Laboratory Approbation of the Algorithm for Isolating People's Faces on a Thermal Infrared Image in the Case of Their Quasi-Stationary Arrangement in a Room

Alyushin M.V.[1], Alyushin A.M.[2], Kolobashkina L.V.[3]

[123]*National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Moscow, Russia*

[1]*mvalyushin@mephi.ru*, [2]*amalyushin@mephi.ru*, [3]*lvkolobashkina@mephi.ru*

Abstract

Increasing the effectiveness of training and training sessions is possible through the implementation of so-called biological feedback. Such feedback allows the teacher, or the instructor, to continuously monitor the current psycho-emotional and functional state of the students. As a result, it becomes possible to adapt the style, pace, training mode and the volume of the material outlined, depending on the current receptivity and fatigue level of the listeners. The main element of systems that implement biological feedback in practice are remote non-contact technologies. Such technologies allow in a fully automatic mode to register the main most informative human bio-parameters. Among them, in the first place are the parameters characterizing the current state of the cardiovascular system of man, his breathing system, as well as his peripheral nervous system. The bulk of information is obtained by processing in real time the thermal infrared image of a person's face. Unfortunately, existing algorithms for distinguishing a person's face have a sufficiently high computational complexity and insufficient reliability. A typical example in this regard can be a family of algorithms based on the Viola-Jones approach. The approach proposed in the work is based on taking into account additional information about the most likely location of a person's face on a thermal image. This approach is most appropriate to use in cases of quasi-stationary location of people in the room. A typical example is the location of students at the tables in the classroom. For such cases it is possible to determine the areas of the most probable location of the trainees' faces, as well as the possible boundaries of their movement. Laboratory tests of the developed program on the basis of the proposed algorithm have confirmed its high productivity, as well as efficiency in identifying students faces in the classroom.

Keywords: Thermal Image of the face, Face Selection Algorithm; Quasi-Stationary Arrangement of People.

1. Introduction

Ensuring reliable trouble-free operation of hazardous facilities is now an important scientific and practical task. The problem is most acute in the nuclear industry. The so-called human factor is one of the components determining the safety of the operation of such facilities. The concept of reliability of the human factor includes a whole complex of indicators. The most important of them are a high degree of mastery of theoretical and practical skills, ability to act in emergency situations, stress resistance. All these indicators are achieved as a result of special classroom training, as well as training sessions on full-scale simulators. The reliability of the human factor largely depends on the effectiveness of these classes and training sessions.

At present, technologies have been developed that make it possible to ensure high efficiency of all types of classroom and training sessions [1]. Increase of efficiency of employment is reached due to maintenance of a high level of attentiveness, assimilability of a new material and a normal working condition. This is achieved by implementing the so-called biological feedback, which allows the teacher to adapt the learning process depending on the current functional and psycho-emotional state of the training group. For this purpose, ongoing monitoring of the current functional and psychoemotional state of students is conducted on the basis of using remote, non-contact technologies for recording their bioparameters [2-4].

The main channel for recording personal bio-parameters is the natural thermal radiation of a person's face. For reliable registration of the parameters of the cardiovascular system, it is necessary to process at least 30-100 frames of thermal image per second, which is due to the possible range of changes in the heart rate. The constant movement of the head of the students is an interfering factor. As a result, reliable registration of the bioparameters of students is possible mainly in cases when their faces are turned towards the camera. Therefore, the applied algorithms for processing the thermal image of the face must additionally realize the function of analyzing the inclination and rotation of the head of each listener. This circumstance imposes additional requirements on the speed of the applied thermal image processing algorithms. Thus, the development of a fast-acting and reliable algorithm for identifying students is an urgent task.

The study suggests a new approach to solving this problem. The approach is based on the use of additional information on the most probable location of persons studying in the case of conducting occupations in a room with a fixed arrangement of tables.

2. Related Work

At present, a lot of scientific works devoted to finding a person's face on a thermal image have been published. The main practical approach is the Viola-Jones method. The main disadvantage of this approach with respect to the problem being solved is the lack of consideration of the most probable position of a person's face when conducting training sessions in a room with a fixed arrangement of tables. As a result, the analysis and search of faces on the entire image frame is carried out. At the same time, computational costs are quite high [5-7]. When using medium-performance computing, there is a possibility of skipping certain frames of a thermal image. And this leads to a decrease in reliability in determining the bio-parameters of students.

3. The essence of the proposed approach

For cases of conducting educational and training sessions with a fixed arrangement of tables in the classroom, it becomes possible to determine and take into account the most likely location of the student's face. Figure 1 shows a typical field of view of a thermal imaging camera located in the classroom. The camera is located in the center of the classroom and its field of view covers all students. The most common option for arranging students' tables is to place them in rows. For this case, students are placed in the classroom in the form of a matrix S (i, j), i = 1, 2, 3, …, M; j = 1, 2, 3, ..., N, where M and N are the number of rows and the number of tables in one row, respectively. The analysis of the position of the head of students relative to the table made it possible to determine the dimensions of the region of its most probable location relative to the table surface. For the majority of people, this area has a rectangular shape with a size of $W_X \approx 0.8$ m, $W_Z \approx 0.6$ m. It is located in the center of the table. Figure 2 shows a plan for a typical arrangement of tables and a thermal imaging camera in the training laboratory.

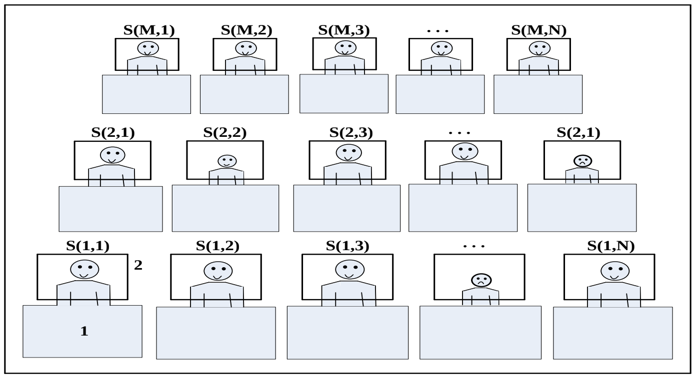

Figure 1: Field of view of the thermal chamber: 1 - tables;
2 - the window of the most probable location of the student's face

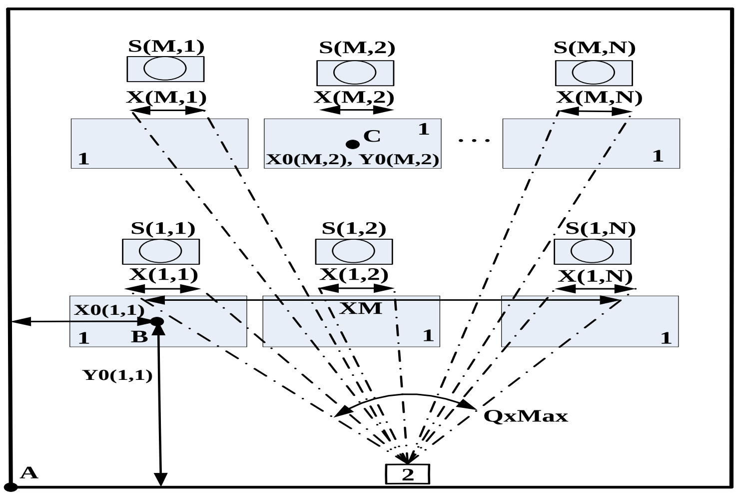

Figure 2: Determination of the parameters of the windows of the most probable position of students' faces: 1 - tables; 2 - thermal imaging camera: A - reference point: B - left table of the first row; C - table of the last row; QxMax - horizontal angle of camera view; XM - the maximum horizontal metric size corresponding to the viewing angle QxMax, for the first row of tables

Knowing the physical coordinates X0(1,1) and Y0(1,1) of the middle of the left table for the student S(1,1), as well as the steps of the location of the tables ΔX and ΔY respectively in the X and Y directions, one can determine the physical coordinates of the centers of all other tables:

$$X0(i, j)=X0(1, 1)+\Delta X\bullet(i-1);\ Y0(i, j)=Y0(1, 1)+\Delta Y\bullet(j-1).$$

Based on the given physical dimensions of the WX and WZ windows of the most probable location of the head, you can determine the size of the windows for each student in pixels. To do this, Figure 3 shows the type of the classroom at the side.

For the student S(1, N/2) located in the center of the first row, the dimensions of the window X(1, N/2) and Z(1, N/2) in pixels of the thermal image frame are determined as follows:

$$X(1, N/2)=NXP\bullet WX/XM,\ \ Z(1, N/2)=NZP\bullet WZ/ZM,$$

where NXP and NZP are the horizontal and vertical dimensions of the thermal image frame in pixels, respectively.

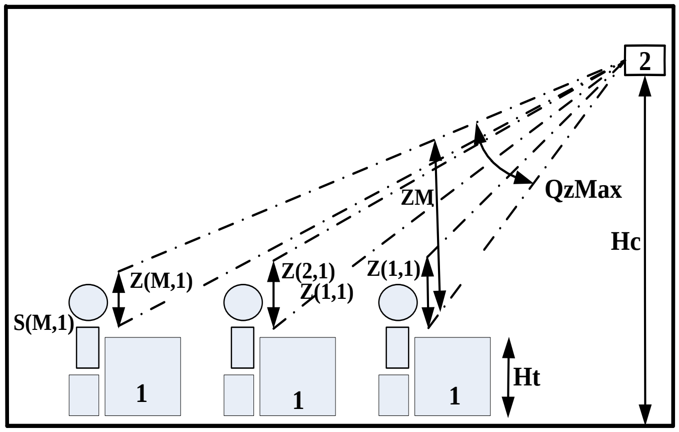

Figure 3: Type of educational audience on the side: 1 - tables; 2 - thermal imaging camera; QzMax - vertical angle of view of the camera

For an arbitrary student S(i, j), the analogous window sizes X(i, j) and Z(i, j) in pixels are defined as:

$$X(i, j)=X(1, N/2) \bullet K; \quad Z(i, j)=Z(1, N/2) \bullet K;$$

where K is the coefficient of window size reduction due to increasing distance to an arbitrary student S(i, j):

$$K = \sqrt{\frac{X0(1, N/2)^2 + (Hc - Ht)^2}{(X0(i, j) - X0(i, N/2))^2 + (Hc - Ht)^2 + Y0(i, j)^2}}$$

Similarly, the X and Z binding coordinates of the window on the thermal image frame, measured in the number of pixels thereof, can be determined. The advantage of the approach is that the sizes of the X(i, j) and Z(i, j) windows considered above, as well as the coordinates of their binding are constant values. They are defined once in the beginning of the program in its configuration mode.

Any suitable algorithm can be used to search for a face image in the selected windows. The problem of selecting a face in this case is greatly simplified due to a significant decrease in the size of the search window, as well as the presence of no more than one face image in each window. In view of the above, it is sufficient to use the method of coordinate projections to find a person in the window. This method allows you to calculate the coordinates of the center of the face in the window, for example, based on the determination of the center of mass (in terms of brightness) of the resulting coordinate projections for each selected window.

The application of the proposed approach also makes it possible to substantially simplify and accelerate the procedure for verifying the correct position of the head of the learner. To do this, it is sufficient to analyze the dynamics of the change in the total brightness of the pixels located in the area around the found face in the window. As the discrimination threshold, the lower limit of the total brightness of the faces of the average person BR(1, N/2), determined for the listener S(1, N/2), can be used. In this case, for an arbitrary listener, the value of the discrimination threshold is:

$$BR(i, j)=BR(1, N/2) \bullet K2.$$

As can be seen from the above formula, the discrimination thresholds depend on the remoteness of the listener's location from the thermal imaging camera. Figure 4 shows a typical qualitative time dependence of the function BR(i, j, t) for an arbitrary listener.

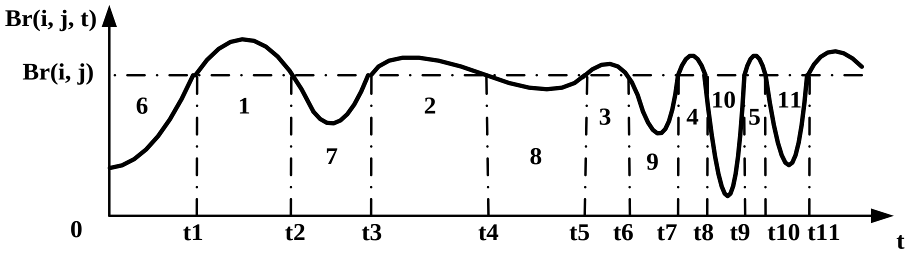

Figure 4: Determination of the time points for reliable determination of the bio-parameters of the learner:
1-5 - intervals of reliable determination of bio-parameters;
6-11 - intervals of unreliable determination of bio-parameters

The time intervals 1-5 correspond to the almost frontal location of the face in the corresponding window. These time intervals can be used for reliable remote registration of bio-parameters. The intervals of time 6-11 indicate the turns and inclinations of the head. The intervals of time 10 and 11 correspond to sharp movements of the student. Remote determination of bio-parameters in these cases is inexpedient.

Similar dependencies can be obtained by using several thermal imaging cameras located in different places of the audience.

4. Experimental results

The proposed algorithm was implemented as a computer program. Its approbation during the training sessions with students showed the possibility of reliable selection of students' faces when processing up to 150 images per second on the basis of a personal computer with an average performance based on the i7 processor with a working frequency of 3.5 GHz. The algorithm was applied to groups with different number of students, as well as with a different location of the thermal imaging camera. The number of students varied from 10 to 25 people. In all cases, it was possible to identify the faces of all students present, as well as to determine the time points for reliable remote determination of bio-parameters. Figure 5 shows an example of the thermal image of a part of the training group with the lateral arrangement of the camera. Despite the periodically overlapping thermal images of individuals due to student movements, the algorithm allowed to reliably determine the time points for reliable determination of bio-parameters. For this purpose, two thresholds were used, corresponding to the lower and upper limits of the permissible values of the total brightness of the pixels of the face area. The upper limit allowed to filter images with superimposed faces.

Figure 5: Typical thermal image of a training group

5. Conclusion

The proposed algorithm for identifying people's faces on a thermal image extends the boundaries of the possible use of technologies for remote determination of human bio-parameters. The algorithm is applicable for processing both the face image in the visible range of optical radiation, and for processing the thermal image. The greatest gain in performance is achieved when processing face images are in the visible range. This is due to the fact that at present the resolution of video cameras of the visible range far exceeds the resolution of the thermal chambers. And this leads to the need to handle larger data sets. The application of the proposed algorithm in practice makes it possible to significantly reduce the performance requirements of the computer tools used. In this case, the probability of detection and the accuracy of determining the coordinates of the image of the face increase.

Laboratory approbation of the algorithm confirmed its high productivity and efficiency. The implementation of the method of detecting significant time intervals for the most reliable determination of bio-parameters considered in the work made it possible to additionally obtain a gain in speed. This is due to the fact that the procedure for remote determination of bio-parameters was initialized only at those times when the person had predominantly frontal orientation.

The presence of a database with personal parameters of people undergoing training or retraining will additionally increase the performance of the algorithm by using windows with minimal dimensions, correlated with personal growth and facial sizes of students.

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