Vision based games is a type of software that can become a promising, modern neuroreha-bilitation tool. This paper presents the possibilities offered for the implementation of this kind of software by the open source vision library. The methods and functions related to the aspect of image processing and analysis are presented in terms of their usefulness in creating programs based on the analysis of the images acquired from the camera. On the basis of the issues contained in the paper, the functionality of the library is presented in terms of the possibilities related primarily to the processing of video sequences, detection, tracking and analysis of the movement of objects.

As part of the work, the software that meets the requirements for modern neurorehablitation games has been implemented. Its main part is responsible for the identification of the current position of the user's hand and is based on the image captured from the webcam. Whereas the tasks set for the user used among others supporting visual-motor coordination.

The main subject of the research was the analysis of the impact of the applied methods of initial image processing on the correctness of the chosen tracking algorithm. It was proposed and experimentally examined the impact of operations such as morphological transformations or apply an additional mask on a functioning of the CamShift algorithm. And hence on the functioning of the whole game which analyzing the user's hand movement.

Key words. Neurological rehabilitation, vision based games, CamShift algorithm, back projection, mathematical morphology.

1 Introduction

In the last years, the use of modern technologies in the field of neurorehabilitation has become extremely popular. Of particular interest is the use of computer games

in the therapies, defined the term "Serious Games". They are treated as very flexible tools that can support or even shape the rehabilitation process.

This was mainly due to discoveries associated with the detection of neuroplasticity mechanisms in the mature cortex and the constantly increasing range of requirements for modern neurological rehabilitation. These discoveries have impacted not only on changes in the perception of the processes related to the reorganization of an adult, an educated brain, but also to changes the rehabilitation process for people these affected by different neurological diseases.

An interesting and increasingly popular solution is the use in the neurorehabilitation process a games based on the analysis of the image from webcam, often referred to as "vision based games". These systems offer very extensive capabilities that are success-fully used for the purpose of patients rehabilitation.

In the world, many research projects that were designed to determine the impact of the use of the games in the rehabilitation of patients with neurological diseases [6, 9, 10, 14]. The published information indicates that the use of computer technology considerably facilitates the process of rehabilitation in this kind of cases, in particular due to the very large strengthening the commitment and motivation of users. An example here can be the report of the use of video games in the rehabilitation of stroke patients, posted on the Community Research and Development Information Service (CORDIS) website.

2 Vision based games

Vision based games are connected to the interacting with a computer game using only a simple web camera. The functionality of such systems is based on the issues related to digital image processing. These programs are characterized by the use of many methods from that area. However, the main element that affects the quality of that type

of soft-ware are usually image processing algorithms for object segmentation, motion detection and tracking specific objects.

The level of precision for this kind of solutions is often lower than competing systems that use additional elements such as motion sensors, light sources or distance sensors. This level allows researchers to use those programs as a tools to support many activities of neurological rehabilitation.

Computer technologies, including rehabilitation games increasingly being used as a support for telerehabilitation or home rehabilitation, which is an extremely important part of the neurorehabilitation process, mainly in case of chronic disease. For this reason, there is a very high demand for projects based on the specification "Low-cost". That is, pro-grams that take advantage of the potential of personal computers, which are equipped, for example, with a simple webcam.

In view of the above, the Vision based games can be widely used in the modern tasks of neurological rehabilitation. These include tasks such as: the ability to control the phenomenon of neuroplasticity through physiotherapy, the use of the beneficial effects of combining physical therapy with cognitive training and the use of elements that support the involvement and motivation of the user. Currently, the most frequently works are conducted to apply the discussed systems in the process of rehabilitation the upper limbs [4, 5].

3 Structure of the built software

W In the context of research work on this thesis, the software that can meet the requirements of a modern neurorehabilitation was created. The designed game uses a high number of image analysis and processing methods primarily to find the current position of the user's hand (Fig. 1). Its main tasks include the isolation of the object with specific values of the selected feature on the image. The color
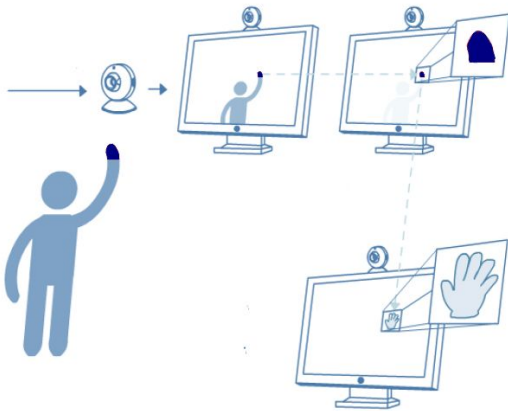
Fig. 1: The overview of the basic part of the designed game

of the object is used as the feature on which the segmentation process is based.

The basis for the process was the back projection, which was made based on a previously created histogram. As a result of its operation, the image that contains the exposed, searched object is obtained. In the next step, this image with the representation of the object is passed as an input parameter to the desired, tracking algorithm.

The effect of its operations is to obtain the exact position of a tracked object and the size of the surface that the object occupies. The scheme of the described parts of built software has been illustrated on Fig. 2. After performing the operations which was described above, information about the current position of the user's hands can be transferred to the elements of the program which are responsible for the implementation of tasks associated with the neurorehabilitation process.

4 Back projection based segmentation

Back projection is a feature that allows to visualize the specified object on the output images. It is based on histogram which was created for the source image that contains only that object [13]. This process has been pre-
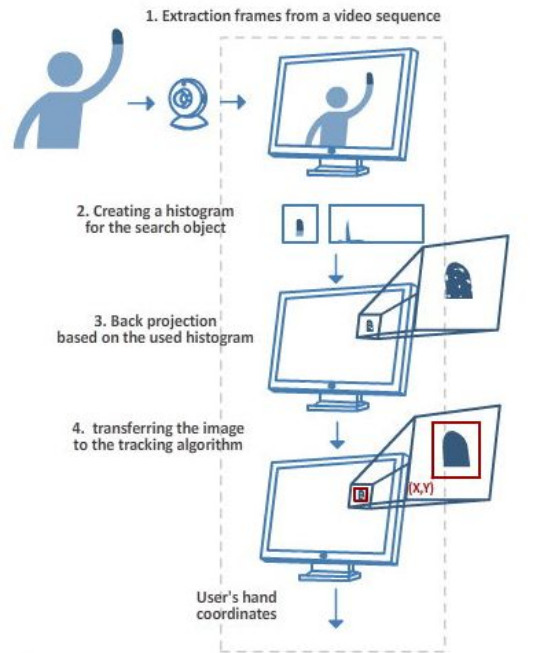

Fig. 2: The Connections of operations which are responsible for the determination of the coordinates of the user's hand

sented in Fig. 3.

The result of using the function that is responsible for back projection is a grayscale image on which the searched object is dis-played. One of the sample images obtained from that operation has been presented on Fig. 4.

The histograms used in the back projection are a very useful tool in image processing, they can be used to characterize their con-tents, detect specific objects or textures contained in them [3, 13]. The histogram of the image is called the characteristics of the distribution of some feature of the image, e.g. brightness, color [1, 3]. Generally, it's used to present the number of occurrences of some features in given ranges. The above description of the histogram structure is quite intuitive. To fully illustrate its capabilities and applications, it should be treated as a nonparametric estimator (statistics used to estimate the value of the distribution parameter) of probability distribution

Fig. 3: The result of the back projection based on the histo-gram which was created for the searched object. In this case it was a red glove

density [15].

Fig. 4: The exemplary image obtained on the basis of back projection

The initial image for which the histogram is calculated may be a fragment of the currently processed video sequence with the designated region of interest (ROI), a specially prepared photo or another image [3]. It is important that in its range was the whole object (in other words, the entire range of the component which is under analysis) that we find on other input images using the back projection. Because its resulting image is the main parameter that is passed to the next software module which is responsible for object tracking.

5   CamShift alorithm

In the case of both the CamShift algorithm and its predecessor the MeanShift algorithm, has been issued many publications carefully describing their strategies and actions and related to them theoretical and mathematical foundations, see [8, 11, 12, 16, 17]. For this reason, in this study, the description of these methods has focused on aspects of their practical application.

5.1   MeanShift

Depending on the adopted taxonomy MeanShift algorithm can be classified to kernel tracking methods or to model-based object tracking methods [7, 17]. The basis of its action is to find the local maxima and minima in the distribution of the density of a particular set of data [3]. It can be described as a process of finding the kernel i.e. image area characterized by the densest distribution of selected feature, which is obtained by getting closer to matching this distribution function to the searched element. It is an iterative process, getting a closer match is usually obtained by a result of a predetermined number of iterations of the main algorithm [11].

MeanShift is a deterministic algorithm that performs the analysis of the data that is only close to the extreme, what is obtained by applying a local window that searches the data only in its environment. This process has been illustrated on Fig. 5. An important feature is that the algorithm's work is not affected by points that are away from the search window [1, 3]. Hence, it seems that the basis for its correct operation is the selection of appropriate parameters for the used search window.

5.2   CamShift

The main difference between the operation of the CamShift algorithm and its predecessor is the ability to automatically adjust the size of the search window to the tracked object [3, 12]. The ability to change them while
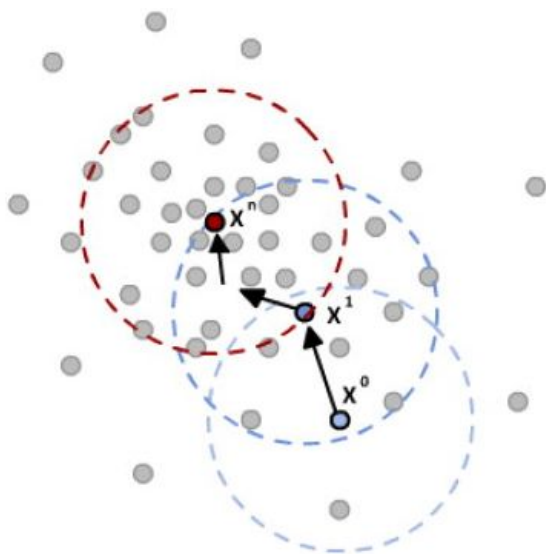
Fig. 5: The procedure of the MeanShift algorithm [2]

Fig. 6: The interface of neurorehabilitation game which was used

the algorithm is working extends its capabilities for detection of objects whose shape changes dynamically, for example one of the most popular applications of the CamShift algorithm is a human tracking [13, 17]. The ability to adapt is also a very important feature from the point of view of building the software that analyses a hand movement.

6 Research

The analyses focused on investigate the impact of the application of additional elements on the effectiveness of the CamShift algorithm.

During the analyses, has been conducted the tests based on the use of a prototype of the neurorehabilitation game, which based its action on the tested algorithm. The interface of software used during the tests has been presented on Fig. 6.

6.1 Motivation for research

In the case of software supporting the rehabilitation process, the highest possible correctness of the applied solutions is very important. The game which is using analy-

sis of user's hand motion should be relatively resistant to changes in the quality of processed images. For example, its operation should not be disturbed, even if the change in lighting, hand tilt, or other factor will partially affect the image passed to the tracking algorithm.

From the point of view of the proper conduct of the process of tracking objects in video sequences, the most important is their best isolation from the processed frames. The function of back projection often returns images that contain a certain amount of artifacts. The image obtained with it is not perfect and often represents more than just a searched object. In order to avoid errors during subsequent tracking process, it is preferable to support back projection by means of additional operations.

As part of the conducted studies, it was decided to examine how big an impact on the validity of tracking objects using the algorithm CamShift has to perform additional preliminary operations. The purpose of these operations was to improve the quality of images obtained on the basis of back projection, which are the input arguments for the used tracking method.

6.2 Description of the tested solutions

One of the applied modifications in relation to the classical use of the CamShift algorithm is to perform additional image processing, which is passed to it. In built software, the special mask, which was created in the threshold op-

eration is responsible for this. This mask is applied to the result of back projection using the binary multiplication. The aim of this operation is binarization and the appropriate filtration of image passed to the tracking algorithm. Correct course of this stage is strongly dependent on the selection of the appropriate value of the applied thresholds [2, 16].

The functions used during the tests were responsible for performing thresholding for color images, and precisely for each channel of the image. Function was used a double limitation and the images were characterized by belonging to the HSV color space . The results of use of this function has been illustrated by the example in the image above (Fig. 7).

the analyzed point [2]. In the case of image transformations they are characterized by the fact that the modification of a pixel depends on the fulfillment of the selected logical condition. This makes the discussed transformations, if they were properly combined, allow very complicated operations.
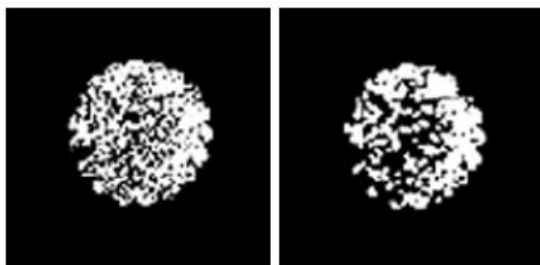

Fig. 8: The example of the opening operation - a used structural element - circle 5×5
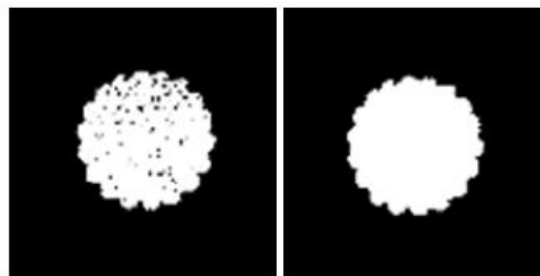

Fig. 9: The example of the closing operation - a used structural element - circle 5×5

Fig. 7: The image after back projection (at the top) and its copy which was processed with a mask created based on threshold operation (at the bottom)

Another tested modification of the process of preparing the input image for the tracking algorithm was related to the application of morphological operations. These transformations are derived from mathematical morphology based on the principles of the set theory. Their basic element is a structural element, on the basis of which these operations take into account the neighbourhood of

The most frequently used morphological operations include erosion and dilatation. However, their major flaw is the fact that they significantly change the surface of the figures, which is an unfavorable phenomenon. In order to eliminate this phenomenon and the efficient use of the advantages of these operations most commonly used their connection i.e. opening or closing [15]. Both these transformations are shown on Fig. 8 and Fig. 9. During the analysis, in order to improve the quality of images has been used precisely this kind of transformation. Example of these operations has been presented in the figure below (Fig. 10).
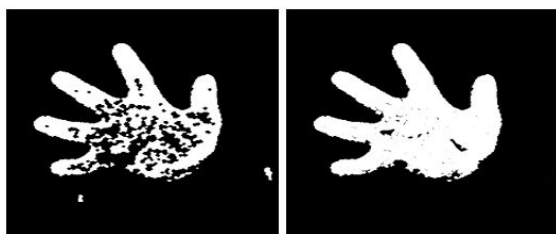
Fig. 10: The example of the result of the combination of opening and closing operations, in the case of user's hand detection

6.3 Results of experiments

The research involved analysis of the impact of the use additional image processing operations on the effectiveness of the CamShift algorithm. The selected tracking algorithm was built into the implementation of the prototype neurorehabilitation game. This type of approach allowed for the analysis of its effectiveness during practical application in a real project.

As part of the experiment, 10 users had to play 12 games in the designed game. One game lasted about 3-4 minutes and it consisted in hand selecting about 30 virtual objects in three turns. Four versions of the game have been prepared for the needs of the tests:

- classic version without image processing operations for images passed to the CamShift algorithm;

- version with initial image processing operations for images passed to the CamShift algorithm - using an additional threshold mask;

- version with initial image processing operations for images passed to the CamShift algorithm - application of morphological operations;

- version with initial image processing operations for images passed to the CamShift algorithm - combined additional threshold mask morphological operations.

The specific version was chosen randomly when the game was loaded. Each version has been extended with a

special function for detecting the phenomenon of "losing" the tracked object through the search window. The function was responsible for signaling the situation when the window doesn't change its position for a specified period of time. This kind of situation was treated as an error in the functioning of the algorithm. Applied time threshold has been chosen by experimentation and it is closely associated with the use of CamShift algorithm in the game controlled with the motion of the hand. Its choice was influenced by factors such as downtime hampering the gameplay or the necessity to use additional program elements to find the object once again by the algorithm after a specified time.

The charts below show the results of the performed tests (Fig. 11). The obtained results clearly show that the use of the additional processing of images, these were input parameters of CamShift algorithm, significantly improve the results of its performance.
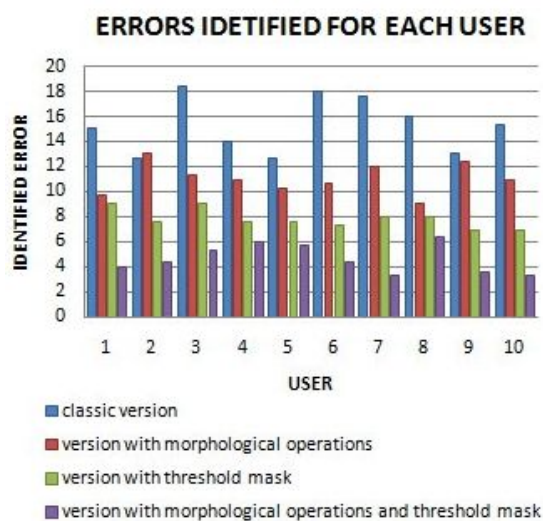

Fig. 11: The charts that shows the number of average of algorithm errors for one game for each user

The best results were obtained by using both tested modifications at the same time. During the application of an additional thresholding operation and morphological operations, the number of detected errors was signif-

icantly reduced. It had a big impact on the improvement of the functioning of the implemented neurorechablitation game.

7   Conclusions

In the case of software used as a tool that can support the process of neurological rehabilitation an extremely important aspect is the reliability and flexibility of the solutions that were used. This aspect has become the motivation for the analyses performed as part of this paper.

In connection with games like "Vision Based Games" most solutions are based on different methods of user's hand tracking. During the implementation of the systems with the "low cost" characteristics, which often include this kind of game, the greatest emphasis is placed on the appropriate software solutions. The proposed solution which consisted in using of additional image processing passed to the analyzed tracking algorithm has greatly improved the its results. Conducted analysis allow to state that the CamShift algorithm is sensitive to small changes in images passed to it as input parameters. This allows for the use of this phenomenon in order to improve its tracking capabilities.

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