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DAFTAR ISI

Pararel 3

Pararel 4

A Robust Ball Tracking for Humanoid Soccer Robot using Kalman Filter

WIDODO BUDIHARTO, VISKA NOVIANTRI, BAYU KANIGORO

***Abstract* — Modern Humanoid Soccer Robots in uncontrolled environments need to be based on vision and versatile. This paper propose a high speed embedded system and ball tracking method using Kalman Filter for Humanoid Soccer, because the ability to accurately track a ball is one of the important features for processing high-definition image. A color-based object detection is used for detecting a ball while PID controller is used for controlling pan tilt camera system. The proposed method is able to determine and estimate the position of a ball and kick the ball correctly with the success percentage greater than 90%. We evaluate and present the performance of the system.**

Index Terms—Kalman filter, humanoid soccer, ball tracking, pan tilt camera

I. INTRODUCTION

The humanoid soccer robots are popular nowadays for the entertainment or contests such as RoboCup Humanoid League. The important features of humanoid soccer, such as accuracy, robustness, efficient determination and tracking of ball size and location; has proven to be a challenging subset of this task and the focus of much research. With the evolution of robotics hardware and subsequent advances in processor performance in recent years, the temporal and spatial complexity of feature extraction algorithms to solve this task has grown accordingly [1].

In the case of Humanoid soccer, vision systems are one of the main sources for environment interpretation. Many problems have to be solved before having a fully featured soccer player. First of all, the robot has to get information from the environment, mainly using the camera. It must detect the ball, goals, lines and the other robots. Having this information, the robot has to self-localize and decide the next action: move, kick, search another object, etc. The robot must perform all these tasks very fast in order to be reactive enough to be competitive in a soccer match. It makes no sense within this environment to have a good localization method if that takes several seconds to compute the robot position or to decide the next movement in few seconds based on the old perceptions [7]. At the same time many other topics like human-machine interaction, robot cooperation and mission and behavior control give humanoid robot soccer a higher level of complexity like no any other robots [2]. So the high speed processor with efficient algorithms is needed for this issue.

One of the performance factors of a humanoid soccer is that it is highly dependent on its tracking ball and motion ability. The vision module collects information that will be the input for the reasoning module that involves the development of behavior control. Complexity of humanoid soccer makes necessary playing with the development of complex behaviors, for example situations of coordination or differ rent role assignment during the match. There are many types of behavior control, each with advantages and disadvantages: reactive control is the simplest way to make the robot play, but do not permit more elaborated strategies as explained for example in [3]. On the other side, behavior- based control are more complex but more difficult to implement, and enables in general the possibility high-level behavior control, useful for showing very good performances [4].

Ball tracking is the estimation of the state of a moving ball. Estimating as accurately as possible of the state of a dynamic system has been a very important topic. Intelligent tracking algorithm for state estimation using Kalman filter has been successfully developed [11], and we want to implement that method for ball tracking for humanoid soccer robot.

In this paper we propose a low cost humanoid soccer robot compared with the well known humanoid robots for education such as DarwIn-OP and NAO and test its ability for image processing to track a ball using color-based object detection method, the robot will kick the ball after getting the nearest position between the robot and the ball. The Kalman filter is used here to estimate state variable of a ball that is excited by random disturbances and measurement noise. It has good results in practice due to optimality and structure and convenient form for online real time processing.

II. PROPOSED SYSTEM

A. Architecture of the System

Humanoid soccer robots design based on the vision involves the need to obtain a mechanical structure with a human appearance, in order to operate into a human real world. Another important feature for modern humanoid robot is the ability to process tasks especially for computer vision. We propose an embedded system that able to handle high speed image processing, so we use main controller based on the ARM7 Processor. Webcam and servo controller are used to track a ball, and the output of the main controller will communicate with the CM510 controller to control the actuators and sensors of the robot as shown in fig. 1.

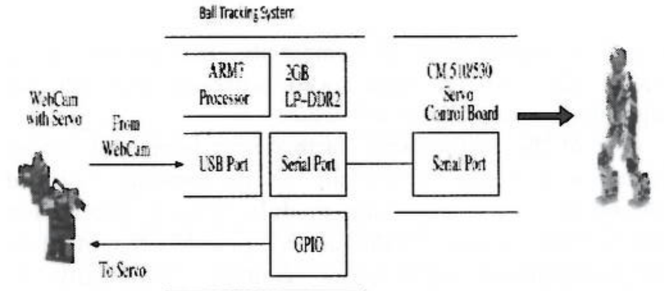


Fig. 1. Architecture of Ball Tracking for Humanoid Soccer

The main controller uses Odroid X2 that consist of Cortex-A9 1.7 GHz and sufficient memory and ports to be connected with other devices as shown in fig. 2

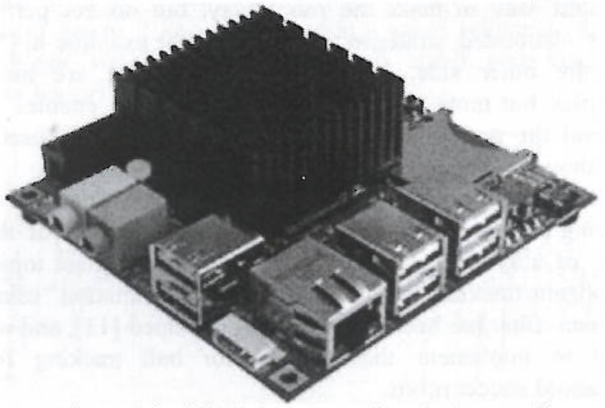


Fig. 2. Odroid X2 for processing the images from webcam[5]

The specification of the Odroid X2:

- Exynos4412 Quad-core ARM Cortex-A9 1.7GHz
- 2GByte Memory
- 6 x High speed USB2.0 Host port
- 10/100Mbps Ethernet with RJ-45 LAN Jack
- Ubuntu OS

The architecture of Odroid shown in fig. 3 is very powerful to be used for the next generation of humanoid robot soccer, comparing with DarwIn-OP or NAO.

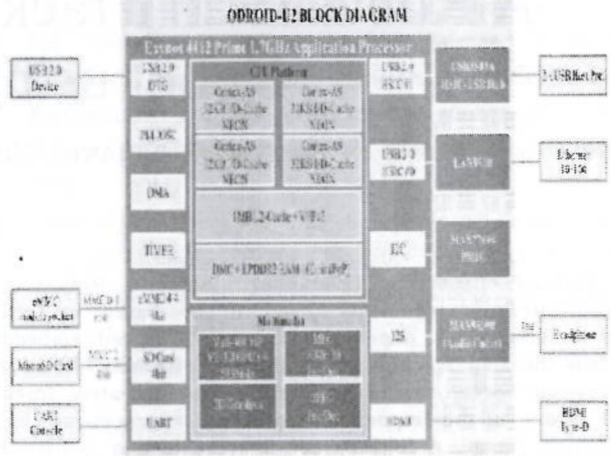


Fig.3. The architecture of the Odroid X2

B. Ball Tracking and Kick the Ball Algorithm

Computer vision is one of the most challenging applications in sensor systems since the signal is complex from spatial and logical point of view. An active camera tracking system for humanoid robot soccer tracks an object of interest (ball) automatically with a pan-tilt camera. We use OpenCV for converting to HSV (Hue Saturation-Value), extract Hue & Saturation and create a mask matching only the selected range of hue value a[6][8].

To have a good estimation, the object must be in the centre of the image, i.e. it must be tracked. Once there, the distance and orientation are calculated, according to the neck's origin position, the current neck's servomotors position and the position of the camera in respect to the origin resulting of the design [7]. Region growing algorithms are also used to locate the ball color blobs that have been identified by region growing and are useful and robust source for further image processing, as demonstrated by [9]. The ball will be tracked based on the color and webcam will track to adjust the position of the ball to the center of the screen based on the Algorithm 1.

Algorithm 1: Ball Tracking and Kick the ball

```
Get input image from the camera
Convert to HSV (Hue-Saturation-Value)
Extract Hue & Saturation
Create a mask matching only for the selected range of hue
Create a mask matching only for the selected saturation levels.
Find the position (moment) of the selected regions.
  If ball detected then
  Object tracking using Kalman Filter
  centering the position of the ball
  Move robot to the ball
  If ball at the nearest position with the robot then
  Kick the ball
  endif
    endif
```

C. *Kalman filter for Ball Tracking*

The Kalman filter is a recursive estimator. This means that only the estimated state from the previous time step and the current measurement are needed to compute the estimate for the current state.

If all noise is Gaussian, the Kalman filter minimizes the mean square error of the estimated parameters. Knowledge of the state allows theoretically prediction of the future (and prior) dynamics and outputs of the deterministic system in the absence of noise [10].

The Kalman Filter is a state estimator which produces an optimal estimate in the sense that the mean value of the sum (actually of any linear combination) of the estimation errors gets a minimal value. In other words, The Kalman Filter gives the following sum of squared errors:

$$E[e_{x1}^2(k) + \cdots e_{xn}^2(k)] \qquad (1)$$

a minimal value. Here

$$e_x\ (k) = e_{est}(x) - x(k) \qquad (2)$$

Is the estimation error vector.

The Kalman Filter presented below assumes that the system model consists of this discrete-time (possibly nonlinear) state space model :

$$x(k+1) = f[x(k), u(k)] + Gw(k) \qquad (3)$$

Where x is the state vector of n state variable, u is the inpur vector of m input variables, f is the system vector function, w is random noise vector, G is the process noise gain matrix relating the process noise to the state variables. It is common to assume that q = n, making G square. In addition it is common to set the elements of G equal to one.

The (possibly nonlinear) measurement model:

$$y(k) = g[x(k), u(k)] + Hw(k) + v(k) \qquad (4)$$

where y is the measurement vector of r measurement variables, g is the measurement vector function, H is a gain matrix relating the disturbances directly to the measurements. It is however common to assume that H is a zero matrix of dimension (r × q):

$$\begin{bmatrix} 0 & 0 & \dots & 0 \\ 0 & 0 & & \vdots \\ 0 & 0 & \dots & H_{rq} \end{bmatrix} \qquad (5)$$

and v is a random (white) measurement noise vector.

Calculation of Kalman Filter State Estimate

1. Calculate initial state estimate x_p

$$x_p(0) = x_{init} \qquad (6)$$

where x_{init} is the initial guess of the state.

2. Calculate the predicted measurement estimate y_p from the predicted state estimate :

$$y_p(k) = g[x_p(k)] \qquad (7)$$

3. Calculate innovation variable as the difference between the measurement y(k) and the predicted measurement$y_p(k)$:

$$e(k) = y(k) - y_p(k) \qquad (8)$$

4. Calculate corrected state estimate Xc:

$$x_c(k) - x_p(k) + Ke(k) \qquad (9)$$

where K is the Kalman Filter gain

5. Calculate the predicted state estimate for the next time step, $x_p(k+1)$:

$$x_p(k+1) = f[x_c(k), u(k)] \qquad (10)$$

Calculation of Kalman filter state estimation can be represented by the block diagram show in Figure 4.

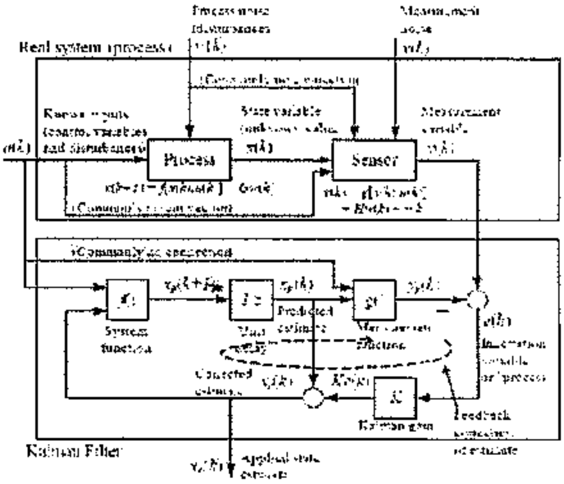


Fig. 4. The Kalman Filter algorithm[11]

The estimated position(x,y) from Kalman filter is used as an input to PID controller. We use a PID controller to calculate an error value as the difference between a measured (input) and a desired set point. The controller attempts to minimize the error by adjusting (an Output). The mode of PID Controller shown in fig. 5 :

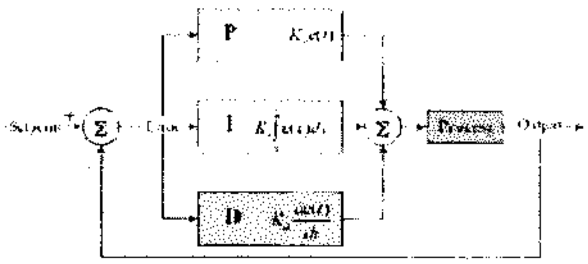


Fig.5. General PID Controller [8]

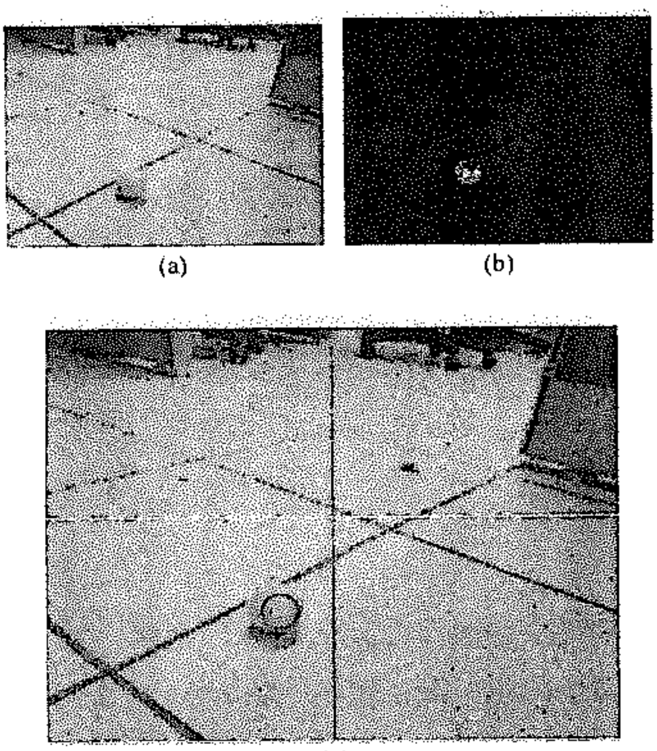
The output of a PID controller, equal to the control input to the system, in the time-domain is as follows :

$$u(t) = K_p e(t) + K_i \int e(t)dt + K_d \frac{de}{dt} \qquad (11)$$

III. EXPERIMENTAL RESULT

The approach proposed in this paper was implemented and tested on a humanoid Robot named Humanoid Robot Soccer Ver 2.0 based on Bioloid Premium Robot. The Firmware of the robot to control the servos is modified from the original one named Robotis Firmware due to the limitation for sending a motion command by serial interface based on Peter Lanius works published in google code [12]. This firmware instead using RoboTask to program the robot controlling its movement but it directly program the AVR Microcontroller inside the CM-510 controller using C language. Using this alternative can reduce the size of the program from originally 170KB to 70KB in the memory. By this firmware, the robot can be connected directly to Ball Tracking System using USB Serial Interface to command its motion. Based of this framework, it open an opportunity to built Real Time Operating System for the robot.

Detecting several colors means creating several binary image maps, as shown in Fig. 6. The tracking system is able to track a ball with the maximum speed of 6cm/s.



(a) (b) (c)

Fig. 6. The original image(a), the mask (a) and ball detected and tracked using Kalman Filters in the green circle(b).

When a ball is in front of the robot and has been detected, the robot tries to track the ball, and if the ball at the nearest position with the robot, robot will kick it as shown in fig. 7

Fig. 7. The robot tracks and kicks a ball when at the correct position.

The result of estimation of position of ball using Kalman filter is shown in fig. 8 :

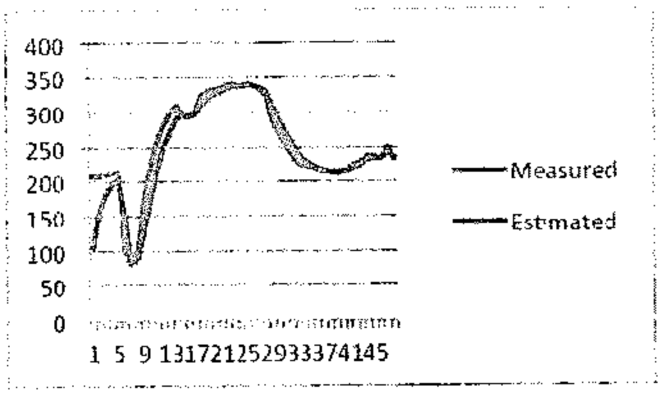


Fig. 8. True measurement versus estimation using Kalman Filter

IV. CONCLUSION

In this paper, we introduced the hardware architecture implemented on our humanoid robot soccer. They are based on Odroid X2 that has powerful ability for high speed image processing. We propose the simple way to track a ball based on the color, and kick the ball after getting the nearest position of the robot from the ball. The Kalman filter is a robust method to track a ball in the real situation. For future work, we want to use shape-based object tracking and defining intelligent behavior for the humanoid robot soccer.

V. REFERENCES

[1] I. Ha, Y. Tamura, Y., H. Asama: Development of open humanoid platform DARwIn-OP. In: SICE Annual Conference (SICE), 2011 Proceedings of. pp. 2178–2181. IEEE, 2011

[2] F. Blanes, Embedded Distributed Vision System for Humanoid Soccer Robot, Journal of Physical Agents, vol. 5(1), 2011
[3] S. Behnke and R. Rojas. A hierarchy of reactive behaviors handles complexity. In Balancing Reactivity and Social Deliberation in Multi Agent Systems, volume 2103 of LNAI, pages 125-136. Springer, 2001.
[4] S. Behnke. Playing soccer with humanoid robots, KI - Zeitschrift Kuenstliche Intelligenz, vol. 3, pp. 51-56, 2006
[5] www.hardkernel.com
[6] R. Szeliski : Computer vision: algorithms and applicat ions. Springer- Verlag New York Inc, 2010
[7] F. Martin, C. Aguero, J. Maria Canas and E. Perdices, Humanoid Soccer Player Design, Robot Soccer, Vladan Papi (Ed.), ISBN: 978-953-307- 036-0, InTech, 2011.
[8] T. Bräunl, Embedded Robotics, Mobile Robot Design and Applications with Embedded System, Springer, 2008.
[9] A. Maggi, T. Guseo, F. Wegher, E. Pagello, E. Menegatti, A light software architecture for a Humanoid Soccer Robot, Workshop on Humanoid Soccer Robots of the IEEE-RAS International Conference on Humanoid Robots (Humanoids'06), Genoa, Italy, 2006.
[10] M. Ghanai and K.Chafaa, Kalman Filter in Control and Modeling, Kalman Filter Recent Advances and Applications, Victor M. Moreno and Alberto Pigazo (Ed.),2009.
[11] S.Y. Noh, J.B. Park and Y.H. Joo, Intelligent Tracking Algorithm for Maneuvering Target Using Kalman Filter With Fuzzy Gain, IET Radar Sonar Navig , pp. 241–247, 2007.
[12] Lanius, Peter, Alternative Firmware for Bioloid CM-510, Google Code, 2013

VI. BIOGRAPHIES

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