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Development of Autonomous Humanoid Robot Control for Competitive Environment Using Fuzzy Logic and Heuristic Search

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Abstract: In this paper, we propose a novel method for interaction between humanoid robots in a competitive environment based on fuzzy logic and its implementation on an experimental platform which was validated using soccer gameplay. The proposed methodology employs vision-based feedback of the humanoid's workspace. The position of the humanoids and other objects are expressed in a newly proposed diagonal coordinate system. Hough transform with moment strategy is used to obtain odometric data of humanoids. The proposed motion planning algorithm is a combination of IDA* and linear interpolation which accounts to a major part of the path estimator. Post the path estimator, the motion execution is achieved by a fuzzy-based control system.

Keywords: Humanoid Robot, Fuzzy Logic Controller, Iterative deepening A*(IDA*) search

1. INTRODUCTION

In recent years, the advancement in the field of automated machines has been evident in numerous industrial and research applications. Humanoid robotics has attracted the special interest of intellects all over the world. To study the dynamics of a humanoid robot and implementation of various linear, nonlinear and data driven control strategies has remained at the epicenter of the research. Dynamics of inverted pendulum problem has been considered a solved problem and effective methods have been developed to tackle both internal [Luis Sentis (2010)] and unknown foreign forces and maintain stable dynamics [Sang-Ho Hyon and Cheng (2007)]. Having considered dynamics and control of humanoid with the benchmark inverted pendulum problem, researchers and hobbyists are now putting efforts in applying various methodologies of previous studies in problems involving more competitiveness, challenge, and commercial value.

The Robo World Cup [H. Kitano and Osawa (1997); Hans-Dieter Burkhard (2002)] is a worldwide body whose aim is "To beat human soccer champions by the year 2050". Soccer is a game not only involving stable body motion, but also many other moves and runtime decision making which is considered crucial for decent game-play. A lot of research work has been done in the field of humanoid robotics regarding variety of applications also keeping sports in mind University and Branch (2013); Kos and Babi (2010). Design of the interaction between human-human and human-robot interaction can be studied to design a robot-robot game scenario. Coming after model design and motion execution of humanoids is the data acquisition problem using computer vision and then the control design [SHI Lei (2010)]. Decision-making algorithm using machine learning and fuzzy logic based approach is one of the research subjects [Pouyan Nasrollahi (2013)]. Fuzzy logic has been studied to be one of the effective control designs which is smooth as supposed to crisp decision and even PID controllers [Albertos and Antonio (1998)]. Hybrid fuzzy logic controllers evolving from genetic algorithms for optimal design have also been worked out Sun and Er (2004). Path planning based on particle swarm optimization University and Branch (2013) has been one of the most crucial methods for the implementation. One of the best-known heuristic based methods to accessing minimal nodes is A* algorithm [Junfeng Yao and Xie (2010)]. During memory limited situations the iterative deepening A*(IDA*) is preferred which gives identical results but with little penalty on time. IDA* is a preferred solution for shortest path plan during football gaming, especially in memory bound structure. Performing inverse kinematics for motion planning has been extensively studied and many new optimized solutions have been proposed [Layale Saab and Fourquet (2013); Franck Plestan and Abba (2003)].

The paper is organized as follows: Section 2 presents the problem formulation and setup of the system. The communication model, motion constraints are explained in section 3. Section 4 comprises of the planning of the game-play of the humanoids.The whole algorithm including every aspect is covered in here briefly. The geometry of field, data

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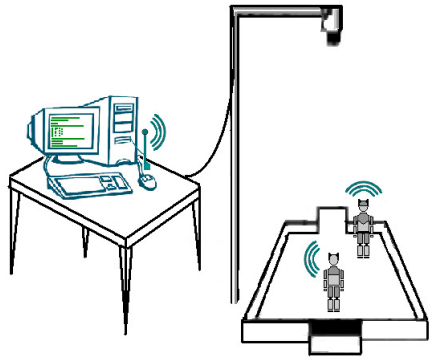

Fig. 1. Experimental Setup

acquisition and motion planning techniques are covered in sections 5, 6 and 7 respectively. The control algorithm using Fuzzy is covered in brief in section 8, which includes the input-output mapping, member function, and rule evaluation in detail. Section 9 contains the experiments and results. The future scope is covered in section 10 followed by the conclusion.

2. PROBLEM FORMULATION

The experiment consisted of 2 humanoids equipped with 2 on-head colour markers and sharp sensors(foot and mid-section), a colored ball, an off-board processor, camera and communication medium between off-board processor and humanoids. The structure of the system is inspired from previous work [Kim J (1997)] is shown in Figure 1. The computer vision system consisted of an overhead camera mounted on a truss, capturing entire field. Camera captures at a resolution of 960x720 at ˜ 20 fps. The camera records data such as odometry of the robot, ball, and obstacles. The robot used for experiment was the Bioloid robot. It had 18 degrees of freedom (DOF) which can perform many complex motions as well as actions sufficient for executing a simple football game. The humanoid had an onboard micro-controller that was used to store and execute all motion steps with precision. The objective is to develop a fuzzy logic based whole-body humanoid control strategy with visual feedback for two player soccer game.

3. MOTIONS AND COMMUNICATION

Considering the bandwidth, speed optimization and taking advantage of on-board micro-controller chip all motion commands were sent in terms of action number represented in multiples of 10 with the units place representing the degree of the motion to be executed. On receiving motion code the actuators are controlled based on predefined motions programmed into the micro-controller. The motions were designed on Bioloid software Robotis platform. The decisions are then sent to respective humanoids via Zigbee protocol.

This decision is then executed by humanoid. The various motions executed by the humanoid and Zigbee values assigned to them are given in Table 1.

Each motion was given a base value. Minimum values output of each motion possible are kept as constants like *Step*, *Turn* giving values of pixels covered in one step and degrees turned in the smallest turn possible. eg: For a certain distance d,

Motion	Zigbee sent value
Walk	10-34
Anti-clockwise turn	50-59
Clockwise turn	40-49
Small walk	9
Kick	60
Defend	61

Table 1. Motion-Zigbee command mapping

Algorithm 1 Program Flow

```
InitilizeCamera()
InitilizeZigBee()
InitilizeHumanoidtoHomePosition()
for Termination Criteria do
    LABEL: Repeat, GetNewFrame()
    DataAquasition()
    DecideStrikerandDefender()
    TreajectoryPlanning()
    while Ball not in Motion do
        GetNewFrame()
        DataAquasition()
        TreajectoryTracking()
        if Error Beyond Limit then
            Goto Repeat
        end if
        SendCommands()
    end while
end for
```

$$Zigbee\ sent\ value = 9 + \lfloor \frac{d}{step} \rfloor$$

$$Full\ Step = 50\,pixels,\ Small\ Step = 20\,pixels,\ Turn = 18^o$$

$$Compliance\ for\ orientation = \frac{Turn}{2} = 9^o$$

$$Compliance\ for\ Distance = \frac{Small\ Step}{2} = 10\,pixels.$$

4. GAME PLAY AND EXECUTION

Humanoids played two different roles of striker and defender according to the position of the ball. The field was divided into two parts by the half line as shown in Figure 2. The humanoid nearest to the ball is assigned as the striker and the other as the defender. The algorithm for both the humanoids run on two threads after initialization, which are almost the similar except the goal points to reach and final motion of kick or defend. The game play was designed to run in an infinite loop where the ball is passed from one quadrant to another. The algorithm is explained in Algorithm 1

Constraints to systems are enlisted below,

- No movement or decisions are taken when ball is in motion
- Ball once out of field, system halts
- Humanoids when out of field system halts
- Lighting conditions have to be fixed
- Possibly complementary colours have to be used for markers
- Humanoids only kick the ball towards goal directly, doesn't forward