Design and Control of a Bipedal Walking Machine (A220.401)

ACCM
AUSTRIAN CENTER OF COMPETENCE IN MECHATRONICS

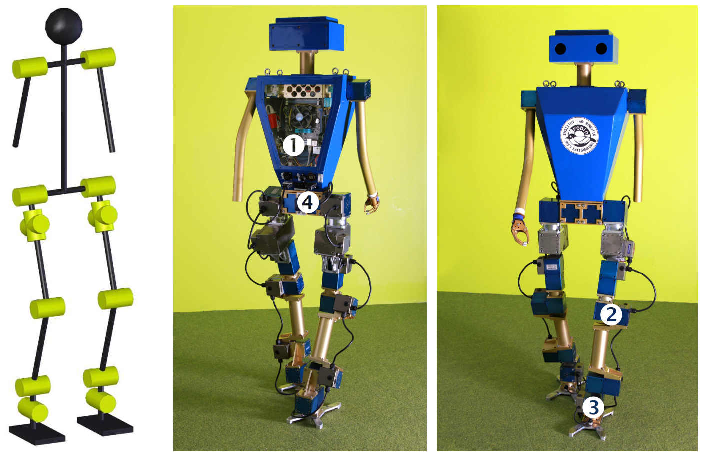
Area 2 – Mechanics and Model-Based Control

Introduction

In the future service robots will play an important role in daily life. Beside wheeled robots, biped locomotion seems to be a promising approach to allow robots to co-exist with humans and to assist them in their daily routines.
For the study of bipedal locomotion an experimental setup was designed and is now used for the evaluation and design of new control algorithms and as a setup to investigate basic human machine interaction methods.

Mechanical Design

To allow a human-like movement an anthropomorphic kinematic structure consisting of 14 rotary drive units is used to imitate the human body. One focus during the mechanical design was the use of standard industrial components to allow short development time and quick changes in the kinematic structure by rearranging joints and structure elements.

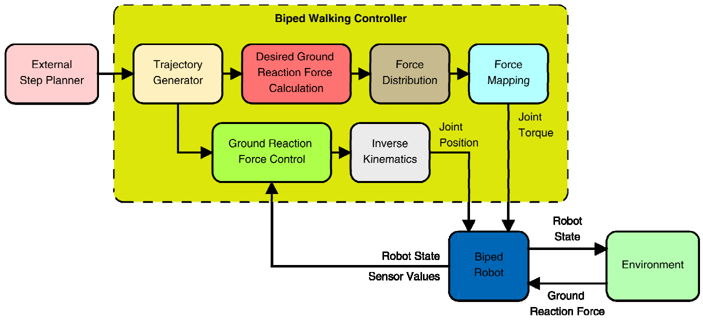


Left: Kinematic structure. Right: System overview: (1) central control unit, (2) drive units, (3) force/torque sensor, (4) inertial measurement unit.

All driving units feature an EC-motor, the necessary electronic control board, a harmonic drive gear, a brake and a motor position sensor. For control issues further sensors like an inertial measurement unit to derive the orientation of the upper body and a three axis force torque sensor in every ankle to measure the contact force of the robot to the environment are added. As central control system an onboard computer is placed in the trunk. For real-time control a standard Ubuntu Linux with Real Time Application Interface (RTAI) patch is used. Controller design is done in Matlab/Simulink.

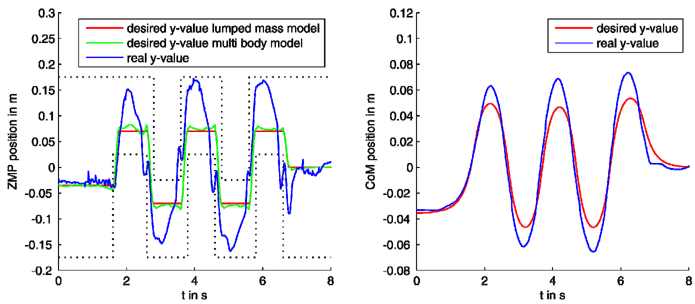
Control

As the stability of bipedal locomotion entirely relies on the contact forces between the robot and the environment they have to be considered in a special manner. Due to the unilateral contact the ground reaction forces have to maintain constraints like that the force along the contact normal has to be positive and that the tangential component has to fulfill friction restrictions. These constraints strictly limit the set of feasible motions.



Overview of used walking control algorithm with ground reaction force control and feed forward joint control.

An online approach using a simplified model approximating the robot as a single lumped mass is used to generate a center of mass trajectory satisfying the above constraints. Polynomial functions are chosen as feet trajectories.
This desired trajectory is then used in an inverse dynamics algorithm to gain the overall ground reaction force which is distributed to all active contact points. As the ground reaction forces have to comply with the above constraints, a quadratic program with inequality constraints is used to calculate a valid force distribution that minimizes the Euclidian norm of them. Contact forces are then mapped into the configuration space to gain the desired feed forward joint torques.
To compensate for model and environment uncertainties and unknown external forces a feedback loop, using the measurements from the force/torque sensors in the ankles, is implemented in the ground reaction force controller.
Finally, a velocity based inverse kinematics algorithm is used to transfer trajectories from the operational space into the configuration space.



Walking experiment with 0.1 m/s. Left: Comparison of the real position of the zero-moment point with the desired position gained by the lumped mass model and the multi body model. Right: Comparison of the real position of the center of mass with the desired position.

References

(1) J. Mayr, H. Gattringer, H. Bremer. Online Walking Gait Generation with Predefined Variable Height of the Center of Mass. Proceedings of International Conference on Intelligent Robotics and Applications 2011.
(2) J. Mayr, H. Gattringer, H. Bremer. On the Suitability of Different Online Gait Generation Methods for Pre-Defined Footsteps. Special Issue: 82nd Annual Meeting of the International Association of Applied Mathematics and Mechanics 2011.

Contact

Project manager – ACCM:
Assoz.Univ-Prof. DI Dr. Hubert Gattringer, hubert.gattringer@jku.at
Research engineers – ACCM:
DI Johannes Mayr, joh.mayr@jku.at
Scientific partner – Johannes Kepler University:
O.Univ.-Prof. Dr.-Ing.habil. Hartmut Bremer, hartmut.bremer@jku.at

JOHANNES KEPLER UNIVERSITY LINZ | JKU

INSTITUT FÜR ROBOTIK · UNIVERSITÄT LINZ