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CB: Exploring Neuroscience with a Humanoid Research Platform

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Abstract*— In this video presentation we introduce a 50 degrees of freedom humanoid robot, CB –** ***Computational Brain **[1]. CB is a humanoid robot created for exploring the underlying processing of the human brain while dealing with the real world. We place our investigations within real world contexts, as humans do. In so doing, we focus on utilising a system that is closer to humans – in sensing, kinematics configuration and performance.**

We present a full-body compliance controller that was developed for the motion control of our humanoid robot [2].

Our initial experimentation on our system includes: 1) full-body compliant control – physical interactions/balancing/motion control; 2) the integrated visual ocular-motor responses; 3) perception and control – reaching, foveation, and active object recognition; 4) our studies of Central Pattern Generator for walking.

I. INTRODUCTION

Our objective is to produce a richly integrated platform for the investigation of human-like information processing – exploring the underlying mechanisms of the human brain in dealing with the real world. In this paper, we present a humanoid robotic system, a platform created to facilitate our studies.

A. Motivations – Our approach

As our research interests fall in line with the notion of "Understanding through Creating", two essential aspects motivate our approach:

- *In Engineering* - Engineers can gain a great deal of understanding through the studies of biological systems, which can provide guiding principles for developing sophisticated and robust artificial systems [1];
- *Scientifically* - Building of a human-like machine and the reproduction of human-like behaviours can in turn teach us more about how humans deal with the world, and the plausible mechanisms involved [3].

Our focus is towards the understanding of humans, more specifically the human brain, and its underlying mechanisms in dealing with the world. We believe that a humanoid robot that is closer to a human being will facilitate this investigation. Such a sophisticated system will impose the appropriate constraints by placing our exploration within the context of human interactions and human environments. As a result, a full-size humanoid robot - CB (Computational Brain)[1] was built to closely match the physical capability of a human, thus making it suitable for the production of a variety of human-like behaviours, utilising algorithms that originate in computational neuroscience.

II. RESEARCH PLATFORM – HARDWARE AND SOFTWARE ARCHITECTURE

To provide an appropriate background to our work, here, we present brief explanation of our research platform.

A. Humanoid Robot – CB

The humanoid robot CB was designed with the general aim of developing a system that is capable of achieving human capabilities, especially in its physical performance. CB, the physical system is of general human form - our initial results are demonstrated in the submitted video[2].

1) Mechanical Configuration: CB is a full-body humanoid robot. It is approximately 157.5 cm in height, approximately 92 kg in weight. It has an active head system with 7 degrees of freedom (2×2 degrees of freedom eyes, 1×3 degrees of freedom neck), 2×7 degrees of freedom arms, 2×7 degrees of freedom legs, 1×3 degrees of freedom torso, 2×6 degrees of freedom hands – 50 degrees of freedom in total. The system has similar ranges of motion and physical performance as a human person.

2) Sensing subsystems: The active head houses a set of inertial sensor (3-axis rotational gyro, 3-axis translational accelerometer). They are used to emulate the human vestibular system (the inner ear), providing head orientation, as used for gaze-stabilisation. An additional inertial sensor is installed at the hip to provide angular velocity/translational acceleration near the center of mass of the whole body, used to provide the overall orientation of the system. The visual system is made up of 2 cameras per eyes, a *Peripheral* (wide-angle view) and a *Foveal* (narrow view) cameras are installed on each eyes to emulate the visual acuity of the human visual system.

3) Proprioceptive sensing: Proprioceptual information plays a key role in human motor control, informing the limbs and higher-level cortices of critical information in carrying out suitable action. Our system is equipped to support various forms of control to account for interactions, position/velocity/torques sensing are provided at the key joints for proper active compliant control (arms/legs/torso/neck -

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[1]developed by SARCOS

[2]further experimentation are currently underway – will be included in the final submission

34 DOFs). Foot force sensors are installed at the soles of each foot to provide information during ground contact and weight distribution, as it is critical for walking and balancing control. The uniqueness of this system over previous system is that torque sensors are installed on the main joints of the system - the arms/legs, torso and the neck, allowing joint-level active compliant possible.

III. Synthesising Human-like Behaviours

Here, we present some of the technical background of our video presentation.

A. Compliant Control: 3D Balancing, physical interactions and motion generation

The developed controller, is a full-body contact force controller with gravity compensation [2]. Gravity compensation was made possible only by force-controllable humanoid like CB. This makes the robot passive with respective to external force applied at *arbitrary* contact points, hence, results in compliant full-body interaction. The additional contact force allows the robot to generate desired ground reaction forces and other necessary interaction forces. Full-body 3D balancing is realised by utilising the desired ground reaction force as a feedback to the Center of Mass (CoM). In the video we shows such an example, where robot being abruptly pushed. The robot was able to recover and maintain balance, as shown in the video.

With the same force control framework, the robot performed force tracking to external forces, and position tracking while keeping balance [2]. Additionally, we demonstrate how human motion can be captured and smoothly generated on our system, we utilised a technique proposed from our earlier work in reproducing human-like movements [4]. The example in the video shows our robot performing the Okinawan folk dance, while the balancer and force-based controller are working simultaneously.

B. Perception - Visual Processing and Ocular-Motor Responses

Human interact with the external world involves the utilisation of a fully integrated sensory system. To deal and interact with the external world, our system is equipped with microphones for hearing and video cameras for seeing (2 eyes for stereo vision processing, 2 cameras per eye - foveal and peripheral camera - to mimic foveated vision of biological systems). The peripheral cameras provide a wide visual view of the environment whereas the foveal cameras provide a more detailed view of a smaller portion of the world.

An incorporation ocular-motor responses similar to that of humans formed part of our overall system. The following ocular-motor control schemes have been included: 1) Vergence – minimising target disparity by symmetric eye movement; 2) Saccadic eye motion – quick knee-jerk type eye movements to redirect gaze; 3) Vestibulo-ocular reflex (VOR) – gaze stabilisation by compensating for externally induced head movements; 4) Coupling of eye movements with head movement; 5) Saccade followed by smooth pursuit of a target in an integrated control environment.

C. Reaching, foveation, and active object recognition

With the already incorporated head/eyes movements control, we then combined a reaching [5] and visual foveation system for active recognition of an object[3] [6]. In the video we first show active tracking and reaching of an object, then demonstrated the foveated vision system, finally we show the robot pointing to the recognised object of interest.

D. Studies of Central Pattern Generator for Walking

To examine human-like walking, we have investigated a number of biologically inspired walking algorithms. Here we present one Central Pattern Generator (CPG) based locomotive controller that managed to produce naturally looking walking movements on our humanoid robot [7].

In the experiment shown in the video, we demonstrated that CB can walk using simple sinusoidal desired joint trajectories with their phase adjusted by a coupled oscillator. The center of pressure and velocity are used to detect the phase of the lateral robot dynamics. This phase information is then utilised to modulate the desired joint trajectories, thus enabling us to generate successful stepping and walking patterns [7]. Further studies showed that the same controller can also be applied, even with an increased mass - the gait of the robot adjusted to accommodate a heavier payload.

IV. Conclusion

This video presentation introduce a new integrated humanoid robotic system, CB, developed for the studies of human-like information processing in dealing with the real world.

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