Autonomous Humanoid Robot AcYut

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Abstract— **This paper describes project AcYut, a project for developing humanoid robots. The paper discusses the history and past accomplishments of the project, followed by the present and future avenues of research and the potential applications of such a project. AcYut-1 was the first indigenously developed humanoid robot in India. The subsequent iterations of the humanoid have focussed on increasing the size and versatility of the humanoid, and developing a cognition module to make the humanoid autonomous.**

I. INTRODUCTION

Project AcYut was conceived in the year 2008 in the university Birla Institute of Technology and Sciences, Pilani, India (BITS Pilani). The project had the short term goal of developing a simple humanoid robot and the long term target of building a humanoid with widespread applications in industry and dangerous operations such as disaster relief. Project AcYut has constructed six humanoid robots of increasing complexity since then, each being more mechanically advanced and more intelligent than the last. Each humanoid has successfully participated in multiple competitions and demonstrations. A representative photo of project AcYut can be found in [1].

II. HISTORY

AcYut 1 was a remote controlled 50 cm tall humanoid. It was capable of walking, fighting and dancing. This humanoid participated in RoboGames 2008 and placed 6th among over 250 teams from around the world.

AcYut 2 could be controlled wirelessly, and had a more robust mechanical structure with an on board processor for online decision making. This humanoid participated in RoboGames 2009 and won the Bronze medal in the competition.

AcYut 3 was an augmented version of AcYut 2, and was interfaced with a tele-operated body suit which would make the robot mimick the actions of the person wearing the suit. The robot also featured several mechanical improvements which increased the stability of the humanoid.

AcYut 4 was the first autonomous humanoid robot developed in India. It was equipped with a camera and a more powerful processor. The robot was capable of playing soccer autonomously. The mechanical structure of AcYut 4 was designed from scratch and could walk more than twice as fast as the previous versions. AcYut 5 was an updated version of its predecessor, featuring several AI improvements including Localisation and Path Planning. AcYut 4 and 5 each participated in RoboCup Teen Size Humanoid league 2011 and 2012 respectively.

AcYut 6 featured the novel coupling construct which allowed the robot joints to be driven by multiple motors working in concert. The technology was successfully demonstrated at RoboCup 2013.

III. ARTIFICIAL INTELLIGENCE

AcYut features multiple intelligent modules cooperating within a XABSL behavioral framework to facilitate an autonomously functioning humanoid capable of complex decision-making:

A. Image Processing

The Image Processing module currently functions on a fish-eye lens which was chosen for its wide field of vision. The image obtained by a fish-eye lens is distorted. A rectilinear image is obtained from the distorted image using Barrel Distortion Correction [2].

Objects of interest are identified on the image using their color and shape, and their distance from the robot is computed using Inverse Perspective Mapping.

In the RoboCup environment, the Image Processing module calculates the positions of obstacles (other humanoids), goal posts and the ball. The lines on the football field are also identified as landmarks to aid in localization.

B. Localisation

The Localisation module uses Monte Carlo localisation to obtain a probabilistic estimate of the robot's current global position by using the relative location of landmarks identified using Image Processing. In the RoboCup environment, the field is perfectly symmetrical, so an Inertial Measurement Unit is used to determine the facing direction of the humanoid.

C. Path Planning

A geometric path planning algorithm is implemented on AcYut which constructs a path composed of line and circles which navigates intervening obstacles and reaches the targeted object with the desired facing direction [3]. To enable the robot to play soccer, the constructed path results in the humanoid being aligned with the ball and goal post.

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D. Footstep Planning Interface

The path comprises lines and circles, but motion on AcYut is generated through footstep positions. The footstep planning interface maps the given path into footstep positions [4]. The footstep locations are computed such that the robot slows down while following a circular trajectory, and speeds up to its maximum velocity whilst traversing a straight line.

E. Motion Model

In many cases the camera may not be able to locate sufficient number of landmarks for Localisation to compute a confident estimate of the global position. In such cases, a motion model serves as a fail safe which supplies an estimate of the global position by advancing the previous known position with the footsteps the robot has carried out so far.

F. XABSL Framework

Complex decision trees have been constructed on XABSL framework. The framework also transfers data packets across the modules detailed above. The current decision tree has two different action sets for a goal keeper robot and a striker robot for playing football.

IV. Gait Generation

AcYut walks on a 3D Linear Inverted Pendulum Model (3D LIPM) trajectory. The implementation is hierarchical in nature with the lowest level being an Inverse Kinematics model which converts foot locations into joint angles, and subsequently motor movements. The highest level is an input of footstep length and angle for which a corresponding trajectory is generated.

An Inertial Measurement Unit is for detecting external disturbances. A Capture Step framework has been implemented on AcYut which calculates a new trajectory the footstep which allows the humanoid to recover from the push. If a non-returning trajectory is detected, the robot activates a falling sequence to minimize damage to itself.

A PID Controller has also been implemented to actively minimize noise and disturbances so that the robot adheres to the nominal trajectory [5].

V. Hardware

AcYut uses dynamixel MX 106 servo motors for actuation, and is powered by 14.8V LiPo batteries. The processing is carried out on an on-board Intel Atom Processor. The circuitry incorporates regulators to reduce voltage fluctuations and connects the actuators in a parallel daisy chain connection. Data communication with the motors is interfaced using FTDI hardware chips.

VI. Future Plans

A new mechanical structure for AcYut has been developed which represents a significant reduction in weight due to the usage of Carbon Fibre Reinforced Plastic as the building material. In the near future, a mechanical design incorporating springs will be contructed so complex motions like jumping and running can be explored.

On the AI front, a cooperative behavioral framework is being developed which would allow two robots to work in concert to achieve a specific goal - for instance, passing a ball between them and scoring a goal.

Research is also being conducted on the possibility of using online learning for push recovery.

In the Image Processing module, a Time of Flight camera will be used to map and navigate complex environments.

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