**The Control of Humanoid Robot: A Preliminary Literature Review**

**Abstract**

A service robot provides a variety of professional and domestic/personal services to companies and persons across a wide range of application fields. Currently, the service robot sector is expanding fast in tandem with the Fourth Industrial Revolution's technical breakthroughs.

Given the high interest and promise of service robots, this study undertakes a thorough overview of previous and current research in the field. This report analyses service robot development efforts across applications and sectors and categorizes service robots into four groups.

The classification gives us insights into the distinct research activities and practices of each service robot category. The paper then examines the technological base that applies to all four types of service robots. Finally, this paper outlines understudied but potentially crucial possibilities and problems for future service robot research.

**Keyword**

Dynamic motion, Model Predictive Control (MPC), QCQP, Angular Momentum, quadratic program, ground reaction force, trajectory optimization, legged robot, velocity tracking, Centroidal Inertia Isotropy metric, inertial measurement unit, proprioceptive actuation, whole-body control, bipedal locomotion, centre of mass, whole body impulse control, linear constraint, nonlinear programming, Model Hierarchy Predictive Control (MPHC)

**Current Research**

Review and compare the existing research and development works, demos, products and projects,

Humanoid robots have grown in popularity in recent years as an increasing demand for more adaptable and autonomous robots that can execute jobs in real-world contexts. Technological advances, such as computing power, sensors, and actuators, have fuelled the development of humanoid robots. These improvements have enabled the implementation of complicated controllers on robots to do tasks previously only conceivable for humans, such as very dynamic walking, running, and object manipulation.

It is challenging to achieve very dynamic movements in robots. In recent years, advances in mechanical design, improved algorithms, and more processing capacity have enabled new robots to execute natural gaits and dynamic maneuvers like backflips. Recently, a kinodynamics-based pose optimization and loco-manipulation MPC framework on humanoid robots to tackle the problem of pushing heavy and large objects by leveraging humanoid whole-body poses and synchronized locomotion and manipulation control has been proposed [1]. It highlights the proposed approaches results in object-pushing tasks, including comparisons with previous systems, pushing large objects, external force disturbance rejection, and tracking a desired object trajectory in 3-D.

Two years have passed since the MIT Humanoid Robot published a paper of their humanoid robot completing a backflip [2]. In their realistic dynamics simulation, they effectively exhibit dynamic behaviours like as back flips, front flips, and spinning jumps using carefully built hardware and control architecture.

The 2015 DARPA Robotics Challenge (DRC) provided the foundation for the next generation of humanoid robots [2] [3] [4]. However, the designs of these robots and the algorithms used to control them have been largely geared at performing the least dynamic activities necessary for the DRC [5]. The MIT Cheetah robot's proprioceptive actuator design provided an effective solution to this trade-off [6]–[8], but has yet to be implemented on a humanoid robot. The research development of the general quadruplet robots are also giving impacts for the development of humanoid robot’s research [6], [9]–[11].

Trajectory optimization-based techniques to motion planning based on full-body dynamics [12], [13] may leverage the robot's whole dynamic range, but they are prone to difficulties such as local minima and excessively lengthy solution times. These concerns can be avoided by utilizing a reduced-order model of the robot, such as a spring-mass model [14], [15], but these techniques are often limited in their applicability due to restrictive assumptions.

Centroidal dynamics-based motion planning systems are popular because of their unique mix of computational tractability and dynamic expressiveness. These techniques capture the basic dynamics of the system without having to worry with the robot's multiple degrees of freedom by addressing only the centroidal dynamics of the robot [16]. Kino-dynamic planners [17], [18] optimize the robot's centroidal dynamics as well as joint-level kinematics at the same time, which has advantages in terms of generality.

To achieve a stable landing, the robot must waste kinetic energy over a lengthy time while fast responding to the controller's expectation mistake caused by unmodeled dynamics, modelling error, or external disturbance. This problem was addressed in one of the work [9] which introduced a hierarchical control framework integrating model predictive control (MPC) with a basic lumped-mass model for long-time horizon optimization and whole-body impulse control (WBIC) for instantaneous high bandwidth control. WBIC and MPC shared the same position command in prior work. To fully exploit the best solution, WBIC uses the optimal motion discovered in MPC as the position reference, together with the response force commands. Furthermore, as long as the body orients command is not disobeyed, WBIC prioritizes a body orientation job above a centroidal momentum work to track desired centroidal angular momentum.

In contrast to the traditional Model Predictive Control (MPC) approach to locomotion, which formulates a hierarchical sequence of optimization problems, the proposed work formulates a single optimization problem posed over a hierarchy of models, and is thus known as Model Hierarchy Predictive Control (MHPC) [19]. A novel representation-free model predictive control (RF-MPC) framework for regulating different dynamic motions of a quadrupedal robot in three-dimensional (3-D) space is presented by [20]. Non-linear MPC (NMPC) presented by [21], [22] for dynamic motions.

An adaptive force-based control for legged robots [23] has demonstrated the effectiveness of adding adaptive control with quadratic programming (QP) force control. Because our method is based on force control, it preserves the benefits of the baseline framework, such as resilience to uneven terrain, adjustable friction restrictions, and mild impacts.

The MIT Humanoid robot is the first attempt to adapt the extremely successful design ideas of the MIT Cheetah robots [6], [6]–[8], [24], [25] to a humanoid robot. A unique kino-[20] planner that efficiently deals with the actuator restrictions of the robot is created in order to harness the full dynamic capabilities of the robot in impulsive motions. We use a hierarchical control system to achieve safe jump landings by efficiently merging model-predictive control with whole-body control.

Previously, Early studies on highly dynamic motion such as jumping and running in legged robots are largely influenced by the heuristic control implemented on Raibert’s hoppers. An unified model with inertia shaping [26] can approximately model the centroidal inertia and has improved the jumping performance on SLIDER, a knee-less bipedal robot. Stanford Doggo [27] merges the dexterity and inherent stability of quadruped robots with a vertical jumping agility greater than specialized monopods and matching that of the highest performing animal, the galago [21], [22].

The combination of MPC and joint PD controller has been propose by [28] to achieve smooth jumping transition and accurate jumping trajectories.

Online optimization has been presented by [10] incorporated with MPC, but it has limitation that their QP program the authors are using is a discretization of the continuous optimization, yielding numerical errors. Force-and-moment-based MPC has also been used by [29] to achieve highy dynamic locomotion on rough terrains for 10 DoF bipedal robots.

The Centroidal Inertia Isotropy metric has been used by [30] To quantify the effect of motor placement on the robot's dynamics, and the cooperation actuation for Hip, Knee, and ankle joints is utilized to generate large force in bipedal robots. However, the CA has increased mechanical complexity.

The work of [31] used proprioceptive actuation and Whole-body control (WBC) to enable bipedal robot has dynamic balance.

For dynamic balancing tasks, adaptive-frequency MPC framework has been presented by [32] and the bipedal locomotion goes over terrain with uneven stepping stones. It is paired by WBC, CoM trajectory, and adaptive-frequency trajectory optimization. Other than that, this work [33] shows a formal connection between template and anchor models, so that the authors derived linear constraints which is CWC criterion that are sufficient conditions for maintaining ground contact.

For multi-tasks dynamic such as picking up and dropping off objects while turning and walking, this work [34] solves multiple contact modes via MPC framework.

**The proposed future research**

find out the best solutions from your view; Describe the best solutions and explain in detail why you select them to be the best.

The fundamental contribution of this study is a unified approach to humanoid robot design, motion planning, and control that permits extremely dynamic motions such as the back flip seen in Fig. 1.

Simulation trials of the robot executing acrobatic actions such as flips, spins, and leaps indicate the practicality of our suggested system design. The performance of the MIT Humanoid's custom actuators is experimentally confirmed and included in the robot's simulation studies to verify that exhibited motions are viable on the fully constructed robot.[27]

**Challenges and Opportunities of Humanoid Robot Research**

Discuss the challenges to improve this type of robots;

* To perform those movements using online optimization with the dynamics of the robot.
* To integrate the approach with vision to automatically detect and jump on obstacles.
* To optimize the MPC formulation to enable faster and more aggressive motions
* Centroical model is not as accurate to represent the behaviour of the bipedal robots due to substantial mass of their limbs
* To improve the balance framework with a higher level planner to handle larger disturbances.
* Account for joint and torque limits, self-collisions, and multicontact scenarios.
* continuous jumping on stepping stones on the robot hardware

**Conclusions**

Discuss what you learned from this review;

Comment on whether this review increases your interest to study further in robotics or pursue a future career in robotics.

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