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Departamento de Engenharia Electrotécnica e de Computadores

## **The Design of the 5dpo Small Size League Team**

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### **The Robocup Challenge as a Standard Benchmark**



- ◆ *Multiple Robots*
- ◆ *Robot, Ball and Adversary Localization (Vision)*
- ◆ *Robot Control*
- ◆ *Communication*
- ◆ *Fast, Precision*
- ◆ *Robustness*
- ◆ *Cooperative Action*

## The Problem



- ◆ *An environment where:*
  - *Multiple robots that can be controlled by the system.*
  - *Passive elements:*
    - *The ball*
    - *Obstacles*
  - *Active and non cooperative elements:*
    - *Robots belonging to the other team*
    - *People*
    - *Other Vehicles*

## Robocup Rules (F-180 League) The Robot Constraints

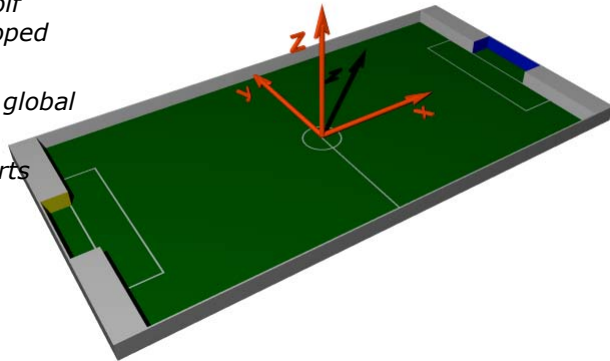


- ◆ *Max five per team*
- ◆ *The height < 15 cm.*
- ◆ *Must fit inside a 18 cm circle*
- ◆ *Black and white top with a an official color (blue or yellow) marker.*
- ◆ *Contact between robots penalized.*
- ◆ *The robots can communicate between them and a an external coach but human intervention is not allowed.*

## Robocup Rules (F-180 League) The Environment



- ◆ The field has 3m by 2m and the goal is 60 cm wide.
- ◆ Played with an orange Golf ball. The field has 45° sloped walls with 5cm height.
- ◆ It is allowed the use of a global vision system.
- ◆ A Game is split in two parts with 10 minutes each.



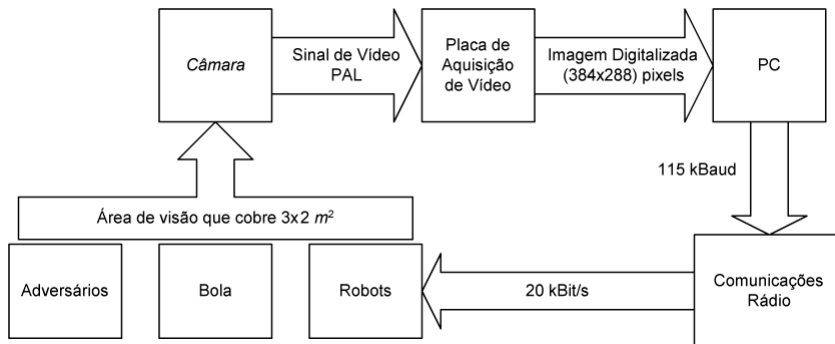
## The Sensorial Problem Robocup (F-180 League)



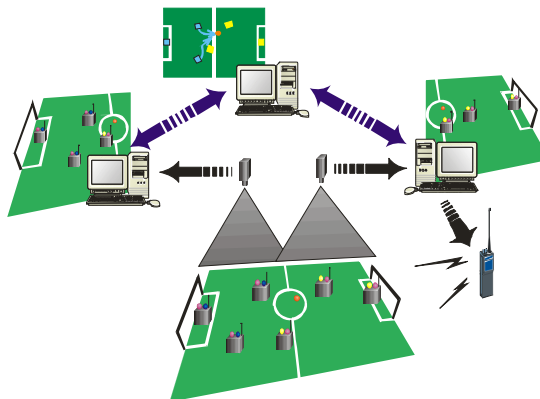
- ◆ Problems:
  - Real Time
  - High resolution video.
  - Too much data to be processed.
  - Not all the variables can be directly measured



## Vision System and Control Loop



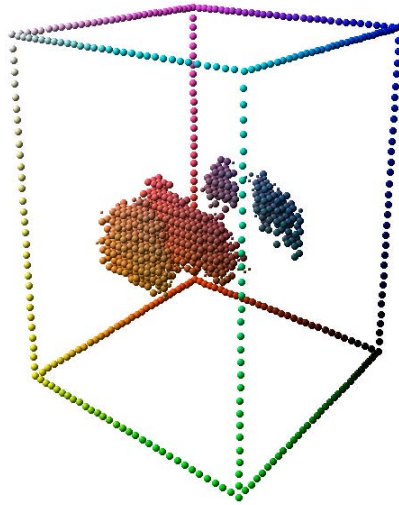
## Actual Global Block Diagram



## Image Processing System Color Histogram



- ◆ *RGB Color Space*
- ◆ *Histogram for each marker.*
- ◆ *Can be actualized:*
  - *Adding*
  - *Subtracting*
- ◆ *We can measure the overlap and the quality of the segmentation.*



## Robots Extra Markers Identification and Validation



- ◆ *Black and white Markers*
- ◆ *Numbering the robot*



## A Ball Model



◆ **State Vector:** 
$$X_b^T = [x_b \ y_b \ v_{bx} \ v_{by}]$$

◆ **Dynamics:**

$$\begin{aligned}\dot{x}_b &= v_{bx} \\ \dot{y}_b &= v_{by} \\ \dot{v}_{bx} &= -\lambda_b v_{bx} \\ \dot{v}_{by} &= -\lambda_b v_{by}\end{aligned}$$

◆ **Not considered:**

- The collisions between the ball and other robots.
- Ball rotation.
- Field bumps.

## A Robot Model



◆ **State Vector:**

$$X_r^T = [x_r \ y_r \ \theta_r \ v_{rt} \ v_{rm} \ \omega_r]$$

◆ **Dynamics:**

$$\dot{x}_r = v_{rt} \cos \theta_r - v_{rm} \sin \theta_r$$

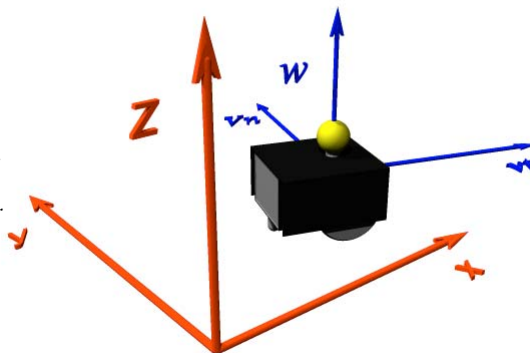
$$\dot{y}_r = v_{rt} \sin \theta_r + v_{rm} \cos \theta_r$$

$$\dot{\theta}_r = \omega_r$$

$$\dot{v}_{rt} = \alpha(v_{ref} - v_{rt})$$

$$\dot{v}_{rm} = 0$$

$$\dot{\omega}_r = \gamma(\omega_{ref} - \omega_r)$$

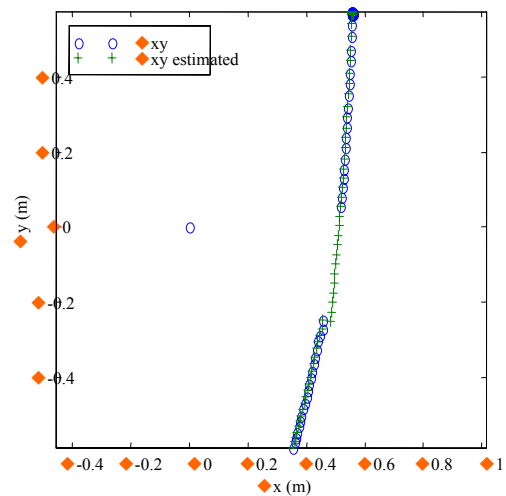
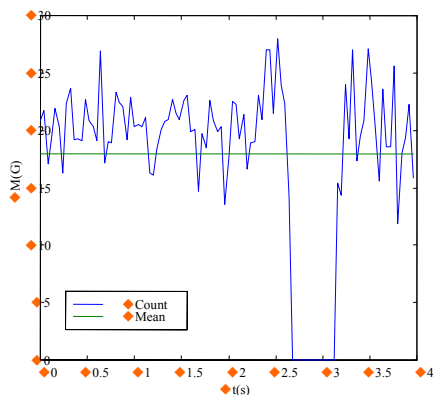


## Tools: Kalman Filter

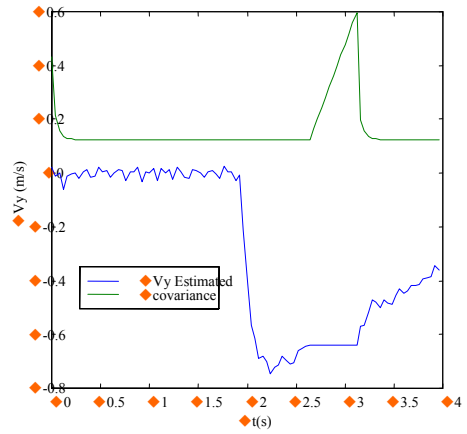
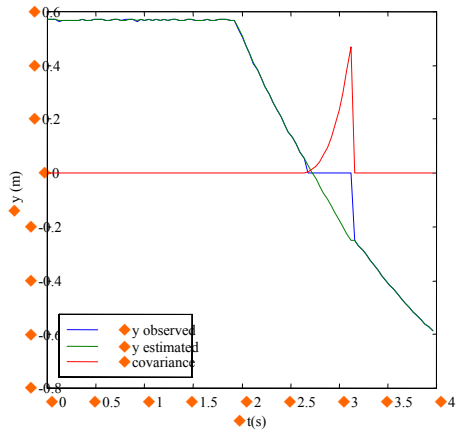


- ◆ **Ball :**
  - Kalman Filter
  - Dynamic model and observations in discrete time.
- ◆ **Robots State Estimate:**
  - Extended Kalman Filter
  - Continuous Time Dynamic model and discrete time observations.

## Some data: A Moving Ball I



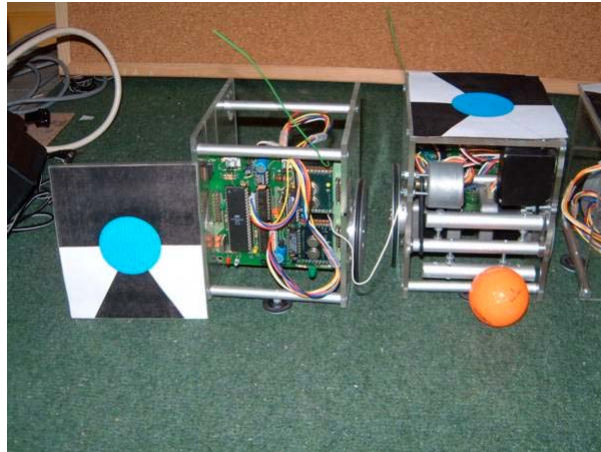
## Some Data: A Moving Ball II



## The Robots and the Humans



## More Robots



## More Robots II










## Human Team and Robot Teams



## Results



 Euro RoboCup	 World RoboCup	5dpo	5dpo-2000	Science
<b>Paris, France, '98</b>		<b>3<sup>rd</sup></b>		1 Conf Artcl
<b>Stockholm, Sweden, '99</b>		✓	✓	3 Conf Artcl
<b>Amsterdam, Netherlands, 2000</b>		✓	✓	1 Conf Artcl + 1 Book Artcl
<b>Padderborne, Germany, 2001</b>		<b>1<sup>st</sup></b>	<b>3<sup>rd</sup></b>	1 Conf Artcl + 1* Book Artcl
<b>Seattle, USA, 2001</b>		<b>6<sup>th</sup></b>		

## References



- ◆ *[Http://www.fe.up.pt/~robosoc](http://www.fe.up.pt/~robosoc)*
- ◆ *Team Descriptions*
- ◆ *Robocup Publications*