STRUCTURE ANALYSIS, VISION BASED CONTROL SYSTEM AND WALKING MECHANISM OF A HUMANOID ROBOT

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ABSTRACT

For the implementation of an idea, it is essential to have a full engineering system design, simulation and analysis. . MISTBOY is such a dream-bot which can perform football skills like a human being. This is an on going humanoid robot project, initially having 17 DoF, 55 cm height and 5 kg weight. In this paper, a systematic approach has been presented about the structure, integrated control and the walking mechanism with analyzed result through simulation and graphical presentation. This paper is specially focused on fracture of structure, color pattern matching based vision system and simultaneous dynamic walking mechanism to make the robot balanced.

Key Words— Robotics, Vision system, Biped walking, Color pattern matching.

1.0 INTRODUCTION

Humanoid robot is a huge field for modern robotics research. Many renowned organizations and intellectuals are still working on it. Some outcome of their long term research are ASIMO [1] by Honda, NAO [2] by Aldebaran, HUBO [3] by KAIST, WABIAN [4] by Wasseda University etc.

The first purpose, on the of making a soccer playing robot, is to develop a stable and universal humanoid platform on which various theories and algorithms such as forward kinematics, trajectory planning, dynamic walking, AI, vision and image recognition and navigation can be implemented.

Machine vision (MV) is developed from the concept of human vision. It works on the basis of pattern and color matching like human. MV is nothing but digital image processing which involves extraction of information from an image. It is the young discipline of modern technology, widely used for industrial purposes, security purposes, medical diagnostics, weapon engineering and so on because of its significant level of accuracy and reliability. Now-a-days, in the field of robotics, MV is expanding its area of research defense robot, industrial robot, and medical robot. The initial step, towards the making of an autonomous humanoid soccer playing robot MISTBOY, was to give it the ability to kick a ball. Next step is to give MISTBOY a vision system so that it can take decisions on the playground by detecting players, goalpost, field and obviously the football.

At first to integrate the vision data with the Arduino for better accuracy, camera has been calibrated using camera geometry and a comparison among various matching algorithms such as color matching, pattern matching and color pattern matching is given. At later part, the most effective matching algorithm for MISTBOY is given.

2.0 MISTBOY: SOCCER PLAYING ROBOT

Mechanical Engineering department of Military Institute of Science and Technology aims to design and built a humanoid that is capable of balancing, walking, turning, standing from a prostrate position and finally can play soccer autonomously [5].

To complete the ultimate goal, to play soccer with human or other humanoid robot, the robot must be able to walk freely on its two legs. It requires a fully functional vision system to detect the ball and players and measures the distance among them [6]. Moreover, the robot must be able to take tactical decision autonomously and kick the ball with desired momentum and velocity.

3.0 STRUCTURE ANALYSIS

3.1 Stress Analysis

Stress analysis represents the internal stresses developed throughout the structure due to the external forces acting on it. To analyze the development of stress in MISTBOY, Von Mises stress criterion is used. Considering the foot base is fixed, 0.2 N normal force is applied on L–bracket mounted on waist. It is observed that maximum stress is developed in waist and ankle joints as shown in figure 1. Maximum stress developed in those joints is 17.13 N/m^2 as shown in figure 1.

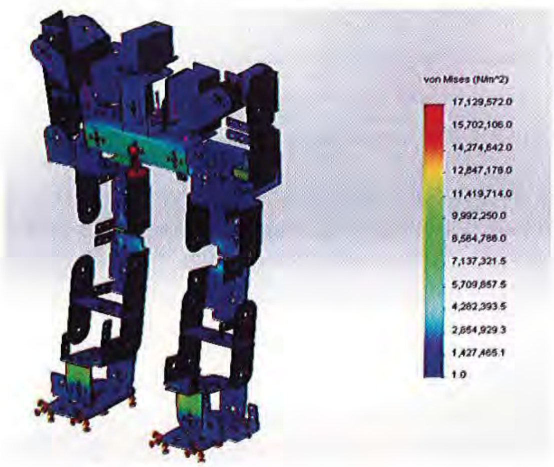


Fig.1: Stress Analysis indicates that at waist and ankle stress is high

To minimize the stress and to prevent the failure, thickness of those brackets are increased from 1.2mm to 1.5mm.

3.2 Buckling study

Buckling analysis determines the critical failure loads of slender structure under compression. Understanding a design's buckling strength is important in predicting possible failure modes or types of analysis.

From figure 2, it is observed that, buckling occurred at short U-bracket below the waist. Like stress analysis, it was measured by increasing the thickness from 1.2 mm to 1.5 mm.

From the analysis, it is found that load factor value is 56 that means as 0.2 N is applied so the structure can withstand for maximum of 56*0.2 = 11.2 N without bending.

4.0 IMAGE PROCESSING AND ANALYSIS:

4.1 Colour Pattern Matching

Colour pattern matching is a unique approach that combines colour and spatial information to find quickly the colour patterns in an image. Colour pattern matching tool locates the reference pattern in an image even when the pattern in the image is rotated and slightly scaled. When a pattern is rotated or scaled in the image, the colour pattern matching tool detects the following features of an image:

- The pattern in the image
- The position of the pattern in the image
- The orientation of the pattern
- Multiple instances of the pattern in the image, if applicable.

When color pattern matching is used to search for a template, the software uses the color information in the template to look for occurrences of the template in the image. The software then applies grayscale pattern matching in a region around each of these occurrences to find the exact position of the template in the image. Figure 2 illustrates the general flow of the color pattern matching algorithm. The size of the searchable region depends on the provided inputs, such as search strategy and color sensitivity.

In Fig 4. NI colour pattern matching cannot detect the red ball when the minimum match score is 750 and colour score weight is 500. As the colour matching score weight is low and also pattern matching cannot give a good score on the white background. A total received matching score remains below 750.

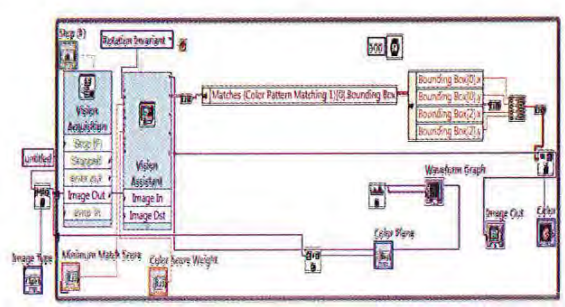


Fig. 2: Color pattern matching algorithm

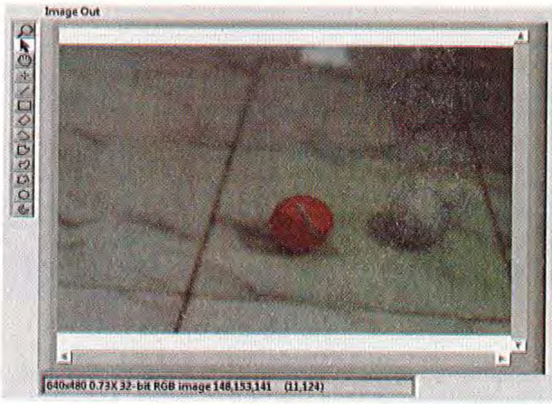


Fig. 3: Original real time RGB image which have to be processed for NI Color Pattern Matching

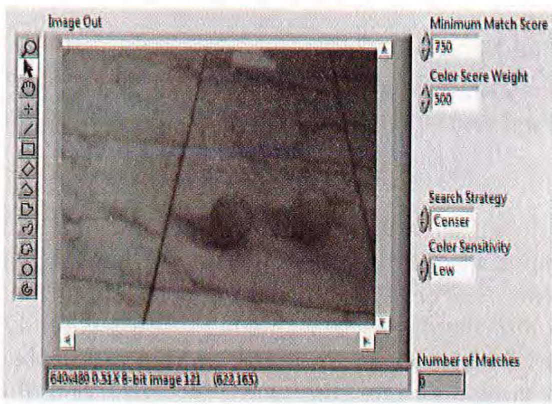


Fig. 4: Color Pattern Matching cannot detect the red ball when the minimum match score is 750 and Color score weight is 500

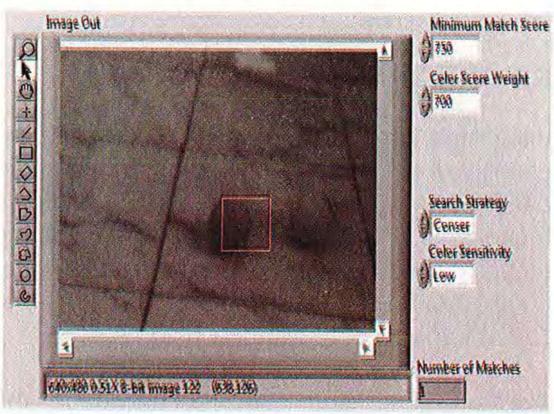


Fig. 5: Color pattern matching with increased color score weight

In Fig 5. it is observed that NI color pattern matching can detect the red ball very preciously when the color score weight is increased from 500 to 700.

4.2 Colour Weight Calibration

Colour weight calibration is very important in colour pattern matching because the matching is based on both the colour matching score and the pattern matching score.

Color weight matching score has to be increased when the colors of ball and the background become similar after gray scale imaging because pattern matching works based on the gray scale image. Otherwise, it is not possible to track the ball as the pattern matching gives very small amount of score as shown in figure 6.

Fig. 6: Calibration for white ball may not work on green or black background

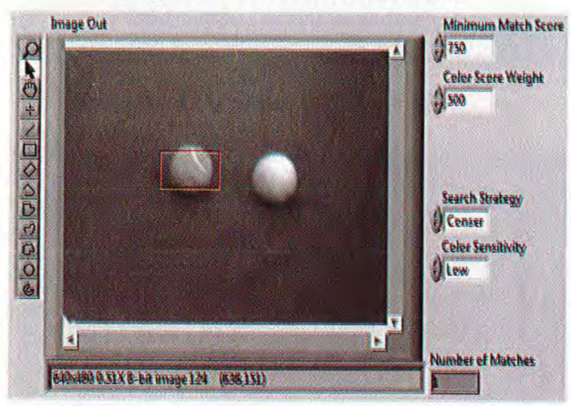


Fig. 7: Color pattern matching with increased color score weight

Colour weight matching score has to be reduced when the object colour and the background colour match with each other. In this the total score remains below the minimum match score. as a result NI vision cannot detect the desired ball shown in figure 6.

In fig. 7 it is formed that NI colour pattern matching can detect the red ball on the green surface when the required colour score weight is reduced to 500, again the vision system start to track the ball.

4.3 Analysis with Histogram

Histogram is a powerful tool to represent whether the image is suitable for analysis or not. Another benefit is that we can understand the pixels of particular color. These informations are used for MISTBOY vision system to analyze the image and to detect the red ball more accurately.

Though Red ball has already been detect by color pattern matching algorithm, its accuracy increases by combining it with histogram.

Fig. 8: (a) Viewing Red ball

Fig. 8: (b) Viewing White ball

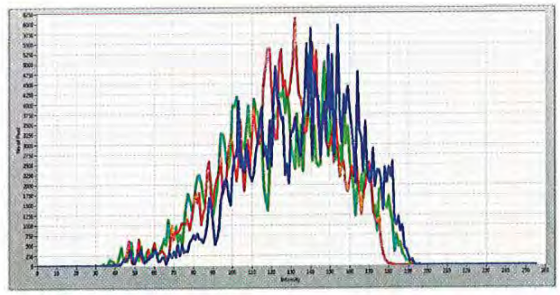


Fig. 9: (a) Histogram of red ball

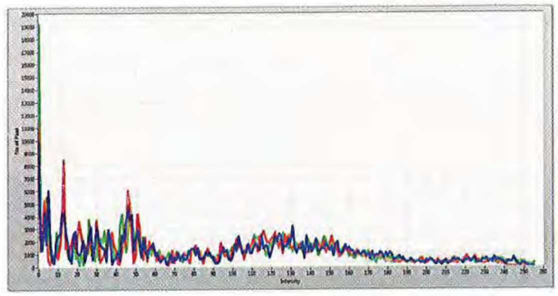


Fig. 9: (b) histogram of white ball

In figures 8(a) and 9(a), when the red ball appears in front of the camera, the intensity as well as the red pixel value increases. On the other hand, in figures 8(b) and 9(b), when the white ball or white things appears, the pixel values become very low. By observing the histogram MISTBOY vision system can easily detects the color of the ball and makes the color pattern matching algorithm more accurate. This technique is suitable to detect other colors also.

5.0 INTEGRATED CONTROL

Integrated control system (ICS) increases the stability of a system. It combines the acquired data from various sources and feedback techniques. The most powerful feedback technique in a biped robot control system is the combination of Gyro-Accelerometer, IR and Sonar sensors data with the vision system.

Accelerometer and Gyro acknowledge the position of the body. These data are helpful to maintain the center of gravity (CG) between the two feet to keep the Zero Moment Point (ZMP) below the feet surface area.
Sonar and IR help to detect and measure distance among the obstacles like own team players, opponent team players.

Arduino and LabVIEW are considered as the brain of the robot. Vision data are analyzed in LabVIEW using the laptop processor. Camera data can be sent there by using the serial or Wi-Fi communication. LabVIEW detects the Game field, Field Markers, D-box, Goal post, same and opposite team players and the ball. Arduino controls all the servo motors according to the vision and other sensing system feedback.

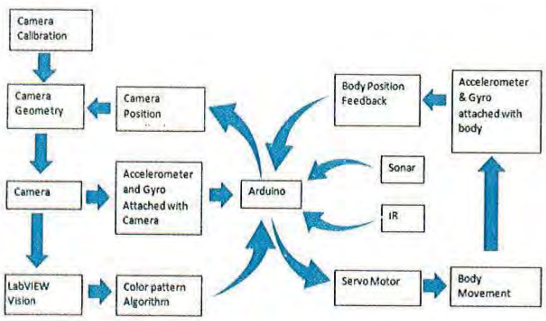
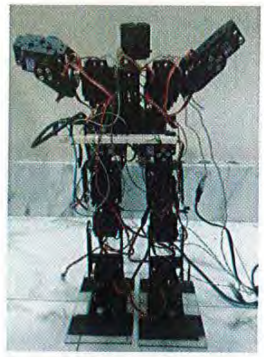


Fig. 10: Integrated Control System

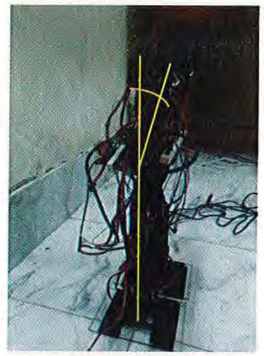
Only a powerful vision system can eliminates the drawback or noises of other feedbacks. One of the most challenging step is to control the accuracy of the position of the motors according to the vision system. Using Vision System, MISTBOY can just detect the desired objects. But, the motors have to be mapped with the vision system, to lead the robot towards the desired position. The image resolution is 640*480.That means the whole image is divided into 640 pixels towards the X axis and 480 pixels towards the Y axis. On the other hand, a typical servo motor can rotate from 0^0 to 180^0. So, if the matching occurs at 320 pixels the camera will rotate about 90^0. This mapping is being processed in Arduino. The camera is attached with a servo motor and the servo is getting the order from Arduino. Arduino takes decision according to the matching happened result.

6.0 WALKING MECHANISM

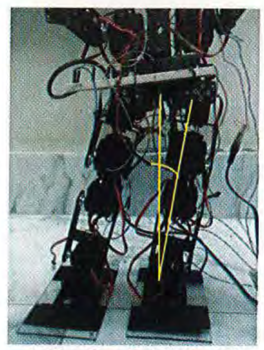
Biped motion of a human is a very critical and harmonic motion. It is a simultaneous combination of some specific joint motion. As MISTBOY has less degree of freedom than human being, there are some deviation in walking mechanism. MISTBOY needs 15^o bending from the waist to keep the Center of Gravity inside the feet area and to stand straight {Fig: 11(b)}. For similar reason, left feet needs to bend for about 15^0 {Fig. 11(c)} when right thigh {Fig. (d)} goes forward for 30^0. Similarly, right leg also needs to bend for the next step.



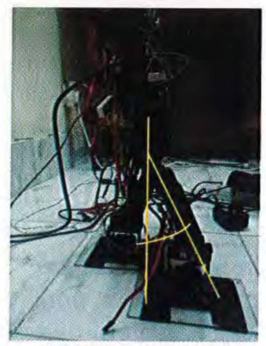
(a) Stable position.



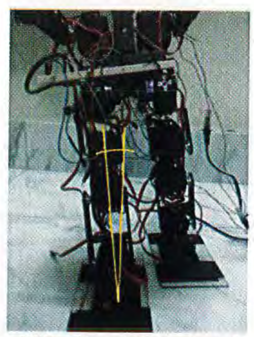
(b) Bow down 15^0



(c) Bending of left leg by 15^0



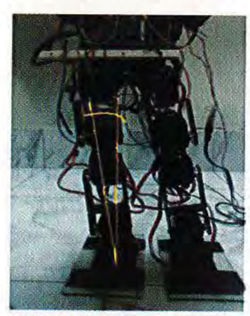
(d) Forward motion by 30^0



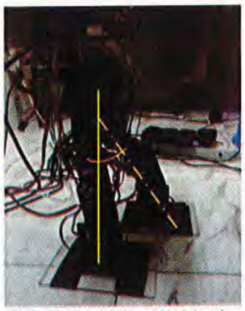
(e) Bending of right leg by 15^0

(f) Right leg stable from bending

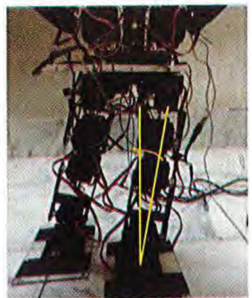
(g) Bow down of head by 15^0



(h) Bending right leg by 15^0



(i) Forward motion of left leg by 30^0



(j) Bending of left leg by 15^0

(k) Right leg came forward

(l) Both leg became stable

Fig. 11: Photographs of walking MISTBOY

7.0 CONCLUSION

In this paper, a systematic approach is presented to derive the parameters for the vision system of a soccer playing robot, best on its ability to sense. At first, the camera geometry and its calibration to integrate it with LabVIEW. In the later part, the matching techniques and algorithms, used in the vision system, are discussed and real time images are analyzed to find out the ball in various critical condition. Therefore, a relation among the electrical sensors, vision and actuators is also established. These discussions are very useful for designing and increasing the accuracy of vision and control system of a soccer playing robot.

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