The Sweaty 2017 RoboCup Humanoid Adult Size Team Description

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Abstract. This paper describes the Sweaty II humanoid adult size robot trying to qualify for the RoboCup 2017 adult size humanoid competition. Sweaty came 2$^{\text{nd}}$ in RoboCup 2016 adult size league. The paper describes the main characteristics of Sweaty that made this success possible, and improvements that have been made or are planned to be implemented for RoboCup 2017.

1 Introduction

The major research goal with Sweaty is the improvement of bipedal walking algorithms eventually allowing the robot to run. Our second robot Sweaty II suffered from several weaknesses.

- The hip was too wide which made it hard to stand on one foot.
- The software-real time kernel we used was unstable.
- The gait pattern we generated lead to a walk, which was not fast enough.
- The hands could not grasp.
- The vision program was not reliable.
- We had to use two computers as the real time kernel was not compatible with the vision program.
- The low ESR capacitors we need for high dynamic control of the motors led to EMV-problems during start-up.
- There were no force or torque sensors to stabilize the gait.
- The trunk was controlled in an inefficient way and thus no stabilization algorithm using the trunk was effective.
- There was potential to optimize the motor controller with respect to speed and precision.
- The gait was designed to an artificial grass with long leaves, but the grass on site had short leaves.

Sweaty II.1 is designed to overcome these issues, while keeping the main advantages.

2 Robot

2.1 Mechanical design

The basis of the mechanical design was the analysis of motion from motion capture data [Sch1] based on data compiled during the KoroiBot project [Ma1]. As actuators we use spindle screw drives with highly efficient motors from Maxon for the leg and torso servos, Dynamixel servos for the arms; Firgelli for the fingers and Volz servos for the head.

Hip The hip was designed with mechanical linkages to enable 3 degrees of freedom [Fr1]. In Figure 1 details of the hip are shown.

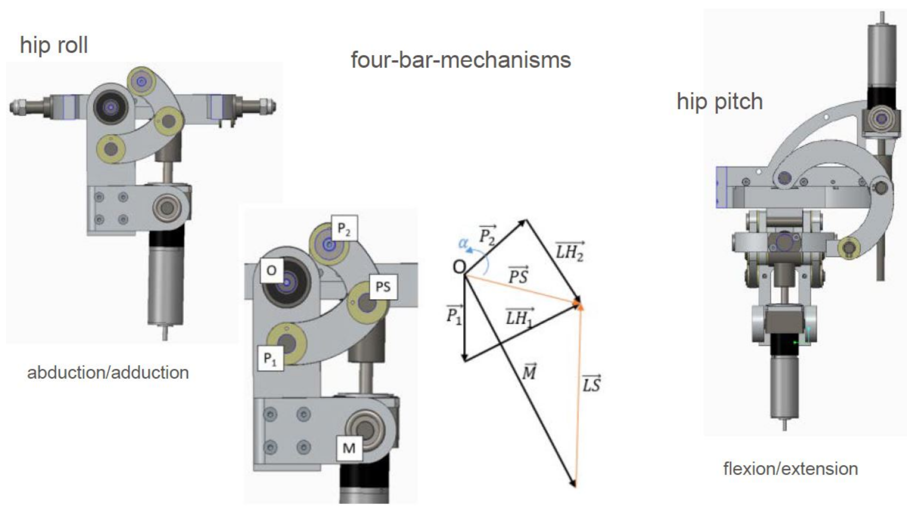

Fig. 1. Details of Sweaty's Hip [Fr1].

Hand The design of the hand was adopted from openbionics [Op1] and printed on a 3D-printer. For the fingers we use linear motors from Firgelli. The design of the hand is shown in Figure 2.

6-axis force and torque sensor For the force and torque sensors in the feet we adopted the idea of a sensor based on a *Maltese cross* [Yu1] to Sweaty's demands. The dimensions of the *Maltese cross* was optimized for the expected gait of Sweaty and the electronics were simplified by using time measurement of a capacitor instead of using a *Wheatstone Bridge* [Sch1]. The sensor including the electronics and its integration is shown in Figure 3, showing also the old foot on the right as comparison.

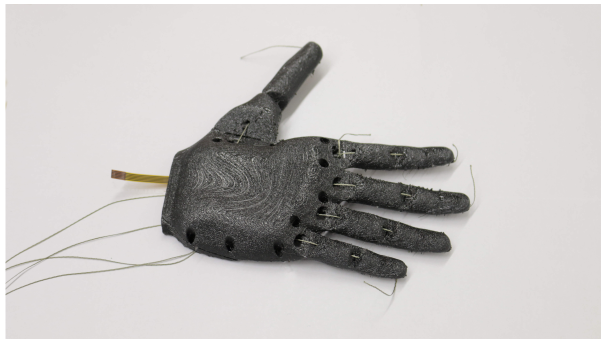

Fig. 2. Design of the hand (under construction, Nov. 2016).

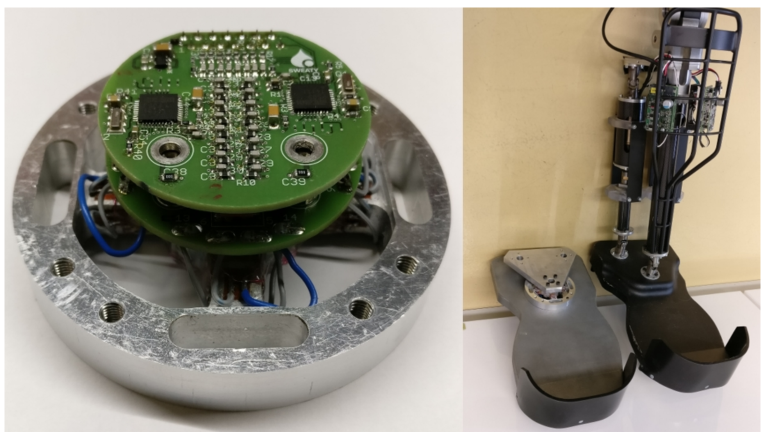

Fig. 3. New Sensor for Sweaty's ankle including the electronics (left) and integration of the new sensor (right) showing the new and the old foot for comparison.

2.2 Electrical layout

Hardware Architecture The architecture is illustrated in Figure 4. There is one main computer installed: decision, motion and vision programs are running in this machine, which is a high-end consumer PC.

For the communication with the servos and sensors there is a communication controller (STM32F4) installed, which gathers the information from the periphery and distributes the commands to the servos. The communication controller also synchronizes the servos with the main computer for the decision and motion. Each package sent to and from the communication controller includes a time-stamp so that there is no jitter. The communication with the motors in the legs, fingers and torso is done via CAN. For the communication with the motors for the arms and the head RS485 and PWM are used.

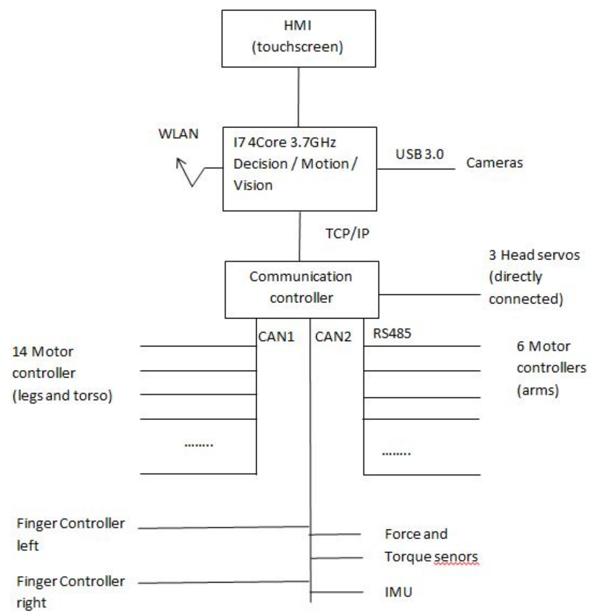

Fig. 4. Architecture of computers and controllers.

Hand A new hand controller is under development to connect the actuators of the finger to the CAN-Bus. Each hand controller consist of 5 H-bridges for the actuator as well as of a circuitry to measure the forces. Separate step-down circuits are foreseen to prevent an impact of the state of charge of the batteries on the behavior.

Torso, Leg and Foot Motor controllers are designed specially for Sweaty II: the voltage drop will be compensated as well as the temperature increase in the coil. The communication protocol is extended for setpoints and process values for positions, velocities, accelerations and external forces, therefore a state controller can be implemented in a later stage.

Power Supply There are two lithium batteries installed, 7S1P each. One battery is mainly for the computers and one for the actuators, therefore two main busbars are foreseen. The final discharge voltage of the batteries is 18.9 V and the charge cut-off voltage is 28.7 V. In addition the voltage of the batteries is also depending on the load due to the internal resistance of the battery (which increases when the state of charge decreases). The robot should move independently of the battery voltage. The fluctuation of the battery voltage is compensated by:

- The motor controllers for the legs and torso are designed so that the torque is independent of the actual voltage.

– Step-down converters are built to supply the other actuators with a constant voltage.
– Additional converters are built for the supply of the computers and the touch screen.

The connection of the two busbars is foreseen via special step-down converters without fly-back so that in case one battery has to be changed there is no need to shutdown the controllers and computers. Figure 5 shows the structure detail.

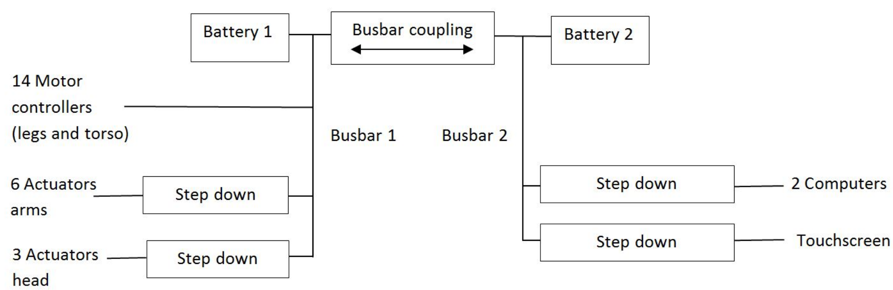

Fig. 5. Sweaty II's power supply.

3 Vision

The visual system of Sweaty has so far been placed in a 3D-printed aluminum support frame. This could be panned, tilted and rolled with three servo motors and two push-rods. This may be replaced by a simpler arrangement with two servo motors for pan and tilt, but with improved control and less slack in the movement. The support frame houses two RGB-cameras of type UI-3241LE-C operated at a resolution of 1280x1024. Each camera is equipped with a 4 mm lens. Up to now only one camera has been used for the detection of the field and the ball. In addition a inertial measurement unit (IMU) will be rigidly linked to the cameras. The IMU provides 3-axis accelerometer and 3-axis angular rate measurements. In this way the oculo-vestibular coupling of humans is imitated. A full size field of play is still available for testing. The artificial lawn (Greenfields FT XP 32) comes in a width of 4.12 m and the rolls are laid out across the field with alternating directions.

The vision software is based on openCV and uses criteria of homogeneity and color space to separate the field of play from the surrounding background. Within the field of play white areas are taken as candidates for the ball. The outer field lines are identified by the change in brightness. White line segments are distinguished by a shape criterion. If this method is applied to the full field of play a frame rate of 3 Hz results. The frame rate was increased to 15 Hz by limiting the ball search to a region around the ball's previous position. Tracking of the ball is possible for almost the whole field of play (see Fig. 6 from the RoboCup 2016 in Leipzig).

For the investigation of color thresholds and shape criteria tiles can be extracted from stand-still frames. With the help of four manually chosen reference points the field lines visible in the field of view are "superimposed" on the image. After this representative features of the field of play like lawn areas, straight lines, corners, T-junctions and X-junctions of lines et cetera are extracted. Similarly, tiles for different balls at different positions and also for the ball moving are stored. For the various categories of such tiles statistical analysis allows to pinpoint relevant detection criteria and cuts.

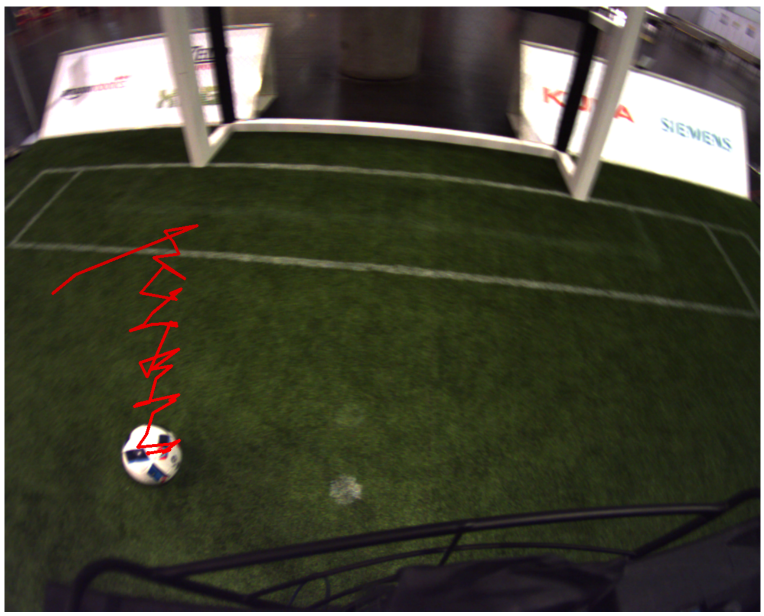

Fig. 6. Tracking the ball on the AdultSize League field at the RoboCup 2016.

4 Software

High level software The high level software for decision making and soccer playing is written in Java and commonly used for the 3D soccer simulation league team magmaOffenburg and our Sweaty II robot. It consists of a runtime and a set of tools to visualize the state of the robot and to designe strategies or motions.

Mid level software For the motion control we use Matlab/Simulink. Code is generated offline and downloaded to the PC. We use 6D foot trajectories to define walk or kick movements and use inverse kinematics to calculate the corresponding joint angles. Since our actuators use a rod and lever system, the joint angles have then to be mapped to motor angles. For some joints like the ankle this involves a two dimensional mapping of pitch and roll angles to two motor angles for the actuating part and vice versa for the sensing part. The communication to the high level software is done via TCP/IP, as well as the communication to the actuators and senors.

Low level software The software for the communication controller and for the motor controller is written in C. Basic routines for the controllers are adopted from STMicroelectronics, the LwIP-stack was adopted from Adam Dunkel and the software for the motor controllers was basically developped for other projects at the University of Offenburg.

5 Formals

- Referee: According to the rules our team will make a person with sufficient knowledge of the rules available as a referee.
- Previous Achievements: Sweaty II came 2$^{\text{nd}}$ place in RoboCup 2016. Sweaty I participated in RoboCup 2014 humanoid adult size league reaching 5th place.
- Use of Software: The software for decision making, modeling the environment and some tools are used from our own 3D soccer simulation team magmaOffenburg. The vision system uses openCV and ROS.
- Use of Hardware: We thank maxon motor GmbH for their sponsorship.

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Fig. 7. Sweaty Team 2016

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