A Training Method for Robust Recognition of Color Uniforms of Soccer Robots

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Abstract

A training method for robust recognition of color uniforms of soccer robots is proposed in this paper. Surface illuminative conditions of playground in competition environment are tested by training before competition. Soccer robots with different single color uniforms move on the playground along the planned trajectory, then color information of the moving robot in different positions on the playground are sampled. Color Feature Vectors are established for different fields. By feedback of the vision system, features and parameters of soccer robot vision systems are verified for robust recognition. The proposed method is implemented in the experimental environment of MiroSot games of FIRA. Automatic training method is about two times faster than manual one. Performances of recognition for soccer robots color uniforms are improved to a great extent.

Keywords: Soccer Robots, Vision Systems, Training, Color Space Transformation.

1. Introduction

Robot soccer game is a new research and competition field all over the world recent years [1]. Many international competitions have been held by different organizations, such as FIRA and RoboCup. Hundreds of teams from universities and institutes have taken part in the games annually [2,3]. Although the competitions are far from the human-robot soccer game which is predicted for the future, competitions of soccer robots prompt research, development, education and popularization related to robotics to a great extent.

Vision systems of soccer robots are very important and complex in current competitions. Locations and motions of robots and the ball are gotten from sensor information processing and vision is the main sensor for soccer robot until now. Because the playgrounds and illuminative conditions may be very different in real competitions, many features and parameters must be modified by hand for practical environments. However, it takes a long time for a team to modify the uniforms color features before competitions. For example, in MiroSot games of FIRA, it takes about or more than one hour for the preparation. It becomes a bottleneck problem of the games.

Main problems of soccer robot vision system are robot self-localization and object detecting, tracking[4-6]. Self-localization is to determine its own position and direction in the playground by vision system. To detect, track and locate the positions and directions of other objects, including other robots and the ball are also very important for soccer robot vision systems.

Soccer robot vision systems are very different from general computer vision problems for two important factors: complexity of vision environment and real-time requirement of visual information processing. The complex environmental factors include illuminative variations, unsymmetrical lamps, different reflectivity, shadow influence, hid by objects, dynamic scene, moving target, opponent situations and so on. Soccer robot vision systems become very difficult for these factors. Many algorithms with high computational complexity can not be used directly for the above factors.

For the reason of real-time, vision features and background knowledge are adopted. Geometrical feature and color feature are two kinds of important visual information in current soccer robot systems [7]. For active local vision systems, geometrical features are often used to locate and recognize objects. In soccer robot systems with global vision systems, colorful marks are widely adopted. Different colors are set for robots, the ball and different fields of the playground to support localization and recognition of moving objects. Color features are employed to distinguish moving objects and the static environments, too. Color features of a robot may be changed to a great extent in different locations for the complex environmental factors.

To adapt complex environments, vision system parameters should be modified before competitions for robust recognition. In human soccer games, training before competition is very important. There are several minutes for athletes to learn conditions of the playground, such as temperature, illumination and quality of lawn for adjusting their bodies. Warm-up competitions are held if the conditions are available. Athletes can play better in familiar grounds than unfamiliar ones. For the same purpose, parameters of robot vision system are modified before competitions in many soccer robot games. The modification procedures mainly depend on manual operations, such as putting robots to different positions by hand, then determine color features and update parameters by researchers or programmers. These are very laborious work in many real situations, such as MiroSot robot soccer games. The time for uniforms color features modification is often longer than that of competition, in fact. Automatic modification methods are expected to solve this bottleneck problem. According to the analyses above, training based automatic color features modification method is proposed in this paper.

2. Training uniforms and competition uniforms

A popular method for dealing with parameters variations caused by illuminative conditions is to transform RGB color space to other ones, such as YUV or HSV color spaces [8]. The transformed color spaces have better performance for different illuminations when global illuminations are changed to some extent. However, it is not enough to deal with so many complex environmental factors, which include local variations of illuminations, different reflectivity and great variations of global illumination. Practical competitions show that performance of vision systems often depend on the positions of soccer robots. It is helpful to establish color features according to different positions all over the playground. Robots in different positions can be detected and recognized by local color features which can be established by robots moving on the playground before competitions. However, there is a antinomy in this procedure. To establish local color features, motion tracking of robots on the playground is needed. The procedure of robot tracking is based on color information especially for multi-color robot uniforms. To solve this problem, the idea of two kinds of uniforms is proposed in this paper. Two sets of uniforms are adopted for the phases of training and competition. Single color uniforms are for training and multiple colors uniforms for competition. Colors for single color uniforms are corresponding to every color used in multiple color uniforms, respectively. Multiple color ones are used to determine the locations and attitudes of soccer robots. If there are N kinds of colors used in a soccer robot team, number of single colors for training is N, too. Training is the process of robots with every kind of single uniforms moving on the playground to cover different illuminative fields. The training paths should be safety and not very long.

In soccer robot vision systems, upper bounds and lower bounds of three components of one kind of color are often used to recognize the color. If three components of a testing color vector are bigger than the three lower bounds and smaller than the three upper bounds of one defined color, respectively, the testing color is recognized to be the defined color. Here, a vector of these lower and upper bounds is defined as Color Feature Vector (CFV). If three components of a testing color t are y', u', v', and $y \leqslant y' \leqslant Y$, $u \leqslant u' \leqslant U$, $v \leqslant v' \leqslant V$, t is recognized to be color K. The Color Feature Vector of K is defined as $C^K(y, Y, u, U, v, V)$. Only one CFV is used for one kind of color in many soccer robot vision systems. For the complex illuminative conditions discussed above, it is difficult to determine the six components of CFV in many practical environments. If the distance between lower and upper bounds is too small, reasonable variations of color features can not be adapted. If the distance between lower and upper bounds is too big, many objects of other colors may be recognized by mistake. When different CFVs are defined for local fields on the playground, the components of CFV are easily determined for local illuminations. Different local CFVs can be computed by training method presented above, then automatic training method for robust recognition of soccer robot color uniforms is implemented.

3. Automatic training for uniforms color features modification

The automatic training method for uniforms color features modification is composed of two phases of training before competition. The first phase is for single color uniforms and the second one is for multi-color uniforms. Firstly, partition of soccer robot playground should be given. Two edges of the rectangular playground are divided into m and n parts, respectively. Then, the playground is divided into $m \times n$ fields equally. When a soccer robot is in a position of $P(x, y)$, a mapping of Q_0 is defined as:

Q_0: $P\ (x, y) \rightarrow (i, j)$

i : integer part of $(x / G\_LENGTH+1)$;

j : integer part of $(y / G\_WIDTH +1)$;

Here, *G_LENGTH* and *G_WIDTH* are values of two edges in length.

CFVs for color k corresponding to the field of (i, j) are presented by

$$C_{ij}^k = (y_{ij}^k, Y_{ij}^k, u_{ij}^k, U_{ij}^k, v_{ij}^k, V_{ij}^k),$$

k is the ID number of uniforms colors.

For k kinds of color, CFVs are computed from k times of training with single color uniforms for the divided fields.

When CFVs are established, a testing color can be recognized as followings: If F_0 and F_1 are CFVs of a testing color in the field of (i, j) in RGB space and in YUV space, respectively, which are noted as:

$F_0 = (r_I, R_I, g_I, G_I, b_I, B_I)$

$F_1 = (y_I, Y_I, u_I, U_I, v_I, V_I)$

Two mappings of Q_1 and Q_2 are defined for recognition.

Q_1: $F_0 \rightarrow F_1$

Q_2: $F_1 \rightarrow d$

Q_1 is the transformation from RGB color space to YUV color space.

$$d = \min_k (\max (|y_{ij}^k - y_I|, |Y_{ij}^k - Y_I|, |u_{ij}^k - u_I|, |U_{ij}^k - U_I|, |v_{ij}^k - v_I|, |V_{ij}^k - V_I|))$$

d is the recognized color index.

The second phase of training before competition is to drive robots to move in the $m \times n$ divided fields one by one in the vertical directions to the first training trajectory. Record recognition results of colors in each filed to find the districts where CFVs are not reliable. CFVs of this kind of districts must be computed by putting the robot manually. For the districts of complex illuminative variations, if one CFV can not express color feature variations, multiple CPFs can be established for better recognition performance for each divided filed. When a robot moves into this kind of district, its color feature vector should be compared with several CFVs for best matching.

4. Experiments

Experimental environment for this paper is the small size soccer robot system of MiroSot. There are three robots in each team with a global vision system. Each robot uniformed by team color, ID color and others. The division parameters of m and n for playground should be selected according to practical illuminative conditions in soccer robot competitions. From analyses and observations, m and n are selected as nine and six, respectively, in 40 m^2 lab with 8 lamps. Total power of these lamps is 320 kwh and distribution of the lamps is not symmetrical for the playground. It is to say that there are total 54 fields in the playground for training different CFVs. Motion trajectories of robots for training with single color uniforms is shown in Fig.1, and the partition of the whole playground is shown in Fig.2. For fast training purpose, some fields are not covered by the planned trajectories, in fact. CFVs for these uncovered fields can be computed from the fields nearby. Components of these 54 CFVs for blue color established automatically are shown in Table.1.

It costs about two minutes for each color before competition to establish corresponding CFVs. Eight to ten minutes are needed to finish the training for complex illuminative conditions. When illuminative conditions are not so bad, automatic modification is about two times faster than manual one. If illuminative conditions are very complex, i.e., illuminative conditions change almost everywhere, automatic modification is much faster than manual one. For the automatic method is suitable for local color features, there are robust recognition performances than manual vision parameter modifying in real competitions.

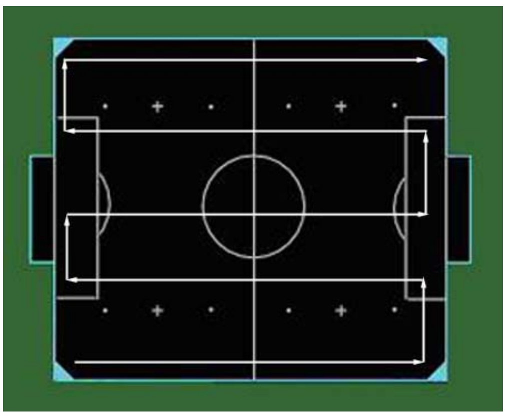

Fig.1 Trajectory of robots for training

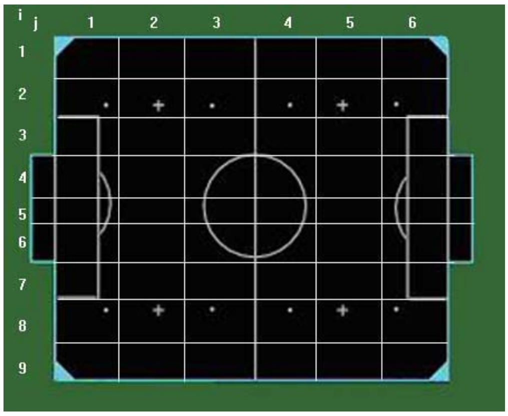

Fig.2 Partition of playground

Table 1. CFVs for fileds of playground. (Here, $k = 0, C_{ij}^0$ is CFV of blue color in uniforms)

C_{ij}^0	i= 1	i= 2	i= 3	i= 4	i= 5	i= 6	i= 7	i= 8	i= 9
j= 1	(21, 53, 166,204 90, 105)	(30, 58, 172,209, 85, 109)	(39, 64, 178,215, 81, 104)	(53, 78, 183,221, 71,100)	(68, 92, 189,228, 62, 96)	(73, 99, 190,227, 62, 92)	(79,107, 192,227, 62, 89)	(85,110, 191,224, 61, 89)	(92,113, 190,221, 61, 90)
j= 2	(26, 52 170,207, 89, 111)	(33, 60, 173,212, 84, 107)	(45, 72, 179,220, 78, 101)	(55, 81, 183,223, 71, 97)	(68, 95, 189,228, 65, 92)	(74,100, 190,227, 62, 91)	(82,108, 192,227, 60, 89)	(85,111, 190,225, 60, 89)	(90,115, 188,225, 60, 90)
j= 3	(28, 54, 174,207, 88, 110)	(37, 62, 176,213, 81, 106)	(50, 74, 182,221, 72, 102)	(58, 83, 185,224, 68, 97)	(70, 95, 190,229, 63, 93)	(75,100, 191,227, 62, 91)	(82,107, 193,224, 61, 89)	(85,111, 190,224, 60, 89)	(90,115, 189,224, 61, 91)
j= 4	(25, 52, 171,208, 89, 112)	(37, 62, 177,213, 81, 106)	(50, 73, 185,218, 73, 101)	(59, 83, 187,222, 67, 98)	(69, 95, 191,226, 62, 96)	(75,101, 191,226, 61, 92)	(83,109, 192,226, 60, 90)	(86,111, 189,225, 61, 89)	(91,115, 186,226, 63, 90)
j= 5	(23, 51, 170,205, 89, 114)	(35, 61, 176,212, 81, 107)	(47, 72, 182,218, 75, 102)	(58, 82, 185,222, 68, 99)	(68, 92, 188,226, 63, 98)	(75,100, 189,226, 61, 94)	(83,108, 190,226, 59, 94)	(86,111, 189,225, 60, 91)	(89,116, 188,224, 61, 90)
j= 6	(22, 51, 168,201, 91, 116)	(33, 60, 174,210, 83, 108)	(44, 68, 180,218, 77, 102)	(56, 80, 184,222, 69, 99)	(66, 90, 188,226, 63, 98)	(73, 98, 189,226, 61, 94)	(80,106, 191,228, 61, 91)	(83,109, 190,225, 61, 90)	(85,112, 192,222, 64, 90)

5. Conclusions

A new automatic training method for robust recognition of color uniforms of soccer robots is proposed in this paper. Two kinds of uniforms are adapted for training and competition phases. The playground is divided into many fields for their different illuminative conditions. For every color used in the uniforms, Color Feature Vectors are established for each divided field by training with single color uniforms. Colorful uniforms of soccer robots are recognized by different Color Feature Vectors according to the positions of robots. Experiments show that the automatic method for soccer robot uniforms color features is faster than traditional manual modification to a great extent for MiroSot soccer robot system. Performance of color recognition is better than global color features. Training based method for automatic uniforms color features modification seems to be effective and robust in soccer robot games.

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