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# Camera's Auto-calibration Algorithm in Broadcast Soccer Video

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**Abstract:** In the traditional soccer video, it is difficult for the camera calibration technology to calibrate and provides the object's three-dimensional height information and other issues, so this paper puts forward camera's auto-calibration algorithm in soccer video. First of all, the two-dimensional model and three-dimensional model of the court are defined and the improved the detection algorithm of court lines obtains the feature points in the court plane to solve camera's isomorphic matrix, and then the solved isomorphic matrix is used to calibrate the goal and obtain the two feature points in the goal plan. Finally, the optimal internal and external parameters of camera are got from the method based on k-means clustering and Hough-like search. The court line detection and the detection experiment of the 3D – 2D camera are conducted, and the simulation experiments show that the improved court line detection algorithm can effectively improve the site regional classification in soccer video (> 96%), and the accuracy of court line detection (> 92%).

**Keywords:** Three-dimensional Reconstruction; Mapping; Competition Video; Edge Pixels

## 1. Introduction

The brightness of each point on the image reflects some points' reflected light intensity on space surface, and the location of that point in the image is related to the geometry position on the object surface of space. These parameters must be determined by experiment and calculation, experiment and calculation process is called camera calibration. Computer vision system involves the use of computer and CCD camera imaging device, so that it can automatically obtain the natural scenery in front of the camera, it provides a very simple method to record or observe the three-dimensional scene, but in terms of their characteristics, it will lose a lot of information by projecting 3 d scene to two-dimensional images, 3 d computer vision system should be able start from the image information got by the camera, reconstruct the location of the 3 d scene Shape geometry information, and thus recognized objects in the environment, here are a few standard of scene reconstruction based on different geometry, they respectively are projective reconstruction, affine reconstruction and metric reconstruction, different visual tasks need reconstruction of different types, however, to human observers, in order to be able to realistically reflect the original scene, most occasions need to get the 3 d metric reconstruction of the scene, to conduct metric reconstruction of scene using computer, it must be conducted prior to the camera calibration.

In the research field of Photogrammetry and computer vision, video camera calibration technology will increasingly play an important role. If you can find the feature points in soccer video image frame and its corresponding coordinates in the 3D world according to the geometric model of camera imaging, and work out the internal and external parameters of camera precisely, it will be good to promote further application research [1-3].

Throughout the development of camera calibration technology in soccer video, the theory roughly experienced three important periods. The early camera calibration is mainly installed some special sensor on the camera and lens to measure the camera shake (Panning) and zoom (Zooming), in order to complete offline camera calibration, the deficiency of this kind of technology is very expensive, and, when unable to close to the camera, it is sometimes hard to implement [4]. This method starting from the second period, the researchers tried to use the image processing and computer vision's related theory, looking for the corresponding feature points' coordinates of two-dimensional field planes and two-dimensional image planes, in order to build a plane perspective projection from two-dimensional to two-dimensional. Kim H etc[6]. put forward a camera calibration algorithm based on Pan - tilt model to realize the two soccer video image sequence's image Mosaic (Mosaic), the main problems of the algorithm is not fully consider the complexity of the camera imaging model, and the algorithm has a large amount of calculation, because it needs to search in the parameter space to get better characteristic line's matching initial value. Farin D proposed a more general camera calibration algorithm, it can be applied to any sports video which contains a sufficient number of soccer's characteristic line, but the algorithm also cannot provide the 3D object height information, and that for some subsequent applications (e.g., estimate the trajectory of football) is a key problem. In the third period, the researchers sought to provide all the 3D object information, namely, to establish a image plane perspective projection from three-dimensional space to two-dimensional. Kim H estimate the location of the ball on the basis of a simple camera model, but the algorithm is facing two difficulties, one is the need for artificial search for two objects which have similar visual depth and perpendicular to the stadium plane, the second, it needs to assume that the athletes height are known. Liu Y proposed a camera calibration algorithm to extract 3D information of the soccer video. Although the initial characteristic line of the algorithm is assigned by artificial, but it is too simple for the calculation of interior parameters of the camera, so that it is difficult to get accurate height information. In general, the camera calibration technique in soccer video is an open hot topic, it still has many problems to be solved. Mainly include: 1) the need to establish a suitable camera perspective projection model and find the feature points which are easy to calculate, in order to realize 3D information's automatic extraction (especially the height information) in soccer video; 2) due to a low resolution of soccer video, and will cause information loss in the process of the MPEG compression, resulting in the big error of feature point detection in image frames; 3) some images frame of the soccer video contains feature points are not sufficient to calibrate the camera. Near the circle of the stadium, for example, it is difficult to find the feature points formed by the intersection of field straight line; 4) because shooting soccer video's main camera is generally in a fixed position of the stage, in the process of filming needs regular camera shaking and zooming, thus leads to the bigger change of interior parameters of the camera, therefore, requires accurate camera calibration method to make the estimation error of the camera internal and external parameter as small as possible.

## 2. Mapping and Model

### 2.1. 3D – 2D Camera Mapping

In 3D - 2D camera calibration, the camera can be regarded as a mapping from 3D real world to 2D image space, in particular, in the video of broadcast football, from the point of 3D field, to soccer video image frames coordinates of Euclidean transformation is shown in figure 2. Among them, the world coordinate system is formed by three axes $w_x, w_y, w_z$, the camera coordinate system is formed by three axes $c_x, c_y, c_z$, the image coordinate system is formed by two axes $i_x, i_y$. The world coordinate system and the camera coordinate system can be transformed through the axis of rotation and translation. O point for camera light heart, starting from point O along the $c_z$ axis is in the camera optical axis, $o_0$ for the camera focal length. If define any point of the world coordinate system T can be expressed by 4 d with conformal array $(x, y, z, i)$ T, and any point of the image coordinates t can be created by 3D with array $(x, y, z)$ (their corresponding Euclidean coordinates is $(x/z, y/z,)$, P is 3 X 4 camera projection matrix, then the mapping from the point T in 3D world to the point t in 2D image frame can be simply described as t = PT, namely.

$$\begin{pmatrix} r \\ s \\ t \end{pmatrix} = \begin{bmatrix} y_{10} & y_{11} & y_{12} \\ y_{20} & y_{21} & y_{22} \\ y_{30} & y_{31} & y_{32} \end{bmatrix} \quad (1)$$

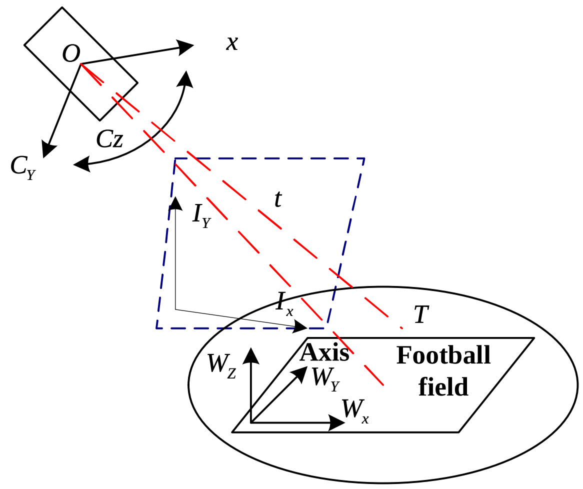


**Figure 1. Transformation in Soccer video from 3D world Coordinates to 2D Image Coordinate.**

In order to solve the internal and external parameters of camera, projection matrix P can factoring for further

$$R = ht[y| - c] \quad (2)$$

Among them, I, K, R is a unit matrix respectively, scaling matrix and the rotation matrix, C is the center for the camera in the world coordinate system coordinates, and $c = (x_c, y_c, z_c)$. $k$ is an upper triangular matrix; it contains the camera's internal parameters, namely

$$t = \begin{bmatrix} y_g & m & m_0 \\ o & y & v_0 \\ o & o & 1 \end{bmatrix} \quad (3)$$

Among them, f is the focal length, γ is the ratio of pixel' high to width, s is distortion factor, $(m_0, v_0)$ is camera's main point (Principal point, the point o in figure 2) coordinates in the image coordinate system.

### 2.2. 3D Field Model and 2D Model of the Stadium

According to FIFA for the football match rules, we know the midcourt line of football stadium (in addition to the line and the bottom line) and the position of the goal and length are fixed, therefore, can be set according to the rules of court lines and the goal to build the stadium model. This paper defined the 2D field model (figure 3) (a) for all pitch line in the pitch plane (mainly has foul line, bottom line, ban line ,midcourt line, and circle, etc.) in the penalty area formed by the area, among them, the location of the pitch line in accordance with the rules of the game set, its length is carried out in accordance with the rules set by the length of scaling, and we will make the pitch lines' intersection as the feature points of camera calibration. Unlike existing work, in addition to actual intersection of the pitch line (hollow white point of figure 3), we also extended the field lines or increase the virtual line to get some virtual node (solid black spots of figure 3), thereby increasing the feature points which can be used for camera calibration.2D football field model and the corresponding feature points in the image frames as shown in Figure 3.

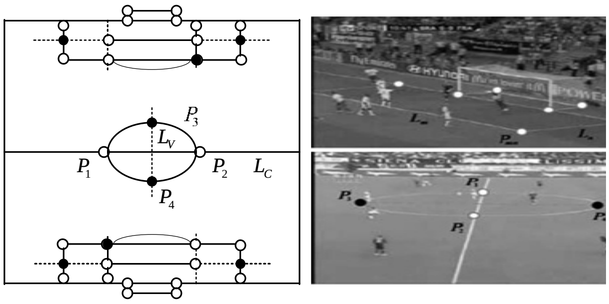


**Figure 2. 2D Football field Model ((a)) and the Corresponding Feature Points in the Image Frames ((b)).**

On this basis, this paper also defines the 3D field model (figure 4 (a)), it includes two perpendicular plane, namely the pitch plane and the goal plane, the pitch plane set is the same with 2D model, the goal plane is according to the football match rules set and corresponding reduction. With the need of not coplanar feature points in the process of 3D - 2D camera calibration, we can increase two points of intersection between the beam and post of goal plane (solid black spots in figure 4) as the feature points to achieve the extraction of 3D information. 3D football field model and the corresponding feature points in the image frames as shown in figure 4

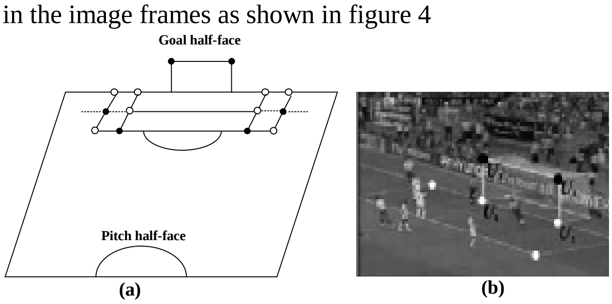


**Figure3. 3D Football Field Model ((a)) and the Corresponding Feature Points in the Image Frames ((b)).**

## 3. 2D - 2D Camera Calibration

### 3.1. Improved Detection Algorithm of Pitch Line

This chapter puts forward an improved automatic detection algorithm of pitch line, it mainly use the color in the image frames and edge features, the algorithm mainly includes three steps, namely area analysis, edge detection and pixel detection and repair, the pitch line positioning.

### 3.2. Field Detection and Regional Analysis

First of all, in order to robust segmentation in soccer video sites, this paper adopts a method based on $G_{aus} - s_{ian}$ mixture model ( $G_{aus} - s_{ian}$ mixture models, GMM) to model the soccer field distribution of the main color in the video. The color of the pixel distribution will be established in HSI (hue, saturation and brightness) space, and does not consider luminance component I. in the $G_{aus} - s_{ian}$ mixture model, the conditional probability density of pixels ξ belongs to the field Φ can be described by M $G_{aus} - s_{ian}$ density convex set, namely

$$p(x|f) = \sum_{k=1}^{u} w_i t_i(z) \quad (4)$$

Among them, $w_i$ is mixed weights, and $\sum_{k=1}^{u} w_i = 1, t_i(z)$ is the $G_{aus} - s_{ian}$ density weight, the average is $t_i$ and the variance is $\sum_i$ .

Due to player or the object often appear on the site, therefore, when the lower part of the template image field matching without success, this paper set up the matching value only reduce 0.5. And after all the pre-set template image matching, to select the maximum value matching of template image, it is represented by the area to enter the field of image frames. The matching process between site image frames and the template image as shown in figure 5, the massive white block image represents the field blocks, black representative field blocks. Known from the figure 5, due to the matching value between input image frames and the template of the midfield zone is highest (271.5), the area of the input image frame for the midfield area.

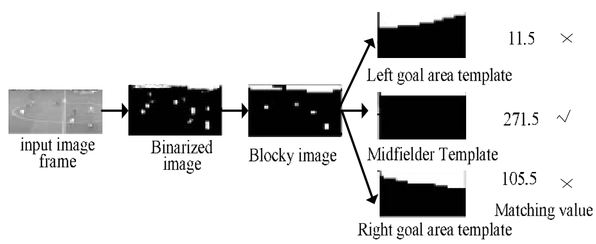


**Figure 4. Sample Graph of Ground area Analysis.**

### 3.3. Pitch Line Positioning

Once you determine the field area of the current image frame, and using edge detection and repair algorithm to get the edge of the robust image, Hough transform can be applied to the left/right of the goal area to detect a straight line, in the midfield area using ellipse matching algorithm to match.

Because in the rebroadcast process of the football game, the camera position is fixed, this makes the pitch line of the left and right goal area will appear at a fixed Angle, therefore, can assume a range of stadium line's slope Angle in Hough straight line detection, in the experiment, we limit on both sides of the pitch line parameter θ meet their goal of $67^0 \le \theta \le 85^0 \le \theta \le -65^0$. In addition, this article also further improve the pitch line detection accuracy through introduced the parallel constraint and repeat line removal, the limit to detect at least two parallel $\left(|\theta_1 - \theta_2| \le 10^0\right)$ pitch line, and the straight line $\left(|\theta_1 - \theta_2| \le 10^0 \text{ and } |d_1 - d_2| \le 5_n\right)$ of the similar parameters is considered to be repeated, only one will be preserved.

In the midfield area, in order to remove the unrelated linear, the parameters restricted to the midline must meet |θ| < 10. In addition, because the ellipse matching algorithm is sensitive to noise, so only running ellipse matching algorithms when precise detection to the vertical Central Line, and, because the coil is symmetrical relative to the center line, you can also use the midline to filter the asymmetric edge points. The experimental results of the pitch line positioning are shown in Figure 6.

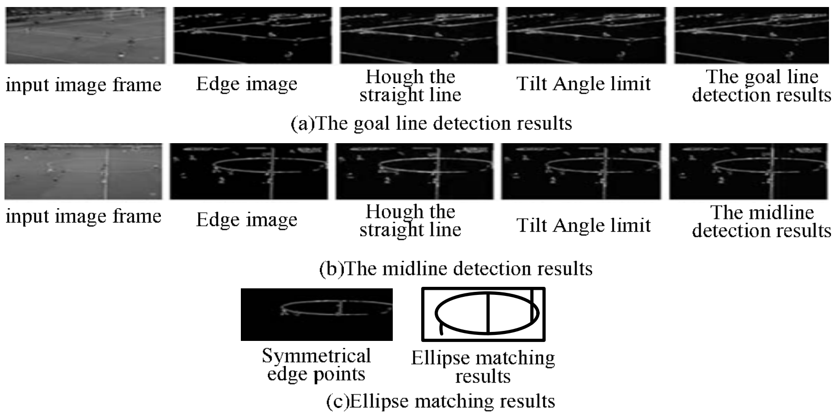


**Figure 5. Experiment Results Diagram of the Pitch line Positioning**

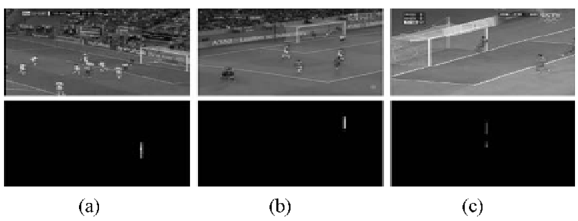


**Figure 6. Experimental Results Graph of the Ball Post Growth Based on the Color Figure ((a) Left Goalposts increase; (b) The Goalposts increase; (c) The Situation of Being Covered).**

## 4. 3D - 2D Camera Calibration

### 4.1. Feature Point's Detection Algorithm of Goal Plane

In order to solve the position of the goalplane's feature points in the image frame, namely $m_3$ and $m_4'$ in figure 4 (b), in this paper, a kind of ball post growth algorithm was proposed based on color to locate the node position between post and beam. Left goalposts' feature point's location as shown in algorithm 2, similarly, we'll be able to locate the right goalposts' feature point. In the experiments, in order to solve some of the non-white object (such as athletes) for goalposts shade problem, this algorithm allows the goalposts growth can be up to over 20 pixels. Figure 7 is the experimental results figure of the goalposts growth based on the color, which figure (a), to the left goalposts growth figure 8 (b) for the right goalposts growth, figure 7 (c) is for the situation which is sheltered by athletes.

Algorithm 1

Step 1 Using the camera projection matrix H solved in section 3, combining type (5), the U1 (see figure 4 (a)) coordinates $(xm_1, ym_1, 1)$ reverse projection image frames, you can get the coordinates of the $m_1(xm_1, ym_1, zm_1)$ (their corresponding Euclidean coordinates $(xm_1/zm_1, ym_1/zm_1)$) ;

Step 2 Set up the left goal posts' point set PSL, and $m_1 \in PSL$;

Step 3 At last the coordinates of a point from PSL goalposts growth up, if the adjacent pixels meet R > 150 and G > 150 and B > 150, it will join the PSL point and repeat step 3, otherwise it will be added to the left goalpost point at which a candidate point set CP SL and go to step 4;

Step 4 If Num(CPSL) ≤ 20, At last the coordinates of a point from CPSL goalposts growth up, if the adjacent pixels meet R > 150 & G > 150 & B >150, that point and all points in the CPSL will join the PSL, and then to empty CPSL and go to step 3, otherwise it will join the CPSL and repeat step 4; If Num(CPSL) > 20, the end of the algorithm, the last point's coordinate in PSL is the endpoint of left goalpost $m_3$ coordinates.

### 4.2. Precise Calculation of Camera's Internal and External Parameters

First, define two types of camera parameters, namely, the parameters of shot change and frame changes. The so-called shot change parameters (namely $c, m_0, v_0, g, s$ ) refers to this kind of camera parameter values only changes over the lens, that is to say, this the same lens image frames are the same in this kind of parameters; And frame change parameters ( $i, e.., r, f$ ) suggests that this kind of camera parameter values will change with the change of image frames.

As it has been got 4 coordinates of feature points of the pitch plane (3), and locate two point's coordinates $m_3$ and $m_4$ of the goal plane (section 4.1), thus it can also use the method of the direct linear transformation to solve the initial values PI of camera matrix, then according to the type (2) for factoring $p_i$. Assume that a single lens $s_i\,(i = 1, 2, ..., m)$ totally contains N image frames F $s_{ij}\,(j = 1, 2, ...n)$, and the initial value of each image frame camera parameters is $\{CF\ S_{ij}, m_{of}\ s_{ij}, v_{of}\ s_{ij}, g_f\ s_{ij}, RF\ s_{ij}, fe\, s_{ij}\}$.

In theory, the value of Camera parameter's change in a single lens is unchanged, but in practice, due to factors such as error in feature point calculation caused the fluctuation of camera lens change parameter values, In order to improve the accuracy of parameters of camera lens change, the lens Si shot change parameter of each image frames respectively for k-means clustering $CF\ S_{ij}$, $m_{of}\ s_{ij}$, $v_{of}\ \ s_{ij}, g_f\ s_{ij}, s_e\ s_{ij}\ (j = 1, 2, ...n)$, the lens changing parameters is respectively marked for $\bar{c}\, s_i$, $\bar{u}\, os_i$, $\bar{v}\, o\, s_i$, $\bar{g}\ s_i$, $\bar{s}\, s_i$, after classification, then, these similar center will instead lens Si change parameters of each image frames $F\ s_{ij}$, namely

CF $s_{ij} = \bar{c}\, s_i$, $m_{of}\ s_{ij} = \bar{m}o\, s_i$, $v_{of}\ s_{ij} = \bar{v}\, s_i$, $g_e\ s_{ij} = \bar{r}\, s_i$, $s_f = \bar{s}\, s_i$, the camera parameters which got after being instead is called the improved camera parameters' initial value P0.

After got the camera parameter values P, three-dimensional pitch model M3D can be projected back to the source image IS, get the model projection IP RO(P, M3D). Due to the estimation error of camera matrix will lead to the difference between source image and the model projection, therefore, in order to improve the frame change parameters of camera, it can find the optimal values of frame changes based on a function of pitch matching, the optimal value can make the source image and projection model of maximum matching values.

Wherein, setting the failed match value as half of succeed matching, mainly because the pitch line of white in the source images are sometimes shade shadow or obstacles. In addition, when the model line beyond the source image range, it will not consider it matching with the source image (matching value is set to 0). At the same time, in order to ensure that it can extract more accurate height information, this article the value of goal matching success and failure to 2 times of the corresponding field line value.

After the definition of stadium matching function is given, and can build Hough space using improved the initial value P0 of camera parameters, and then, based on the matching function in Hough space for Hough - like search, to find the optimal parameters of camera frame change.

## 5. Experiments and Analysis

Robustness and effectiveness of the algorithm in this paper, we collected five soccer video data with different compression format and different resolution from radio and television signals (see table 1), and then, choose 500 video clips as test data from artificial selection, the average video clips for 30 seconds long, these segments appear a clearer line of the stadium. All the code in the experiment are achieved by $VC + 6.0$, DirectX9.0 SDK and Open $C_v$, among them, DirectX has proven to be a very effective solution in multimedia processing.

**Table 1. Soccer video DATA**

| Video Name | Competition category | Compression format | Resolution |
|---|---|---|---|
| Brazil vs France | Premier League | MPEG | 490×360 |

| | | | |
|---|---|---|---|
| AC Milan vs Siena | Serie A | RMVB | 490×360 |
| China vs Brazil | World Cup | MPEG | 353×242 |
| Arnason vs Brazil | Olympic Games | MPEG | 353×242 |
| Real Madrid vs Liverpool | European Champions Cup | AV1 | 353×242 |

### 5.1. Detection Experiments of Pitch Line

In order to quantitatively evaluate the performance of this course line detection algorithm, first, artificially mark the site area of soccer video clips and the real value of pitch line, mainly including labeling left/right /midfield zone area and the parameters of the pitch line θ and d. if the pitch line Ld detected by this algorithm meet the parameter limit ($|q_d - q_{gi}| < 5$ and $|d_d - d_{gi}| < 3$, among them, the $q_{gi}$ and $d_{gi}$ is the $i$ pitch line's real value), the detection result Ld is the correct detection result. Site area classification and the final experimental results of pitch line detection are shown in table 2, among them, the precision = right count/detection detection and recall = correct detection number/total. Can be seen from table 2, the site area (left/right/in) classification's precision and recall rate are above 0.95, satisfy the subsequent processing, such as the pitch line detection, camera calibration, etc.). But on the pitch line detection, although straight line detection's precision and recall rate reached 0.921 and 0.959 respectively, the ellipse's matching result is still not satisfactory (precision ratio is 0.875 and recall ratio is 0.908), the main cause of the ellipse's matching error is often can only appear part of elliptical (that is, in the circle) in the video frames.

**Table 2. Detection Results of Pitchline**

| Type | Total number | Probe number | Correct probe number | Precision rate | Recall rate |
|---|---|---|---|---|---|
| Right goal area | 165 | 198 | 192 | 0.983 | 0.981 |
| Left Right goal area | 198 | 199 | 163 | 0.924 | 0.978 |
| Midfielder area | 140 | 143 | 138 | 0.959 | 0.954 |
| Pitch line | 1824 | 910 | 1802 | 0.921 | 0.958 |
| Pitch line (oval) | 132 | 138 | 125 | 0.875 | 0.908 |

### 5.2. Calibration Experiment of 2D - 2D Camera

Because soccer video in this article's experiment from the radio and TV signals, so it is difficult to get the real value of the camera projection matrix H, so, we use the camera projection matrix which has been solved to put course line of the model projected back to the source video frame, in order to test the effectiveness of the camera calibration algorithm. Figure 8 are some examples of the source of video frames and pitch line projection, among them, the white line is the pitch line of source video frame, and the black line is the course model's line's projection in the source video frame, it is worth mentioning that in the midfield area of figure 8 (b), this algorithm also succeeded in camera calibration, which is difficult to calibrate the camera, in many existing literature.

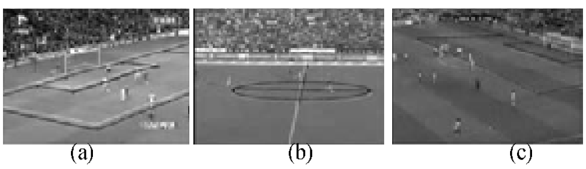


**Figure 7. Source video Frames and the Pitch line Projection instance ((a) The Left Goal area; (b) the Midfield area; (c) The Right Goal Area).**

It are also met with some difficulties in the experiment, such as only part of the circle appear in the video frames (figure 9) (a), or shadow (figure 9) (b) and the superposition objects (such as slow motion marks, as shown in figure 9 (c)) hides most of the stadium, estimation error of camera matrix is bigger, this algorithm will be hard to implement. However, the camera tracking algorithm can be introduce in the future to solve this problem.

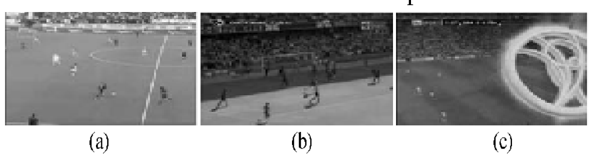


**Figure 8. The Difficult Situation to Conduct the Camera Calibration**

### 5.3. Calibration Experiment of 3D - 2D Camera

Table 3 is the experimental instances of clustering center of camera change parameters, among them, the coordinates of the camera center ( $\bar{x}s_i, \bar{y}s_i, \bar{z}s_i$ ) is the world coordinate system 's coordinate(the world coordinate system's origin at the middle of the goal model), the unit is meters. You can see from table 3, broadcast football game's main cameras generally located in the midline extension cord ( $\bar{x}s_i \approx 0$ ) near the podium, but the specific location will varies according to the site, such as the premier league games are in professional football (no runway near the soccer course), therefore, the main camera position closer to the center ( $e,...g,\bar{y}s_i$ of camera 2 is smaller), and the Olympic football games are in comprehensive stadium (have runway near the soccer course), so the main camera position is further to the center ( $\bar{y}s_i$ of camera 2 is bigger).

**Table 2. Clutering Center Instance of Cameras Change Parameter**

| lens | $\bar{c}s_{s_i}(\bar{x}s_i,\bar{y}s_i,\bar{z}s_i)$ | $\bar{v}o_{s_i}$ | $\bar{r}o_{s_i}$ | $\bar{m}o_{s_i}$ | $\bar{s}o_{s_i}$ |
|---|---|---|---|---|---|
| Lens 1 | (0.039,63.1,12.4) | 269.01 | -69.01 | 0.988 | 0.114 |
| Lens 2 | (0.087,57.3,9.8) | 149.05 | -73.59 | 0.953 | 0.105 |
| Lens 3 | (0.042,,73.2,12.4) | 245.04 | -65.02 | 0.918 | 0.140 |
| Lens 4 | (0.049,59.01,10.3) | 170.02 | -73.61 | 0.988 | 0.096 |
| Lens 5 | (0.0991,69.01,15.3) | 256.35 | -66.02 | 0.972 | 0.110 |

The same as the section 5.2, it is hard to get real values of soccer video camera projection matrix P, therefore, in order to test the performance of the algorithm. 3, still measure the accuracy of the projection matrix P by calculating pitch matching function PMF (IS, IP RO (P, M3D)) (formula (8)).

Specific process is: first, using the method of section 4.1 and section 4.2 to get each image frames $FS_{ij}(j=1,2,...,n)$ in lens Si 's initial projection matrix $p_{ij}$ and improve the initial value P0j of the camera parameters, and then calculate the corresponding matching pitch values of projection matrix and the notes for $PMF\ p_{ij}$ and $PMF\ p_{oj}$ respectively, finally, the algorithm 3 are used to get the optimal camera projection matrix $P_{optj}$ and matching and calculating the corresponding field value $PMF\ pop_{tj}$. Make the AP MFPI for the average of $PMF\ p_{ij}$ in all the lens, the $AP\ MFPI=\sum_n^j PMFPI_j/n=1$, the same can be got AP MFP0 and AP $MFP_{opt}$. Table 4 is compared to AP MFPI, AP MFP0 and AP $MFP_{opt}$ in the ten lenses, among them, the last line is the increase percentage of field matching values, namely IP % = AP $MFP_{opt}$ − AP MFPI/AP MFPI×100 %. Seen from table 4 that APMFPI and APMFP0 value has no significant difference, and even many times APMFP0 value is lower than APMFPI, therefore, It needs use algorithm 3 to get the optimal cameras matrix. Most of the lens in table 4 (except the lens 5, and 7), $APMFP_{opt}$ value is improved compared to APMFPI (average percentage increase 4.32%), through the further analysis to lens 7 and 5 found that the main reason is that the camera parameters' global optimal value is not contained the constructed Hough space which $m_{es}\ p_{oj}$ as the initial value, which leads to algorithm 3 can only find the local optimal value, this is a problem to be solved in the future work.

**Table 4. Comparison Of Camera Projection Matrix Initial Value Improved Value And The Accuracy Of The Optimal Value**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $A_{PMp_{pt}}$ | 938 | 807.5 | 839 | 530 | 904 | 622 | 856 | 923 | 846 | 727.7 |
| $A_{PMp_{po}}$ | 946.3 | 813.3 | 820.1 | 823.5 | 887 | 601.3 | 800.6 | 903 | 813.2 | 708 |
| $A_{PMp_{opt}}$ | 978 | 829 | 893.1 | 893.4 | 892 | 699 | 836.7 | 958 | 897 | 768 |
| $IP\%$ | 3.54 | 2.47 | 6.68 | 4.51 | -1.01 | -13.06 | -2.07 | 3.78 | 6.07 | 5.47 |

In addition, in addition to consider the size of the pitch matching values, we also compared the camera parameters' optimum value $P_{optj}$ and initial value P0j stability in the consecutive frames (see figure 11),this is very important for some subsequent applications such as the superposition of virtual objects, because in the process of superposition of virtual objects, the instability of camera parameter values will result in volatility of object position, thus affecting the visual effect of stacking. Figure 11 said the changes of camera focal length's (mm) optimal value (solid line) and the initial value (dashed line) in successive frames. It is clear that the optimal value of the camera focal length is more stable than the initial value, and it also proves the camera calibration algorithm presented in this paper can effectively reduce the wave phenomenon of camera parameters, more conducive to the subsequent application.

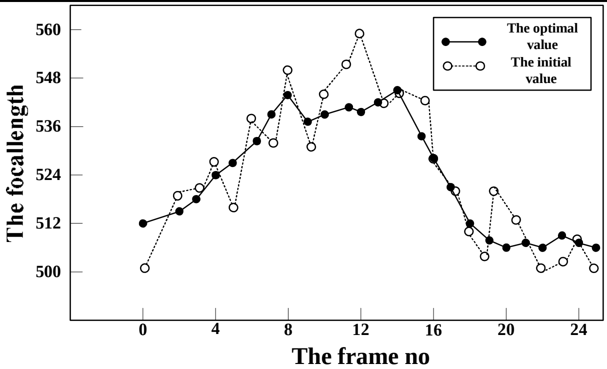


**Figure 9. Comparison Of Camera Parameter Values Stability In The Consecutive Frames**

## 6. Conclusion

Camera automatic calibration algorithm proposed in this paper. The algorithm is established on the basis of the two-dimensional model and a three-dimensional model of the court, first of all, feature points of the pitch plane is obtained by improved pitch line detection algorithm, and solve the camera isomorphic matrix, then using the isomorphic matrix to fix goal position, get two feature points of the goal plane, in the end, to get the optimal internal and external parameters of camera based on k-means clustering and Hough - like search method. The experimental results show that the improved pitch line detection algorithm can effectively improve the soccer video site area classification (> 96%), and the accuracy of pitch line detection (> 92%), and camera automatic calibration algorithm can not only get the camera isomorphic matrix, but also can get inside and outside parameters of the camera, so as to make the extraction of three-dimensional information in soccer video become possible. In addition, optimal value precision of camera parameter is higher compared to the initial value by using the method (field value increased by an average 4.32%), and it also more stable in the consecutive frames.

## References

[1] Kuo-Feng Huang, Shih-Jung Wu, Real-time-service-based Distributed Scheduling Scheme for IEEE 802.16j Networks. Journal of Networks, Vol 8, No 3 (2013), 513-517

[2] M. Moayedi, Y. K. Foo, and Y. C. Soh, "Optimal and suboptimal minimum-variance filtering in networked systems with mixed uncertainties of random sensor delays, packet dropouts and missing measurements," Int. J. Contr. Autom. Syst., vol. 8, pp. 1179-1188, 2010.

[3] C.Y. Lin, T. C. Wu, and J. J. Hwang, "Multi-proxy Signature Schemes for Partial Delegation with Cheater Identification," The Second Int. Workshop for Asia Public Key Infrastructure, Netherlands: IOS Press, 2002, pp.147-152.

[4] J. Albowitz, A. Chen, and L. Zhang. Recursive position estimation in sensor networks. In Proceedings of IEEE ICNP, pages 35–41, 2007.

[5] D. Moore, J. Leonard, D. Rus, S. Teller. "Robust distributed network localization with noisy range measurements." In Proceedings of the Second ACM Conference on Embedded Networked Sensor Systems (SenSys '04). Baltimore, MD. November 3-5, 2004. pp. 50–61. Winner of the Best Paper Award.

[6] J. Lee, T. Chung, S. Gundavelli, "A Comparative Signaling Cost Analysis of Hierarchical Mobile IPv6 and Proxy Mobile IPv6, " In Proc. of IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC) 2008, pages 1–6, September 2008.

[7] Kasman Suhairi, Ford Lumban Gaol, The Measurement of Optimization Performance of Managed Service Division with ITIL Framework using Statistical Process Control. Journal of Networks, Vol 8, No 3 (2013), 518-529