Autonomous Safety Frame for Humanoid Robots: Low-level Control and Initial Operation

Semester Thesis / Interdisciplinary Project (IDP)

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Note: This is a project in parallel to "Autonomous Safety Frame for Humanoid Robots: High-Level Control and Human Machine Interface"

Introduction and Problem Description

In recent years major improvements in biped locomotion of humanoid robots have been achieved. Aside from planning stable walking patterns, hybrid position-force control, and various stabilization techniques have been investigated. Currently the Chair of Applied Mechanics focuses on using tactile feedback for force control and developing planning methods for dynamic multi-contact problems, i.e. explicit usage of the arms during walking. The developed methods are then implemented on the humanoid robot LOLA (see Figure 1 left).

![Figure 1](image)

Figure 1: Left: laboratory with the humanoid robot LOLA and manually operated safety frame as of mid 2017. In the meantime the safety frame has been equipped with various sensors and actuators necessary for an autonomous operation. Right: layout of all components and its communication channels.

In order to avoid damage to the robot, a manually operated safety frame is used, see Figure 1 left. Currently a human has to secure the robot during each experiment. Especially in complex test cases, in which the robot autonomously navigates through a cluttered environment, this proves to be a difficult task. While maintaining the safety of the robot, one also has to avoid any influence (or even disturbance) of the robot by the safety system itself. Finally the safety frame is also used to recover the robot after falling and bringing it right back to the starting position.

In 2018 the safety frame has been completely overhauled. Additionally, it has been equipped with

- Industrial servo drives for actuation of the x, y, and z axis,
- Laser range finders for motionless homing of x and y axis,
Limit switches as alternative to motionless homing and for safety concerns. Moreover various basic low-level communication drivers have already been implemented such that an embedded microcontroller (Atmel SAM4E) can interact with each component using GPIOs, UART, CANopen and Ethernet (TCP), see Figure 1 right. The superior goal is to allow an autonomous (tele-)operation of the safety frame, such that it tracks the robot during walking which is localized using a commercial visual tracking system (Vicon Motion Systems Ltd; sends 6D pose of robot; already installed and in operation, thus no further development necessary).

Task Description

The specific goal of this project is to develop and realize a concept for safe and robust low-level control of all components attached to the microcontroller, see Figure 1 right. This includes the communication with the Safetyframe Server, which will mainly be worked on by the parallel project “Autonomous Safety Frame for Humanoid Robots: High-Level Control and Human Machine Interface”.

Within this project the student is expected to handle following tasks

- Literature research and getting familiar with
  - safety systems for robot laboratories,
  - electric actuators and servo controllers,
  - developing software with high requirements on safety and robustness, and
  - fundamental control theory.
- Design of a low-level control concept with the main focus on robustness and safety
- Implementing low-level communication (GPIOs, UART, CANopen and Ethernet (TCP))
  (basic implementations are already available)
- Design and realization of the interface to the Safetyframe Server (Ethernet)
- Development and implementation of error handling strategies
- Initial operation, i.e. autonomous tracking of a predefined trajectory
- Tests and validation
- Documentation of code and additionally in the style of a “regular” thesis

Requirements

From students applying for this project we expect

- at least...
  - ...interest
  - ...motivation
  - ...creativity
  - ...a structured and accurate way of working
  - ...reliability and sense of responsibility
  - ...ability to work in a team with another student
- ideally...
  - ...experience with programming microcontrollers in C
  - ...knowledge on common bus systems (UART, CANopen, Ethernet)
  - ...basic CAD skills (most likely not required)

Other

Feel free to ask a fellow student who is interested in working on the parallel project such that you can apply together.