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# Detecting Human Head and Shoulders Trajectory in a Smart Classroom

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***Abstract***

*With the development of multimedia technology, intelligent monitoring systems, etc. smart classrooms emerged, people want to get involved through multimedia and smart technology, and thus the teachers with intelligent monitoring can get the students' attention time, points of interest , attendance , and exam invigilation and other activities more effectively, through the student movement of the head shoulder trajectory tracking and judgment and improve the efficiency of the teacher's work and strengthen the interaction between teachers and students to improve students' learning efficiency. In this paper, we use the multimedia technology on the student's head and shoulders trajectory tracking and analysis, so as to solve the above problems, mainly divided into three phases: firstly is human face recognition, using Ababoost; secondly is to get the head and shoulders' pose, analysis to determine the effective head and shoulder trajectory; analysis and judgment on the results after using Camshift for tracking. The experimental results show that this method has strong real-time, when the head with a partially occluded or background interference it still can get better target trajectory and movement direction for us to make better judgment and analysis.*

***Keywords:*** *Multimedia, ababoost, camshift, pose analysis*

## 1. Introduction

Smart Classroom is a classroom that facilitate to control the audio-visual equipment, computers, projectors, interactive whiteboards and other sound, light, electricity equipment, helping the teachers and students to seamlessly access resources and engaged in teaching activities, and able to use human-computer interaction and smart space technology to adapt a variety of learning styles which include distance learning. It has the advanced equipment, convenient operation, rich resource, real-time interaction, and flexible teaching.

From the literature we studied, there are many smart classroom model come into use at home and abroad, where there are typical college as McGill, Northwestern, Chicago, MIT, California and California State, Toronto University. But there are still significant differences between home and abroad on the smart classroom, most colleges and universities abroad, especially the United States, used to call the classroom with equipped with computers, projectors (LCD and optical), DVD, VCR and other video equipment, public address equipment and control equipment as smart classroom, this classroom in our country are mostly known as multimedia classrooms. Besides some secondary schools have equipped the whiteboard (multimedia projector with interactive feature called Smart Classroom), and now more and more schools begin to equip this type of smart classroom.

Hoidn Sabine from Stanford University has researched the teaching and learning in the smart classroom, the study found that it not only improve the ability of teaching professional, but also improve the skills in technology, learning, social and diversity

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awareness, Moreover, smart classrooms can promote the learner to present their learning outcomes. TuncaySevindik from Firat University in Turkey studied about the influence on the students' academic achievement in Health College, from the survey analysis of 66 college students, he found that the smart classroom enhance the students' academic achievements significantly, so reasonable use the smart classrooms can be beneficial supplement and alternative form, at the same time it can be an effective classroom environment for face to face education.

Tu'lio, Tibu'rcio and Edward F.Finch from the University of Reading in UK did some research in 2003-2004,it is about the behavior of students who intelligent interactive with the smart classroom, the aims is to explore the new smart classrooms INTEGER (Intelligent and Green) can affect the learners behavior in the new learning environment. Through two studies, we found that mobility, flexibility, technology applications and interactive[1] in the new learning environments will affect the positive behavior of learners.

The functional of the Smart classrooms including the automation of lecture notes, classroom Record and integrated control of electrical equipment, automation, intelligent remote education *etc* [2].

By comparing and carding of the existing smart classrooms home and abroad, we found that according to the technical conditions to build smart classroom, smart classrooms mainly have three types : the first one is based on hardware technology , like many foreign universities and some domestic enterprises equip multimedia computers , computer networks, LCD projector , AV systems video Showcase , public address systems and other equipment with the mand called it smart classrooms, such as the University of Alberta, University of California, Mahatma Gandhi University *etc.*; second is software-based smart classroom, this type of smart classroom is mainly achieved by means of the network which is a virtual intelligent software-based classroom. It can offer the support for learners, provide a variety of resources and learning forms [3], community exchanges and cooperation, such as classroom 2000, NASA 's future classroom programs etc; third is combination the two merits who both has hardware technology support and meanwhile use software system integrated control the hardware, and it can track and record the learners intelligent , most important is it can make the information exchange between the real classrooms and virtual classrooms ( for distance learning persons ) come true. [4]such as the smart classroom projects of Toronto University, intelligent remote classroom projects Tsinghua University[5] [6], smart classroom projects of Northwestern University and Mixed Reality Smart Classroom Project of Information Engineering of Central China Normal University and so on[7]. Divided by the type of functional, smart classrooms can be divided into Essential Smart Classrooms, [8] Interactive Smart Classrooms and Two-Way Video Smart Classrooms(Daniel Niemeyer 2003). (1)Essential Smart Classrooms --is the multimedia classrooms which consist of computer , video, data projector, integrated control panel, PA system, *etc.*; (2) Interactive smart Classrooms --not only have the basic functional characteristics of smart classrooms , but also can provide the interaction between teachers and students; (3)Two-Way Video Smart Classrooms --it has all the characteristics of the basic smart classrooms , also added a television camera and microphone in order to facilitate distance learning. In addition, according to the hardware configuration and the applicable space of the smart classrooms it can be distinguished, such as Clarion University divided the smart classrooms into Basic, Teaching Station, Science labs or limited space areas, Dedicated Smart Classroom, Large Venue / Auditoria and R-Portable Cart five types; Northern Colorado university divided the classrooms into smart (touch panel control), High-Tech Rooms, Mobile Podium Rooms, Projector Rooms and Smart Cart.

This paper is focused on intelligent monitoring module, in order to observe the trajectory of the head; the face tracking must be carried out. Face tracking is a small area in target tracking but recent years it attracts more and more attention, it is a key technology of the face recognition, video retrieval, virtual games and graphics control and because of its huge application prospects and market potential, it has become a hot topic in computer vision research. Now there are four ideas about face tracking algorithm: the use of motion tracking information [9], the use of color information tracking [10], the use of parametric models or templates to similar tracking the entire human [11] and the use of local features for face tracking [12]. Baoming Liu, who use color information achieved a face tracking which is not affect from face pose restrictions, but this algorithm sometimes can't put the face and hands with similar color apart. P.M.Antoszczyszyn built the model of eyes and mouth which can track these organs accurately. However, the tracking speed, especially the tracking speed about more precise location, are still need to be improved, so it is difficult to apply to a real-time video tracking.

In this paper, we use Adaboost [13] detects the human face automatically, and then tracks the extracted human face with Camshift [14], it avoids the subjectivity of artificial selected ,combines the two merits and forms an efficient, accurate face tracking system.

Camshift is based on the color, because the RGB is sensitive to light intensity changes , in order to reduce the effect of the light intensity changes on the track, Camshift converse the color space of the image from RGB to HSV [15] , using the H component establish the target histogram model , the original image pixel values is replaced by the statistics of the respective pixels in the histogram, the results will be re-quantized to the range from 0 to 255 and color probability distribution is obtained for the subsequent processing . Camshift can be divided into three parts [16]: reverse projection calculation, Meanshift, Camshift implementation. The Camshift can achieve real-time tracking of objects and not affected by noise, has good robustness and real-time performance is good too. But there are some weaknesses: Trace window must be manually selected, if the face is not appropriate, it will directly affect the tracking results, and even lead to tracking failure. Therefore, we combines the Adaboost face detection algorithm to automatically detect the video sequence of the human face, and then according to the probability distribution of color achieve with Camshift for face tracking. The specific framework of the method shows in Figure 1.

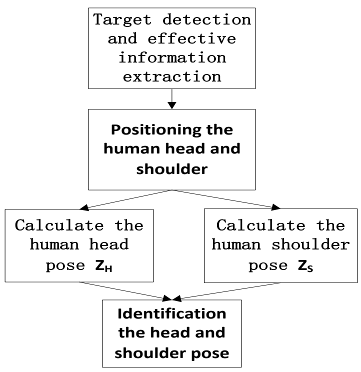



**Figure 1. The Specific Framework of the Method**

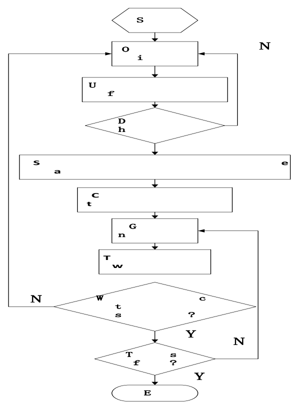


**Figure 2. Flowchart of the Algorithm**

## 2. Adaptive Tracking Algorithm of the Head

In order to track the trajectory of the head, this paper presents that detecting of human faces with Adaboost at first and then using Camshiftfor face tracking. The whole process of the algorithm, we won't need artificial selection for Camshift in order to avoid the subjectivity of artificial selection cause the tracking failure, when temporal occlusion causes face tracking failure, we use Adaboost for face detecting and track the target. From the actual face detection and tracking test, we found that the experiments show that the combination of these two algorithms in automatic face tracking has the advantages of speed, accuracy, and can effectively overcome the occlusion as well as interference of skin color. Flowchart of the algorithm is shown in Figure 2:

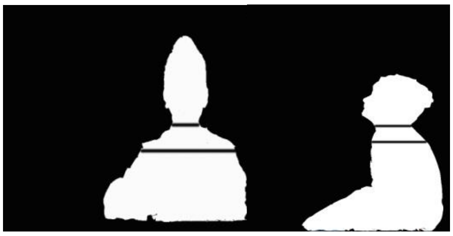
First of all, we detect the human faces, from the first frame until detected the target, Adaboost may take the results as: 1. Detect multiple faces; 2 detect the fault target (non-face). In this paper, we filtered the detected face and selected the samples of the face from the sequence successively, if the face isn't the one we required, it can sequentially switched the next face, if detected by fault, the user can re-detect the next frame . Through the above operation, the user can get the desired target area.

While we are still preparing for the Camshift, since the RGB color space is sensitive to the light, so we need to convert the target area to HSV color space, calculate the probability distribution of hue H and then use probability of color replace the value of each pixel in the image so we obtain the probability distribution of the color at last. This process is called back projection; color probability distribution is a grayscale image. Through the above steps we complete the preparation of the Camshift.

## 3 Automatic Identification of the Head Shoulder Deflection

### 3.1. Mathematical Modeling of the Human Body

In this paper, we use Adaboost to detect the target area, through the three fitting functions to model the human body. First of all we should obtain the minimum vertical rectangle of the body and extract the human body from the rectangular area, we define the height of the rectangle as h; we use the horizontal line h to capture the body contour from the highest point of the body, so that each horizontal line may get two points from both sides, then we will obtain two eigenvectors as: $R = (r_1, r_2, \ldots, r_n)$, and $L = (l_1, l_2, \ldots, l_n)$. Where $r_i$ denotes the right node on x axis of the i-th horizontal line catch from the body, $l_i$ represents the i-th left node and define vector $B = (b_1, b_2, \ldots, b_n)$, which$b_i = r_i - l_i$shows that the the body width on the i-th horizontal line. Vigenvector R, L, B respectively fitted into function as $f_R(x)$, $f_L(x)$ and $f_B(x)$, where $x_I$ [0, n], when x is an integer, $f_R(x) = r_x$, $f_L(x) = l_x$, $f_B(x) = b_x$, the following information of the body contour all through these three fitting functions.



a

**Figure 3. The Method used on Different Pose of the Head and Shoulder**

b

**Figure 4. Different Pose of Human Head**

### 3.2. Positioning Methods of the Head and Shoulder

As there are groups of students sitting in the Smart classrooms so that we adopt the approach which based on contour feature to locate the human head. According to the mathematical description on 3.1, since the human head is shown as an oval contour, so that the body function $f_B(x)$ that denote the width of human will appear local minima at the boundary. The curve shows the function $f_B(x)$ (typical human width). Here $X_{min}$is the local minimum point set of the function $f_B(x)$ on the x-values, and $x > 0$, $x_{HL} = \min(xi)$ is defined as the position of the human head boundary, $x_i \in X$, is the minimum of set X.

There is a certain ratio between the human head and shoulder position in physical, in this article we define the shoulder position as $x_{JL} = x_{HL} + ŋ \times x_{HL}$, ŋ is a proportionality factor, which need to be determined by the experiment, we take ŋ = 0.33. Figure 3shown the method used on different body posture of the head and shoulder , there are two black dividing line in the minimum vertical rectangular area, the up dividing line shows the position of the human head , the following dividing line indicates the shoulder position . Note that this feature is based on the human body so that under natural conditions of human subjects it has good ability to adapt, and has low complexity. When a person's head showing non- elliptical (such as special hairstyle, wear a hat or other accessories), the method will no longer apply.

## 3.3. The Pose of Hpuman Head

### 3.3.1. Judgment of the Head's Movement

Assuming the area of the human head with $F_{H,}$ it can be divided into two parts skin region and non-skin region. [17] built a skin model for detecting the skin color pixels in the known human head area of the image, use the method it proposed ,we can detect the skin region and non-skin area. Figure 4 shows the two images, human head in the image all showing different pose. If we divide the head area along the center line into two parts, then when the head face or the back the camera, the grayscale distribution of the two regions are substantially symmetric (Figure 4 (a) shown), and when the face is facing the camera from the left or right, the distribution of the grayscale around the two is obvious different, make $F_L$、$F_R$、$F_H$as the left half of the head skin region, the right half of the skin region and the hole head region respectively, this part of the body pose is defined as $Z_H$:

$$Z_H = \begin{cases} 1 & \begin{matrix} |F_L - F_R| < \mu \\ \frac{F_L+F_R}{F_H} < 0.5 \end{matrix} \\ 0 & \begin{matrix} |F_L - F_R| < \mu \\ \frac{F_L+F_R}{F_H} \geq 0.5 \end{matrix} \\ \frac{F_L-F_R}{F_H} & |F_L - F_R| \geq \mu \end{cases} \quad (1)$$

Where, μ is a pre-set threshold, when $Z_H = 1$ means that the head back to the camera, $Z_H = 0$ means that the face is facing the camera, when the $Z_H > 0$, it means that the head face the left of the camera, $Z_H<0$ means that the head face right of the camera. Formula (1) is to calculate the $F_L$ and $F_R$, when the two are closer, we can confirm that the head is facing or back to the camera, on this basis, we can calculate the $F_L + F_RF_H$, if $F_L+ F_RF_H>$ 0.5, it means the skin color region get the larger proportion of the head, so we determined that the face is facing the camera, otherwise, determining the face is back to the camera; if $F_L$ and $F_R$is quite different from each other, we can judge that the face is facing the camera from the left or right side. By calculating the value of $F_L$-$F_RF_H$, the final judgment can be given, if the value is greater than 0,so the head face the left side of the camera, if the value is less than 0, means the head face the right side of the camera.

### 3.3.2. Judgment of the Head's Rotation

In order to improve the accuracy, we introduce the orientation angle θ as another criterion. The Camshift output is an elliptical area, when the head face the camera, the vertical axis of the ellipse is similar to vertical and the direction angle is about 90°. When the head spin will causes the ellipse orientation angle of the Camshift changed, so we can use it to judge spin of the head, in order to supplement the lack of the above method.

When $Z_H \neq 0$, indicating that the head move or spin, and then use the direction angle as the formula ( 2).

$$Z_\theta = \begin{cases} 1 & \theta > 90° + \theta_0 \\ -1 & \theta < 90° - \theta_0 \\ 0 & \text{Otherwise} \end{cases} \quad (2)$$

Wherein, $Z_\theta$shows the deflected state of the head according θ, $\theta_0$(0°≤θ≤45°) is the threshold of the direction angle. When the head turns to the left, the major axis direction angle will greater than 90°, so that $Z_\theta$=1; when the head turns to the right, the major axis direction angle will be less than 90°, so that $Z_\theta$=-1; otherwise the head did not make any action, so that $Z_\theta$= 0. Consideringthe two criteria, we can summarize the head pose discriminant as follows:

(1) $Z_H$=1,$Z_\theta$=-1,that means the head back to the camera and the head spin to the right;
(2) $Z_H$=1,$Z_\theta$=1, that means the head back to the camera and the head spin to the left;
(3) $Z_H$=0,$Z_\theta$=-1, that means the head face to the camera and the head spin to the right;
(4) $Z_H$=0,$Z_\theta$=1, that means the head face to the camera and the head spin to the left;
(5) $Z_H$>0,$Z_\theta$=1, that means the head face to the camera sideways to the left and spin to the left;
(6) $Z_H$>0,$Z_\theta$=-1, that means the head face to the camera sideways to the left and spin to the right;
(7) $Z_H$<0,$Z_\theta$=1, that means the head face to the camera sideways to the right and spin to the left;
(7) $Z_H$<0,$Z_\theta$=1, that means the head face to the camera sideways to the right and spin to the right;

### 3.4. Pose of the Shoulders

$S(x_H)$ indicates the width of the shoulder, we found that when range of the sideways becomes larger and larger, $S(x_S)$ became smaller and the contour of the shoulder closer to the camera changes rapidly.

Figure 5 (a) is the original image, the left side of the body contour is close to the camera, Figure 5 (b) is the contour extraction and head and shoulder positioning. Obviously, the left contour changes larger, and the right contour changes relatively flat. Take the advantage of human body we defined the shoulders pose variable $Z_S$. It is calculated as follows:

$$Z_S = \begin{cases} 0 & |[S_L(x_S) - S_L(x_H)] + [S_R(x_S) - S_R(x_H)]| < \Omega \\ \frac{S_L(x_S)-S_L(x_H)}{x_S-x_H} + \frac{S_R(x_S)-S_R(x_H)}{x_S-x_H} & |[S_L(x_S) - S_L(x_H)] + [S_R(x_S) - S_R(x_H)]| \geq \Omega \end{cases} \quad (3)$$

Where, Ω is a threshold value, $x_H$ is the boundary of the human head position, $x_S$ is the boundary of the shoulder position and we can find that $x_S > x_H$. Where the first term $\frac{S_L(x_S)-S_L(x_H)}{x_S-x_H}$represents the gradient of the left shoulder, is negative as a rule;$\frac{S_R(x_S)-S_R(x_H)}{x_S-x_H}$ representsthe gradient of the right shoulder, is usually positive. $Z_S$<0 means the left contour of the shoulder gradient is large, the left side of the body contour is closer to the camera; $Z_S$> 0, which means that right body contour is closer to the camera; $Z_S$ = 0, which means that the contour line around shoulder region is symmetric, and the body face or the back to the camera. Generally the greater the absolute value of $Z_S$, the larger the body sideways.

a b

**Figure 5. Pose of the Shoulders**

### 3.5. Human Pose State Discrimination

After calculating the first part of the human head pose and shoulders pose $Z_H$ and $Z_S$, we also need certain rules to determine the final body posture. As people sit normally, its head and shoulders pose has a certain constraint relations, based on experience, we can be defined the discriminant rules as:

1) $Z_H = 0$, $Z_S = 0$, the body on the state a, that is facing the camera;
2) $Z_H = 1$, $Z_S = 0$, the body on the state b, that back to the camera;
3) $Z_H \geq 0$, $Z_S < 0$, the body on the state c, that is facing the camera sideways to the right;
4) $Z_H \leq 0$, $Z_S > 0$, the body of the state d, that is facing the camera sideways to the left;
5) $Z_H < 0$ or $Z_H = 1$, $Z_S < 0$, the body of the state e, that is back to the camera sideways to the right;
6) $Z_H > 0$ or $Z_H = 1$, $Z_S > 0$, the body of the state f, that is back to the camera sideways to the left. $Z_H$ and $Z_S$ will put into the above rules so that we can get the human video pose estimation.

## 4. Experiment Simulation

To test the performance, we compared the methods with 2 experiments. The computer use in the experiments configured as Intel (R) Pentium (R) Dual-Core, CPU 2.5GHz, 2G, simulation experiments using VC + + programming.

Experiment 1 using a USB webcam capture a video of 600 frames, natural light, the entire video exists changes in illumination, in Figure 6 the four images were the video section 90th, 120th, 220th and 340thframe, wherein Figure 6 (c) (d) have the more intense illumination. This algorithm estimates the human head and shoulders pose $Z_H$, $Z_S$, and through the human body pose estimation discriminant rule. The experimental results are shown in Table 1.

a b c d

**Figure 6. Frames of the Experiment Video**

**Table 1. The Human Pose Estimation Results**

| Frames | a | b | c | d |
|---|---|---|---|---|
| $Z_H$ | -0.2 | 0 | 0.1 | 0.8 |
| $Z_S$ | 1.1 | 0 | 0.5 | 1.5 |
| Pose | d | a | c | f |

Experiment 2 is to use a frame grabber with professional camera obtain 1000 frames of video (see Figure 7).The video use the indoor light and the pose estimation results shown in Table 2.

The results coincide with the actual situation. Similar to the experiment 1, the correct detecting image is 912 in the experimental 2 and the correct rate is nearly 92%, the processing speed is 25 frames/s.

a b c d

**Figure 7. Frames of the Experiment Video**

**Table 2. Human Pose Estimation Results**

| Frames | a | b | c | d |
|---|---|---|---|---|
| $Z_H$ | 0 | -2.5 | -0.6 | -0.1 |
| $Z_S$ | 0 | 0.3 | 2.2 | 0.1 |
| Pose | a | ddd | | |

In the above two experiments, pose estimation errors occur because of the following two points: 1) noise of the image or camera shake which caused the body region detection is not idealand the extraction of the contour is not accurate, thus the final pose estimation results is affected; 2) because of the human body may have the movement as bow, arm swings too severe, self-occlusion so that cause the wrong pose estimate.

**Table 3. Result in 3D Reconstruction**

| Frame | a | b | c | d |
|---|---|---|---|---|
| Depth of eft end point | 4.77 | 4.53 | 4.78 | 5.62 |
| Depth of right end point | 5.41 | 4.60 | 4.81 | 4.5 |

From the results above, traditional methods as 3D reconstruction can obtain the depth of the feature point from the two-dimensional image, and then estimate the sideways angle. For example in Table 3, Figure 6(a)(b) the depth of the left size close to the right feature point, which means the sideway angle is small, Figure 6(c)(d) there are some differences between the left and the right feature point of the depth, which means the body sideways a larger angle. However, this method can't determine the body projection is the front or the back, in addition, when the target detection is not accurate, the calculation result will have error too. The use of 3D reconstruction to dispose the images in the video can get a similar effect, the processing speed is 6 frames/s, and its efficiency is not so as the method we proposed.

Through the 2 experiments we can find that: this algorithm may have good stability and effectiveness results when the object pose estimation under normal conditions, so whatever the human at different imaging devices, different scenes and lighting changes will not affect the result. The processing speed of this algorithm is 25 frames/s, the traditional 3D-reconstruction is 6 frames/s, so we can find that our method have the low computational complexity; and in practical we only need a single camera, the 3D-reconstruction requires multiple cameras and each one needs to measure the optics and location parameters before the experiment; about the pose estimation results, although the method we proposed can't get the exact quantitative values of the body pose, but we can get the reasonable estimate on the human body and use natural language to interpret it, the 3D-reconstructionalthough able to estimate the angle of the body sideways, but it can't recognize the body projection is the front projection or rear projection.

**Table 4. Comparison of our Method and the 3D-reconstruction**

| | Efficiency | limitation | Result |
|---|---|---|---|
| Ours | fast | small | good and can give natural language to interpret it |
| 3D | slow | big | Can only estimate the sideways angle, can't estimate the orientation |

## 5. Conclusions

In this paper, we propose that combine the Adaboost and Camshift to track the head and shoulders' movement, and thus by constructing mathematical models to determine the trajectory of the head and shoulders, which has an important application in intelligent video surveillance system. Pose estimation we simplified the body pose in finite state space at first, and then use the rules and characteristics of the body in the 2D imaging to estimate the body pose and use natural language give us a reasonable interpretation. By importing the Adaboost face detection to achieve Camshift automatic tracking, effectively overcome the occlusion that cases tracking failures which ensure reliable tracking of the head. At the same time, we construct mathematical models for determining the correct trajectory of the head and have good robustness, timeliness and convenience. If the object does not appear severely deformed and severe occlusion our method can handle it but when the body is in another pose (running, jumping, squatting, *etc*.) how to estimate the body pose is the next step of research work.

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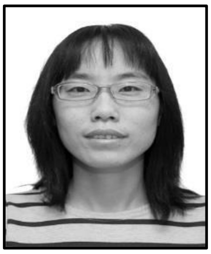
# Authors



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