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HUMANOID ROBOT BASED ON STEREO VISION TO AVOID AN OBSTACLE

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ABSTRACT

In this research to improve humanoid robot was used to a single camera vision for the RoboCup soccer league competitions in Thailand. This research proposed the technique for humanoid robot avoids an obstacle based on a better vision system, called a stereo vision. To get more efficiency, two Logitech 905 model CCD cameras and microprocessor ATOM PICO 820 board can be used on humanoid robot to visualize the object and obstacle. The humanoid robot can recognize the object called tennis ball. The issue problem is mostly the robots bumping between competitions humanoid robot league due to the humanoid robots were used a camera vision system. Using two cameras for stereo vision can increase more angle of view than using a camera. Indeed, one of stereo vision frameworks is used to disparity between left and right cameras, and the relative baseline is fixed 5 centimeters. To measure the distance of the humanoid robot can measure well at 20 centimeters between the obstacle and the humanoid robot. As a result, humanoid robot to avoid obstacle was selected at a distance of 20 centimeters optimized.

Keywords: Humanoid robot, Stereo vision, Baseline, Disparity, Recognition

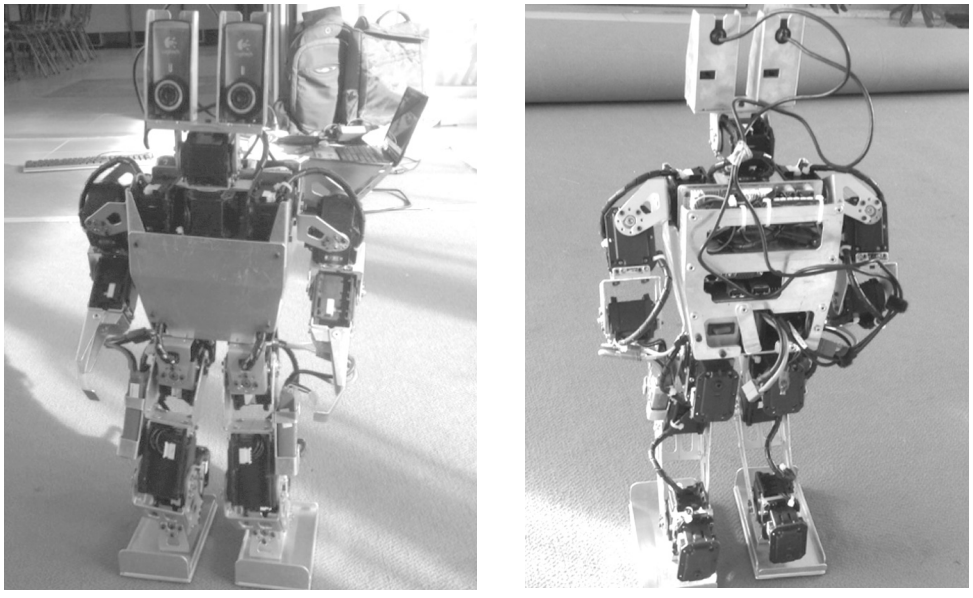
Introduction

In the research for robots have more become mostly importance for daily life. On the other hand, daily life in an environment has more complex that did not the robot to work as well such as intelligent robots, autonomous robots, medical robots, and UAV robots. So any problems of the autonomous robots are the dynamic environment their prediction to mistake. The vision system is one of the robots which can the robot work better. Humanoid robot in the RoboCup soccer humanoid league competition 2010 is used to the vision system to perform various functions such as object recognition, robot localization, and obstruction avoidance. In the obstruction avoidance, the humanoid robot is not only handling as well because the humanoid robot used to one camera vision occurred as collisions between th robots as shown in figure 1.

(a) (b)

Figure1 Humanoid robots were bumping between the robots in the RoboCup soccer league competition used to one camera vision: (a) Humanoid robot from Thai invention. (b) DRAwin humainod robot with humanoid robot from Thai invention.

Humanoid robot has practical application to avoid an obstruction and object recognition that was a better vision system. This research aims to design accurately stereo vision fixed baseline to attach on humanoid robot as shown a completely in figure 2. Survey the paper from (Yasir et al., 2012) proposed the technique of image processing system uses two images which can measure the distance of the object in the images between left and right but object recognition that uses stereo matching to find feature similarity in two cameras that use in the robot cannot be calculated in the real-time. Generally source input images may come from either an indoor environment for this research. In case, outdoor environment including vary illumination occurs difficult to perform measurement and object recognition. Stereo vision to avoid obstacle implemented on a humanoid robot falls into 2 groups consist of object recognition and measure obstruction. In general, object recognition (Jen et al., 2013) proposed the technique using stereo vision based-self localization technique and color segmentation with five feature points and the stereo vision model is baseline extended to 10 cm which is not suitable to attach on the humanoid robot head in the RoboCup soccer competitions. In case segmentation from (Romi et al., 2016) proposed the technique is color segmentation depend on group of RGB to covert HSV color and RGB to covert YCrCb color. The method was only skin segmentation technique for human which be not suitable to the humanoid robot for object segmentation. Another surveys from (Siviram & Soma, 2016) proposed a technique called stereo matching cost for partial face recognition contains low resolution as same (Wilman & Pong, 2012) (Ningbro et al., 2016) images from surveillance video but computation time is the highest than other approaches. The objective of this research designs a method to recognize the object, and measure a distant obstacle compared with mono vision. A most stereo vision system for distant measurement, which was error problem, is more challenged to find the accuracy and is challenged to the navigation of autonomous robot for obstruction avoidance.



(a) (b)

Figure 2 Humanoid robot based on stereo vision:
(a) A front of the humanoid robot.
(b) A back of the humanoid robot

In this survey from (Maurice et al., 2015) proposed a passive stereo camera creating irregular terrain and a rotating LIDAR scanner are efficient on rough surfaces in the locomotion of the humanoid robot which requires two devices to conduct research. Another survey from (Manaf et al., 2013; Signoret et al., 2016; Jonathan & Ary, 2016) proposed the technique is stereo vision with a pair of cameras mouthed on the humanoid robot to create a map for autonomous movement avoiding obstruction that differs to apply real time for obstacle avoidance. However, stereo vision systems are an important one of the autonomous robots such as navigation and recognition. In this way, body-language from (Te-C et al., 2009) proposed the technique is posture hand recognition based on local feature called SIFT. This approach uses Hidden Conditional Random Fields (HCRFs) to recognize hand posture which was appropriate better than used to object recognition. The rest of this paper is established as follows the method below. Implement stereo vision fixed baseline prepared in the topic A and Basic coordinate system of stereo vision provided in the topic B and Color-base

object recognition as shown in topic C and Operation of humanoid robot to avoid an obstacle provided in the topic D respectively.

Methods

A. Implement stereo vision fixed baseline

In this research applies stereo vision on humanoid robot head used to auto detection-object from distant measurement (Jen et al., 2013). In this research for humanoid robot soccer competition in Thailand 2010 to improve vision system avoid obstacle with two cameras. The issue problem is mostly the robots bumping between competitions of humanoid robot league due to the humanoid robots were used a camera vision system. Stereo vision fixed baseline is designed on the humanoid robot head as shown in figure 3. In the other research with stereo vision are mostly extended more than 5 cm measured in the results that were accuracy.

(a) (b)

Figure 3 Humanoid robot head with stereo vision:
(a) Stereo vision fixed baseline model. (b) Implement stereo vision fixed baseline to attach on digital servo motors.

The figure as above using two Logitech 905 model CCD cameras for input images captured as real time operation. The distance between left and right cameras are baseline fixed as 5 cm to attach on digital servo motor as shown in figure 3(b).

B. Basic coordinate system of stereo vision

Humanoid robot to avoid obstacle is necessary to get knowledge as depth information from two cameras with relatively coordinate geometry called epipolar plane image (Jen et al., 2013; Jain et al., 1995). In figure 4, to given some any object point P to present both images are left image (X_l) and right image (X_r) included as epipolar plane image called 3D projection. The 3D projection, we can be calculated that using triangulation geometry. In the cameras for capture input images are knowledge to internal parameter such as focal length for triangulation geometry. In the figure 4, we can find a relationship of an equation as following.

$$d = X_l - X_r \qquad (1)$$

$$Z = f*b/d \qquad (2)$$

Where d is disparity that was originated from the number of left camera pixels minus to the number of right camera pixels, and Z is distance between two cameras to object consist of b (baseline) is distance between center of left and right camera where f is focal length of each of the cameras.

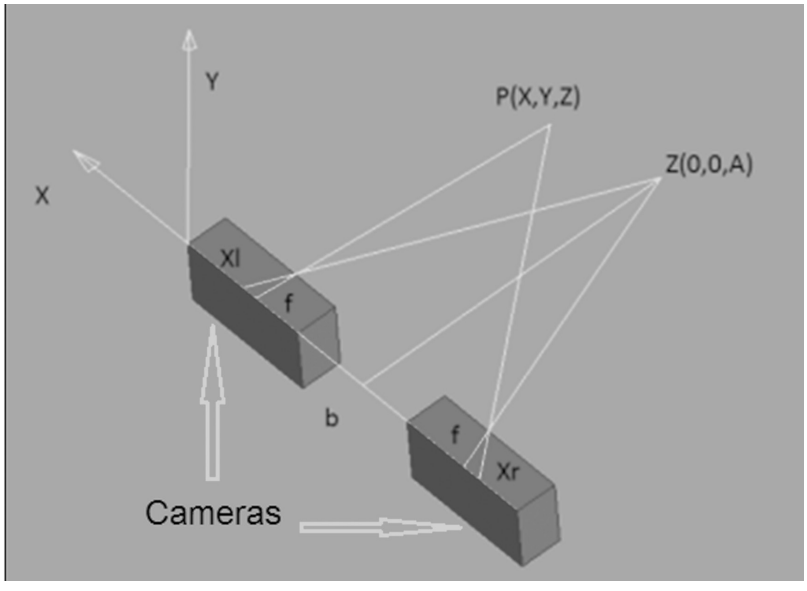


Figure 4 3D model epipolar coordinate plane system of stereo vision.

In the camera consist of focus parameter from another research as (Tsung-S & Ta-C, 2013) proposed the technique is a distant measurement of the object that follows equation respectively as below.

$$Z = \omega d^{-1} \qquad (3)$$

$$\omega = bf \qquad (4)$$

Where ω is focus value fixed parameter include b (baseline), f (focal length) between left and right cameras. We can calculate new equation as following respectively.

$$\frac{1}{Z} + \frac{1}{b} = \frac{1}{f} \qquad (5)$$

So we rewrite new equation of distant geometry as below.

$$Z = \frac{fb}{d} \qquad (6)$$

We apply equation 5 and 6 solved as distance of object as following.

$$Z = \frac{fd + fb}{d} \qquad (7)$$

C. Color-base object recognition

In this way, threshold-base object recognition for humanoid robot based on stereo vision in our research only used tennis ball for object. The input images frames come from together two cameras are RGB color 24-bit that was color space included as Red (R), Green (G), and Blue (B). Survey the papers to convert RGB color space to HSV color from (Romi et al., 2016; Eko et al., 2017) are only using HSV color excepted YCrCb color because it was powerful skin segmentation. HSV color is the detail for human eyes which were mostly familiar and in order to devalue various illuminations come from RGB color as shown in figure 5.

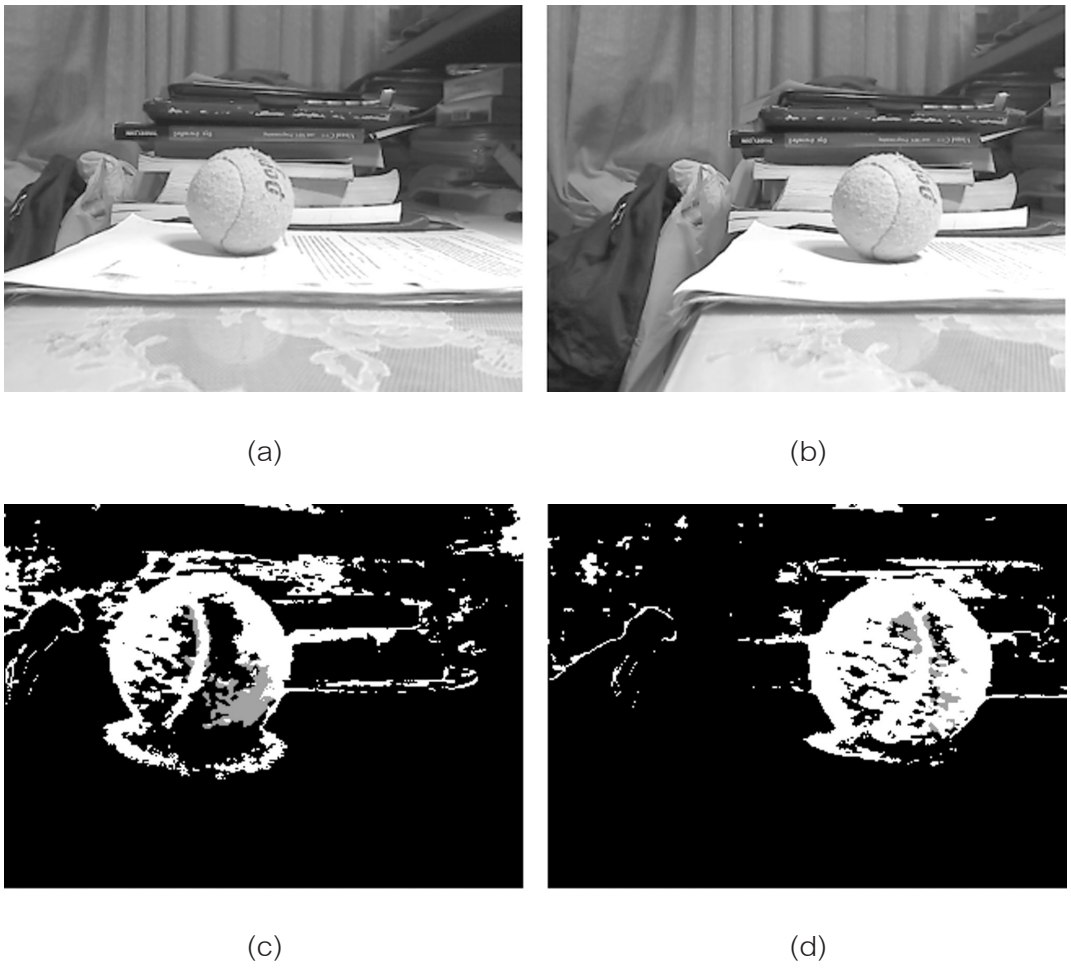


Figure 5 Sample RGB colors convert HSV colors:
(a) Left original input image, (b) Right original input image,
(c) Hsv color of left camera , and (d) Hsv color of right camera.

Intrinsic threshold image, we separate objects from the scene in order to image segmentation. (Nishad PM et al., 2013) proposed the technique is RGB color space to convert HSV color. In this research, we using threshold for colors that are not stored in the database will be ignored as background color and other colors were converted HSV color. In this way, the object recognition is designed as the object and obstacle color as store in database. On the other hands, the robot finds other objects recognized an obstacle. The sample test, we using tennis ball for object and polymer battery instance of obstacle, and measures distant obstacle to the robot indicated

channel "Z" in depth as shown in figure 6. In the object recognition, the humanoid robot to add more function center of mass is finding the object from right image source *rsrc (x, y)* and left image source *lsrc (x, y)* as following the equation respectively from (Jen et al., 2013)(Jain et al., 1995).

$$A = \sum_{i=1}^{n} \sum_{j=1}^{m} B[i, j] \quad (8)$$

$$\bar{x} \sum_{i=1}^{n} \sum_{j=1}^{m} B[i, j] = \sum_{i=1}^{n} \sum_{j=1}^{m} jB[i, j] \quad (9)$$

$$\bar{y} \sum_{i=1}^{n} \sum_{j=1}^{m} B[i, j] = \sum_{i=1}^{n} \sum_{j=1}^{m} iB[i, j] \quad (10)$$

All as above equation, A denotes an area of the object, and B is a binary image from HSV color threshold, where $\bar{x}$ and $\bar{y}$ are the extent of the common center. We can find the positions of $\bar{x}$ and $\bar{y}$ for center of mass of the object as following respectively.

$$\bar{x} = \frac{\sum_{i=1}^{n} \sum_{j=1}^{m} jB[i, j]}{A} \quad (11)$$

$$\bar{y} = \frac{\sum_{i=1}^{n} \sum_{j=1}^{m} iB[i, j]}{A} \quad (12)$$

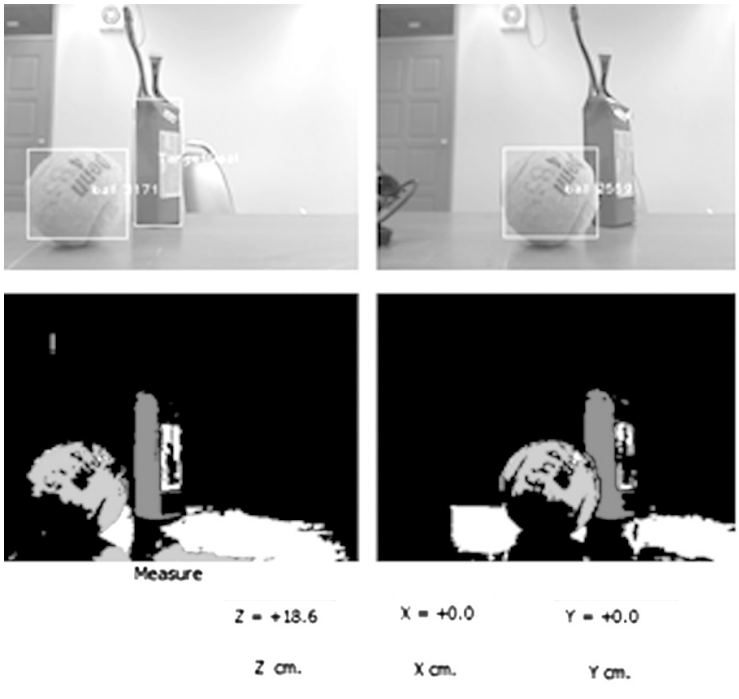


Figure 6 Sample for object and obstacle recognition.

The color of the object is orange and another color is obstacle. The function of two cameras receives images finding the object as reference in the database separated colors by converting RGB to HSV color space in order to devalue various illuminations and takes center of mass to add more accuracy for object recognition from equation 8 to 12.

D. Operation of humanoid robot to avoid an obstacle

In this way, we apply stereo vision model to attachment on digital servo motors controlled by microprocessor ATOM PICO 820 board. In order to achieve goal, we use library Open CV from survey (Bradski & Kaehler, 2008) and combines with program VC++2008. The function of humanoid robot is beginning from two cameras to receive images and transmits to ATOM PICO 820 board for image processing. The stereo vision model attached on two digital servo motors performed both pan and tile to find the object. The humanoid robot can find the object with distant more than 20

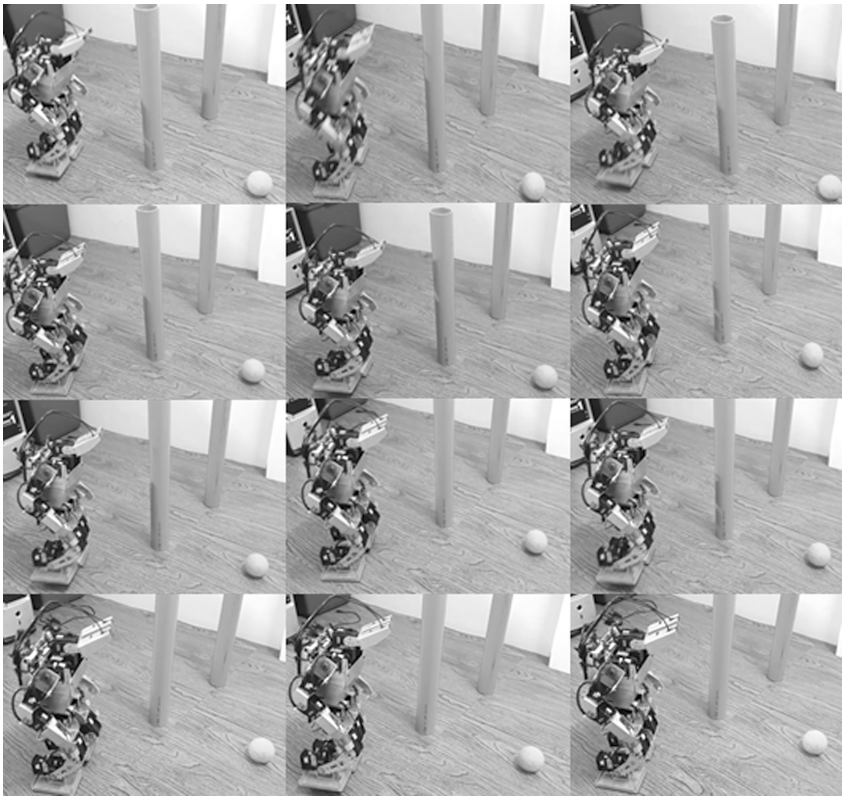


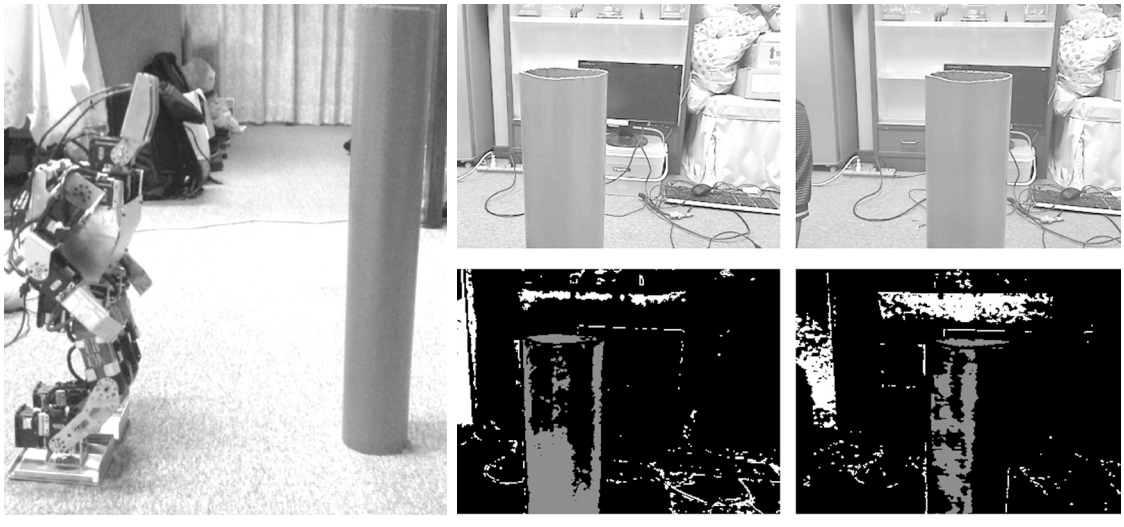
Figure 7 The experiment for the humanoid robot is avoided an obstacle by walking slide.

centimeters between humanoid robot and obstacle that operates locomotion if the humanoid robot measures distant less than or equal 20 centimeters to avoid obstacle, and if the humanoid robot was not found an obstacle will to stop as shown in figure 7.

Result

Humanoid robot based on a stereo vision to avoid an obstacle is using two cameras to receive two images with the position of the robot to determine a coordinate system extracted feature to calculate disparity of image. The experiment to measure depth for acculacy to avoid obstacle performed 10 times, and we setting the robot infront of the obstacle (shown in figure 8) to measure of depth compared with standard measurement as shown in table1.

The humanoid robot can be movement at the 20 centimeters from the robot to obstacle. Humanoid robot can avoid at the 20 centimeters from result of the robot to the obstacle. In the criteria of measure, we select the resulting to small error used for autonomous movement.



(a) (b)

Figure 8 Experiment of humanoid robot measures distant an obstacle:
(a) Setting humanoid robot measures distant an obstacle.
(b) Threshold obstacle from RGB colors covert HSV colors.

Table 1 Comparison measures an obstacle between test and standard.

Item	Standard (cm.)	Test (cm.)	Error (%)
1	10	12.8	28.0
2	15	17.0	13.0
3	20	21.2	6.0
4	25	26.8	7.2
5	30	27.5	8.3
6	35	28.5	18.5
7	40	33.8	15.5
8	45	35.7	20.6
9	50	38.8	22.4
10	55	41.3	24.9

From the table 1, the result of the distance between a robot with an obstacle is selected as 20 centimeters for obstacle avoidance optimized into the robot to the movement because in the RoboCup soccer league competition was used a field has a long distance 6 meters. Due to, one of the intrinsic stereo visions to measure an accurate distance is suitable to expand the baseline. In this research, we don't care to be remote and accurate due to the distance was fixed at 6 meters for RoboCup soccer league competitions. In the other hands, we using humanoid robot base on stereo vision to avoid obstacle for RoboCup soccer league competition to decrease collisions between of the robot. Since 2006 to 2017 RoboCup soccer league competitions, we investigate humanoid robot used as the vision system was applied one camera to vision. Our research aims to propose humanoid robot base on stereo vision for RoboCup soccer league competitions as shown in table 2.

Table 2 Comparison of humanoid robot with our research

Type of humanoid robot	Object recognition	Obstacle avoidance
Thai invention soccer robot	Performed	Un-performed
DARwin soccer robot	Performed	Un-performed
Our research	Performed	Performed

Conclusions and Discussion

The results of experiment for humanoid robot based on stereo vision to avoid an obstacle included as object recognition and measure obstruction. Using two cameras for stereo vision can increase more angle of view than using a camera. In this way, the experiment to measure depth for obstacle avoidance is performed 10 values, and the result at 20 centimeters optimized. The problem one of the humanoid robots based on a stereo vision to avoid obstacles is walking of a humanoid robot (Locomotion) in order to turn left and turn right made its falling on the floor made microprocessor ATOM PICO 820 board shut down. Due to, the robot fixed baseline of stereo vision model is 5 centimeters measured as distant obstacle becomes highly error as well as the result of the distance between a robot with an obstacle is selected as 20 centimeters for obstacle avoidance optimized into the robot to the movement. In the future, our research can be applied to the blind for navigation that used stereo vision with Raspberry Pi 2 board.

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