



**19<sup>th</sup> Portuguese Conference on Pattern Recognition**

**Instituto Superior Técnico, Lisboa  
November 1<sup>st</sup>, 2013**



**TÉCNICO LISBOA**

PÓLO DO I.S.T

## Programme Overview

Time	Event	Location
09h30 – 10h15	Registration	Salão Nobre, Pavilhão Central
10h00 – 10h15	Welcome session	Salão Nobre, Pavilhão Central
10h15 – 11h00	Poster session 1	Salão Nobre, Pavilhão Central
10h45 – 11h15	Coffee break	Salão Nobre, Pavilhão Central
11h15 – 12:00	Poster session 2	Salão Nobre, Pavilhão Central
12h00 – 14h00	Lunch break	Restaurante Café Império
14h00 – 15h30	Invited Talk by Prof. Ana Fred	Salão Nobre, Pavilhão Central
15h30 – 15h45	Coffee break	Salão Nobre, Pavilhão Central
15h45 – 16h45	Poster session 3	Salão Nobre, Pavilhão Central
16h45 – 17h00	Best poster award and closing session	Salão Nobre, Pavilhão Central

## Invited Talk

### Physiological Computing: a PR Perspective

Prof. Ana L. N. Fred

Department of Electrical and Computer Engineering, Instituto Superior Técnico, Lisbon and Instituto de Telecomunicações (IT), Lisbon.

#### Abstract:

In a sentence, physiological computing (PC) deals with the study and development of interactive systems that sense and react to the human body. The most basic sort of PC simply records a signal, such as a heartbeat, and displays it on a screen. More complex systems work on a basis of a bio-cybernetic loop, the main purpose of this loop being to translate patterns of physiological activity into meaningful interaction. From emotional status to identity assessment, this talk addresses the exploration of electrophysiological data in the context of intelligent human-computer interaction. Electrocardiographic signals and electro-dermal responses, acquired in a pervasive manner at the hands level, are shown to be two complementary modalities in the emotion / identity dual assessment goal. The role of pattern recognition in the development of such systems is discussed. Finally, BITalino, a versatile and low cost biosignal acquisition system is presented as a promising tool for pervasive biosignal monitoring and physiological computation.

#### Speaker Biography:



Ana Fred received the M.S. and Ph.D. degrees in Electrical and Computer Engineering, in 1989 and 1994, respectively, both from Instituto Superior Técnico (IST), Technical University of Lisbon, Portugal. She is a Faculty Member of IST since 1986, where she is currently a professor with the Department of Electrical and Computer Engineering. She is a researcher at the Pattern and Image Analysis Group of the Instituto de Telecomunicações. Her main research areas are on pattern recognition, both structural and statistical approaches, with application to data mining, learning systems, behavioral biometrics, and biomedical applications. She has done pioneering work on clustering, namely on cluster ensemble approaches. Recent work on biosensors hardware (including BITalino – [www.bitalino.com](http://www.bitalino.com)) and ECG-based biometrics (Vitalidi project) have been object of several national and international awards, as well as wide dissemination on international media, constituting a success story of knowledge transfer from research to market. She has published over 160 papers in international refereed conferences, peer reviewed journals, and book chapters. She received the "Best paper award in Pattern Recognition and Basic Technologies", awarded by the IAPR, for the paper "Learning pairwise similarity for data clustering". She is the editor of over 40 books with the proceedings of international workshops that she organized or co-chaired, including S+SSPR 2004 (Lisbon), S+SSPR 2006 (Hong Kong), ICAART, KDIR and BIOSTEC and editor of 12 Springer books of selected papers.

## Poster Session 1 (10h15 to 11h00)

- 1 **Staffline Detection in Grayscale Domain**  
Ana Rebelo and Jaime Cardoso
- 2 **Cancer cell tracking using a Kalman filter**  
Tiago Esteves, Maria Oliveira and Pedro Quelhas
- 3 **Automatic images spectral unmixing of Leishmania infection macrophage cell culture for improved infection indexes accessing**  
Pedro Leal and Pedro Quelhas
- 5 **Mass detection on mammogram images: A first assessment of deep learning techniques**  
Inês Domingues and Jaime Cardoso
- 6 **An Automatic Method for Assessing Retinal Vessel Width Changes**  
Behdad Dashtbozorg, A. M. Mendonça and A. Campilho
- 14 **Learning from uneven video streams in a multi-camera scenario**  
Samaneh Khoshrou, Jaime S. Cardoso and Luís F. Teixeira
- 17 **Land and water segmentation of SAR images using textons**  
Francisco Seixas, Margarida Silveira and Sandra Heleno
- 20 **Quality measures for iris images in mobile applications**  
Ana Sequeira, Juliano Murari and Jaime S. Cardoso
- 33 **Interactive Air Traffic Control automation in oceanic airspace**  
Francisco Freitas, Rodrigo Ventura and Miguel Barão
- 38 **Large Scale Automatic Detection of Sub-km Craters Using Texture Information**  
Marlene Machado, Lourenço Bandeira, Jorge Salvador Marques and Pedro Pina
- 39 **An interactive application for the detection of impact craters in planetary images**  
Nuno Benavente, Lourenço Bandeira, Marlene Machado, José Saraiva, Jorge S. Marques and Pedro Pina
- 41 **3D Texture Analysis using Local Binary Patterns**  
Pedro M. Morgado, Margarida Silveira and Jorge S. Marques
- 44 **3D Breast Parametric Model for Surgery Planning - a Technical Review**  
Hooshiar Zolfagharnasab, Jaime S. Cardoso and Hélder P. Oliveira
- 45 **Total Variation Denoising using a Recursive and Spatially Adaptive Filter**  
Manya Afonso and João Sanches
- 46 **Selection of epilepsy-related EEG ICA components for simultaneous fMRI analysis**  
Rodolfo Abreu, Alberto Leal and Patrícia Figueiredo
- 53 **Clustering 802.11 Wireless Access Points Using Mixture of Hidden Markov Models**  
Anisa Allahdadi, Ricardo Morla and Jaime S. Cardoso
- 55 **Towards efficient path planning of a mobile robot in rough terrain**  
Diogo Amorim and Rodrigo Ventura
- 65 **Assessment of reliability of cerebrovascular reactivity measurements using breath-holding fMRI**  
Joana Pinto, Inês Sousa, Pedro Vilela and Patrícia Figueiredo
- 66 **A Critical Analysis about a Motion-based Approach to Extract Global Trajectories**  
Eduardo Marques, Jaime Cardoso and Ricardo Morla
- 67 **Ground-plane based indoor mobile robot localization using RGB-D sensor**  
Miguel Vaz and Rodrigo Ventura
- 68 **Parameter Estimation for a Quad Rotor Dynamics**  
Rui Oliveira and Rodrigo Ventura
- 70 **Exploring monogenic decomposition in carotid atherosclerotic plaque characterization**  
David Afonso and João Sanches
- 72 **Sialolith metrics computed from microtomography data**  
Pedro Nolasco, Antonio P. Alves de Matos, Paulo V. Coelho, Carla Coelho, António Máuricio, Manuel F.C. Pereira, Raúl C. Martins, João M.R. Sanches and Patrícia A. Carvalho
- 73 **Automatic gesture segmentation based on a predictive event segmentation approach**  
Sofija Spasojevic and Rodrigo Ventura

## Poster Session 2 (11h15 to 12h00)

- 4 **An assessment of the potential of distinct facial regions for biometric recognition**  
João C. Monteiro and Eduardo Mota
- 7 **Colour Invariant Features for Narrow-Band Imaging in Gastroenterological Examinations**  
Bruno Mendes, Ricardo Sousa, Carla Rosa and Miguel Coimbra
- 8 **Insights into primates genomic evolution using a compression distance**  
Diogo Pratas and Armando Pinho
- 11 **Impact of SVM Multiclass Decomposition Rules for Recognition of Cancer in Gastroenterology Images**  
Ricardo Sousa, Mario-Dinis Ribeiro, Pedro Pimentel-Nunes and Miguel Tavares Coimbra
- 13 **Forecasting the Usage of Home Appliances with Denoised Signal Patterns**  
Marisa Figueiredo, Bernardete Ribeiro and Ana Maria De Almeida
- 15 **Temporal subsampling impact on echocardiography based analysis of the left ventricle dynamics**  
Susana Brás, José Ribeiro, Augusto Silva and José L. Oliveira
- 19 **Nociception/Anti-Nociception Balance During Anesthesia**  
Ana Castro, Pedro Amorim and Miguel T. Coimbra

- 22 **Automatic Classification of Meals with Calorie Count**  
Pedro Rodrigues, Pedro Brandão and Miguel Coimbra
- 23 **Face Recognition with Neural Networks Classifier using SIFT and SURF Descriptors**  
João Sargo, João Caldas Pinto and João Costa Sousa
- 24 **Automatic Visual Inspection of Ceramic Plates based on SIFT and SURF Descriptors**  
João Caldas Pinto, Rafael Baeta, Mariana Pereira, Ricardo Laranjeira, João Sargo and Carlos Carreira
- 25 **Classificação da posição de estores de uma fachada de um edifício por análise de fotografias**  
José Mota and João Caldas Pinto
- 26 **Building and Evaluation of a Mosaic of Images using Aerial Photographs**  
João Costa, Tiago Coito, João Caldas Pinto and José Azinheira
- 34 **Development of a System for Automatic Detection of Air Embolism Using a Precordial Doppler**  
Ana Rita Costa Tedim, Pedro Amorim and Ana Castro
- 35 **Neural Network Model for Wind Power Forecasting**  
Paulo Salgado and Paulo Afonso
- 36 **Prediction of solar radiation using artificial neural networks**  
João Faceira and Paulo Salgado
- 47 **Detection, classification and localisation of football players and ball from Handycam videos**  
Tiago Vilas, J.M.F Rodrigues and Pedro Cardoso
- 50 **Region clustering using colour tuned keypoints**  
Miguel Farrajota, J.M.F. Rodrigues and J.M.H. Du Buf
- 51 **AAM Based Vocal Tract Segmentation from Real-Time MRI Image Sequences**  
Samuel Silva and António Teixeira
- 54 **Antifungal defense Psd1 increases membrane roughness and promotes apoptosis in Candida albicans**  
Patricia Silva, Sónia Gonçalves, Luciano Medeiros, Eleonora Kurtenbach and Nuno C. Santos
- 57 **Processing sports acquired information from a tracking system**  
António Belguinha, Pedro Cardoso and J. M. F. Rodrigues
- 59 **Caracterização de Patologias da Pele por Ultrassons**  
Sara Barbosa, Jose Silvestre Silva, Jaime B. Santos, Mario Santos and Alexandra Andre
- 62 **Object tracking with UAVs**  
João Palma, Pedro Mendes Jorge and Arnaldo Abrantes
- 63 **Análise da Textura de Padrões Pulmonares em Imagens TCAR Baseada na Lacunaridade**  
Verónica Vasconcelos, José Silvestre Silva, Luís Marques and João Barroso
- 69 **Using bioinformatics and biological approaches to uncover novel non-coding disease-related variants**  
Patricia Oliveira, Hugo Pinheiro, Sonia Sousa, Joana Carvalho, Karey Shumansky, David Huntsman and Carla Oliveira
- 71 **Voice Type Discovery**  
Mário Amado Alves, Ricardo Sousa, Sérgio Lopes, Vítor Almeida and Aníbal Ferreira

### Poster Session 3 (15h45 to 16h45)

- 9 **Comparative study of two movement identification strategies on BCI motor task**  
Mariana Branco, João Sanches and Rodrigo Ventura
- 10 **EEG time-frequency analysis for ERD/ERS temporal pattern characterization on brain computer interface motor task**  
Mariana Branco, Fernando Lopes Da Silva and João Sanches
- 12 **Heart Sound Analysis for Cardiac Pathology Identification: Detection of Systolic Murmurs**  
João Pedrosa, Ana Castro and Tiago T. V. Vinhoza
- 16 **Knowledge on Heart Condition of Children based on Demographic and Physiological Features**  
Pedro Ferreira, Tiago Vinhoza, Ana Castro, Felipe Mourato, Thiago Tavares, Sandra Mattos, Inês Dutra and Miguel Coimbra
- 18 **Mobile framework for recognition of musical characters**  
Rui Silva, Jaime Cardoso and Ana Rebelo
- 27 **SignalBIT Framework: Principles and Applications**  
Ana Priscila Alves, Hugo Silva, Andre Lourenco and Ana Fred
- 28 **Correction of Geometrical Distortions in Bands of Chromatography Images**  
Bruno Moreira, António Sousa, Ana Maria Mendonça and Aurélio Campilho
- 29 **A novel sparsity and clustering regularization**  
Xiangrong Zeng and Mário A. T. Figueiredo
- 30 **Exploiting Two-Dimensional Group Sparsity in 1-Bit Compressive Sensing**  
Xiangrong Zeng and Mário A. T. Figueiredo
- 31 **Exploring Heartbeat Sub-patterns for Person Identification**  
Carlos Carreiras, Hugo Silva, André Lourenço and Ana Fred
- 32 **Fluorescence Microscopy Based Classification of E-cadherin Missense Mutation Pathogenicity**  
Martina Fonseca, Joana Figueiredo, Raquel Seruca and João Sanches
- 40 **A mathematical model of the baroreflex physiology: model parameters measurement**  
Anastasiya Strembitska, Alexandre Domingues and João Sanches
- 42 **Automatic sleep parameter computation from Activity and Cardiovascular data**  
Alexandre Domingues, João Sanches and Teresa Paiva
- 43 **Supervised Feature Discretization with a Dynamic Bit-Allocation Strategy**  
Artur Ferreira and Mario Figueiredo
- 48 **Mosaicing the Interior of Tubular Structures**  
David Pereira, João Tomaz, Ricardo Ferreira and José Gaspar

- 49 **On Compression-Based Text Authorship Attribution**  
David Pereira Coutinho and Mário A. T. Figueiredo
- 52 **AFM based-force spectroscopy as a functional diagnostic nanotool for hematological diseases**  
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- 56 **Lens Auto-Classification using a Featureless Methodology**  
Ricardo Galego, Ricardo Ferreira, Alexandre Bernardino, Etienne Grossmann and José Gaspar
- 58 **Development of amyloid-based biomaterials for nanotechnology**  
Gabriela M. Guerra, Sónia Gonçalves, Nuno C. Santos and Ivo C. Martins
- 60 **Autonomous Learning of Tool Affordances**  
Afonso Gonçalves, Giovanni Saponaro, Lorenzo Jamone and Alexandre Bernardino
- 61 **Visual Tracking of Buses in a Parking Lot**  
Tiago Castanheira, Pedro Silva, Ricardo Ferreira, Alexandre Bernardino and José Gaspar
- 64 **Homing a Teleoperated Car using Monocular SLAM**  
Nuno Ribeiro, Ricardo Ferreira and José Gaspar
- 74 **Simultaneous Model Estimation, Denoising, and Noise Decomposition**  
Manyá Afonso and João Sanches
- 75 **Webcam Based Optical Tracker for free-hand US**  
João André Coelho, David Afonso and João Sanches

# Detection, classification and localisation of football players and ball from Handycam videos

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## Abstract

The current performance requirements in football make imperative the use of new technologies for game observation and analysis, providing detailed information about the team's actions. This paper presents in resume an algorithm to collect information from Handycam videos, namely, the football pitch, player and ball detection, player classification within the team, the tracking and localisation of players and ball, being the main contribution the determination of the exact localisation of players and ball in the pitch.

## 1 Introduction

Footdata [1] is a project to build a new multi-platform product for football. Footdata is based on information technologies, and integrates two fundamental components of the football world: i) a social network, with all the typical features and ii) the professional component, which features an acquisition and information system to meet all the football management needs. One of the modules is a framework that reports the exact positions of the players and ball in the football pitch.

There are several models available in the literature do detect and track players and ball, e.g. [2-4]. In this paper we present in resume an algorithm that can be applied to Handycam videos that allows: (a) the detection of the football pitch, (b) the detection of players and ball, (c) the assignment of players to their teams, (d) the tracking of players and ball and (e) their localisation (in meters) in the pitch. The main contribution is the exact localisation of players and ball from Handycam videos.

## 2 Football pitch detection

Let  $I_{RGB}(x, y, t)$  and  $I_{HSV}(x, y, t)$  represent a frame with dimensions  $M \times N$ , acquired with an Handycam (FullHD or HD) situated for instance in the stands, where  $M$  is the width and  $N$  is the height of the image,  $t$  is the instance when the frame was acquired and RGB and HSV the colour spaces.

The first step was the football pitch detection, which consists in (a) the segmentation of the green (grass) regions for each frame using  $I_{HSV}$ . This was done by a semi-automatic process, where selected pitch patches were used to compute the HSV thresholds intervals. For the pitch shown in Fig. 1, it was used the following thresholds levels:  $H \in [0\%, 50\%]$ ,  $S \in [12\%, 100\%]$  and  $V \in [27\%, 100\%]$ , which returns a binary image  $I_c$ , with  $I_c = 1$  corresponds to the green pixels.

The next step has the purpose to eliminate the areas outside the pitch. This was carried out in several stages: First (b), in  $I_c$  was chosen a central point of the image as the seed (in most frames, the central area corresponds to the pitch, the exceptions are zooms to players or to the stands). The central point of  $I_c$  has to have a green colour (see above), and recursively from this initial point, using  $3 \times 3$  neighbourhood, all central pixels that have all neighbours green are kept,  $I'_c = 1$ , the remaining are put to 0 ( $I'_c = 0$ ).

Over the last image, but only in areas where exists pitch, i.e.  $I'_c = 1$ , was applied (c) the Canny edge ( $I_{ce}$ ) detection [5] on  $I_{RGB}$ . After this, (d) the Hough transform [5] was applied over the  $I_{ce}$ , in order to detect the lines ( $I_{Hl}$ ) that limits the pitch. Finally (e), using  $I_{Hl}$  the most horizontal and vertical lines (left, right, up and down) are computed. Those lines correspond to the limits of the pitch, and everything outside these limits (lines) was removed. The final results consist only in the segmentation of the pitch (with some black blobs inside),  $I_{fj}$ .

## 3 Players and ball detection

For the player detection it was used the  $I_{fj}$  image. In this image, most of the work for the players' detection was already done, once the pitch area was delimited, the black blobs inside this area are considered players. Nevertheless, 3 major problems arise: (a) blobs that are not players, e.g., areas with short grass, (b) players that almost disappear due to low image definition, or been partially equipped in "green," and (c) the overlap of various players.

To solve these situations and to obtain only the contours of the players, morphological filters were applied, i.e., first it was applied the dilation filter (D) followed by an erosion filter (E) and finally a  $9 \times 9$  medium filter (M). The result was an image where the players were better defined and specific noise regions were removed,  $I_{ff}(x, y, t) = M(E(D(I_{fj}(x, y, t))))$ .

After this, some player still have more than 1 region (usually due to the equipment that they use), a vertical mask was applied to connect those regions. The next step was the confirmation that each blob corresponding to a possible player (in  $I_{ff}$ ) has at least one edge contour correspondence in  $I_{ce}$ . Finally, it was checked if the final blob region of each player (in  $I_{ff}$ ) doesn't had more than 10% of green pixels (using  $I_H$ ). The final image after this validation was called  $I_f$ .

To differentiate between players and the ball, all pixels with the "white colour" (in  $I_V$ ) inside  $I_f$  were detected. Those pixels can represent lines belonging to the pitch, the ball, and if it was the case, teams that had white predominantly equipment's. For this purpose an threshold with  $V \in [75\%, 100\%]$  was applied to  $I_V$ , returning a binary image,  $I_b$ , with all the white regions inside the pitch ( $I_b = 1$ ).

Combining the previous information with the size and shape of the blobs, the blobs that corresponds to the balls can be classified. The first step, consists in detect if the blob as more or less circular or oval shape, which was different from the player blobs that had (usually) a more "vertical-rectangular" shape. This way most of the players blobs were discarded. The second step, was to remove the areas corresponding to the pitch marks, eliminating the areas that correspond to the lines detected by the Hough transform in  $I_{Hl}$ . The final step consists in removing areas which exceed  $M \times N/k$  pixels ( $k = 100000$ , this value was empirically determined).

Figure 1 top shows the player delimited by rectangles, and the ball by a circle. Having the ball classified, it was necessary to classify the blobs as players from team A or B, referee or keepers.

## 4 Assignment of the players to their teams

The players' classification to a team was based on the colour of the equipment. It was assumed that the video starts at the beginning of the game (with the ball in the middle of the pitch), if that doesn't happen, then a semi-automatic process selects the most probable 7 player from each team. Considering that the video starts at the beginning of the game, then a group of 7 players on the right, and 7 players on the left of the middle pitch line (represents each team) was automatically selected.

For each team, in separate, and using the blobs regions defined as players in  $I_f$ , the average of Hue using the  $I_H$  image was computed. Having the two average Hues values from team A and B, the middle threshold was computed to separate the teams.

The keepers were relatively easier to classify, once they correspond to the first blob that appear in the right and in the left of the image with significant difference from the two average Hues values computed for the teams (it is important to remember that the keepers use a different equipment from the team). The major problem was the referee, they usually use black, but that is not mandatory. If the video starts from the beginning of the game, the referee usually was very close to the middle line, in those cases it was a blob with a Hue different from the players near the middle line. If the video starts from a different position then a semi-automatic process is applied, i.e., the referee was considered the blob with the most different Hue (comparing with the Hues from the teams), and if by mistake was assigned as a team player, then a web base tool (out of the focus of this paper) allows the user to manually change the player classified as referee and vice-versa.

All those Hues once detected were memorised by the system and adapted dynamically in function of the video conditions (light, etc.).

The numbers assigned to the players were in function of the position they occupy in the pitch, and those number were associated to the real player number and name in function of the position posted in the game

sheet (e.g. right defender). If necessary, this can be corrected later using the web base tool mentioned above.

Finally, obviously there is also the validation that it was impossible to assign more than 1 referee, 2 keepers and 10 players per team. Figure 1 shows the result of player's assignment to a team and referee.

## 5 Players position in the pitch

In order to make a correct analysis of a soccer game, it is important to have knowledge of the correct position of the player in the pitch. To calculate that position, a perspective transformation from the frame to a normalized pitch was needed, see Fig. 1 bottom.

For this purpose a set of references in the pitch was computed. Those were extracted from the lines detected in the Hough transform,  $I_{Hl}$ , and the pitch delimitations in  $I_f$ . For the position of the player, it was considered the middle point in the bottom line that limits the player, which corresponds in most cases to the coordinates of the players' feet, see Fig. 1 top and the respective projection in the bottom.

Since the pitches have different sizes (weight and height), it was important to compute the size of a pixel (in our case, in meters). For this computation, in the first frames (as soon as possible) the lines of the centre circle, penalty area or goal area has to be automatically detected to calibrate the value of a pixel in meters (the dimensions of this areas are the same for all pitches). An automatic process was then applied every time there was a small zoom, or a zoom to a player.

## 6 Tracking of players and ball

The players and ball tracking avoids doing all the steps mentioned in Section 3 and 4 for all frames. The implemented tracking process, though simple, was effective except in situation of great confluence of player, such as corner, or discussions with the referee. Nevertheless the main focus of this framework is not to follow the players' everywhere, but to compute the distances between players and players to the ball.

The tracking was divided into five steps for each frame  $t$ : (a) the distance (in meters) was calculated for each player, between the previous frame  $t-1$  to the current frame  $t$ . Making the correspondence to the player that was closer. If there were two or more players at the same distance (non-overlapping) the player was assigned to the one that in the previous frame has the nearest Hue.

(b) If there was no player in frame  $t$  near to the position occupied in frame  $t-1$  (few meters apart), then it was checked in frame  $t$  with increasing circle diameters the player with the same colour as the player in frame  $t-1$ . It was used the trajectory of the previous 5 frames to limit within the circle the "sectors" of this search.

(c) For situations in which a particular player was not tracked/located during a long frameset (2 seconds), this player was then searched from the position where he was lost, with increasing circle diameters, for blobs that were not tracked and has the same Hue. The first blob found with this characteristic was assign as the lost player.

(d) It is important to note that in the majority of the frames, there was the possibility that some players were not detected because they are not in the field of view of the camera, e.g., at the beginning of the game, due to fact that the camera doesn't capture the entire pitch. Every player that appear at the left or right (top or bottom, depending if there has a zoom applied) was considered as new player to track, except if a player was "lost" on a previous frame in a nearby position.

(e) Finally, it was also necessary to verify the existence of collisions. If after the above procedure (a-c), a player was not found, it was assumed that there was a collision (junction of two or more players). For those situations, all blobs that correspond to players, that were in positions very close and were lost, were associated with a single blob, assigning to 2 or more players that were tracked in  $t-1$  in a nearby position. When the collision ends (separation of two or more players) the Hue of each blob were checked and players reassigned.

After a collision there was always the possibility of players being wrongly identified, for instance when the collision was between two players of the same team. To solve this, the already mentioned web base tool can be used to correct the numbers of the players or even the team. The process of tracking the ball and referee is similar to the players.

## 7 Discussion

This paper presents a proposal for detection and tracking of football players and ball with the objective of computing distances between players and players to the ball. For now, it was an initial framework that still needs improvements. Nevertheless some tests were carried out showing promising results.

Five different games, with approximately 15 minutes of each video (4 FULL HD and 1 HD) were analysed. The results obtained were: (a) the detection of players with 92.3% of correctness, (b) 2.0% of assignments of detected players to the wrong team and (c) 0.4% of false positives, i.e., detection of players, in locations where there weren't. To compute this numbers all the situations where a cluster of players occurs were removed, such as corners and discussions with the referee, etc.

It is also important to mention, that in cases when a player is expelled or when there is a substitution it is necessary to pass this information using the web tool.

All the steps presented can be subject to numerous improvements, one essential was the code optimization in terms of time consuming. Despite the code has already some parallelisation, an entire or partial implementation using the GPU's is expected to improve times.

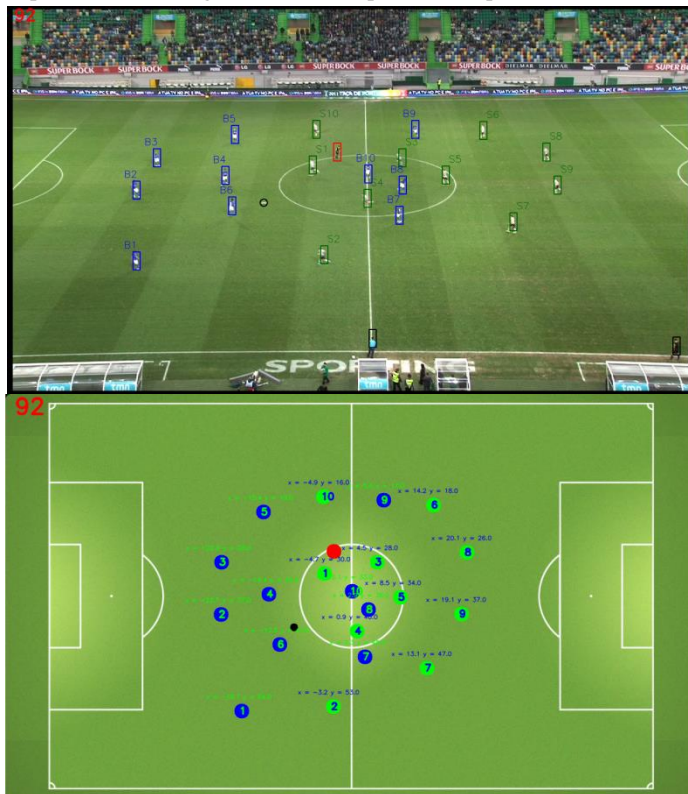


Figure 1: Top, the result of the ball, referee and player's detection and assignment to team. Bottom, the representation of the players position considering the origin of coordinates the interception between the middle line and the top lateral line.

## Acknowledgments

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