Hambot

An Open Source Robot for RoboCup Soccer

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Abstract

Hambot was designed to give teams in the Humanoid League a low-cost possibility to upgrade from the currently used small robots to a larger platform. The whole robot was 3d printed with a consumer 3d printer, thus making production and further development possible for everyone. More degrees of freedom were introduced in the legs and waist to enable more human like walking, especially on artificial grass. In addition, multiple interaction possibilities, including a touch screen, were added to ease working with the robot. The complete hard- and software is open source to encourage usage and further development by other teams.

Introduction

Since the release of the Darwin-OP robot for the IEEE Humanoids Conference in 2010 there was not much development of hardware in the Humanoid League. Nearly all currently used platforms use the same structure as the Darwin-OP and are still expensive. Therefore we started developing our own robot platform, designed to be cheap, open source and usable in kid- and teen-size league. The first prototype, made out of sheet-metal, was developed in 2014 and was presented at the RoboCup world championship in Brazil. An improved second prototype was 3D-printed in early 2015 and tried at the Iran Open. Afterwards further improvements were done and a second robot was printed.

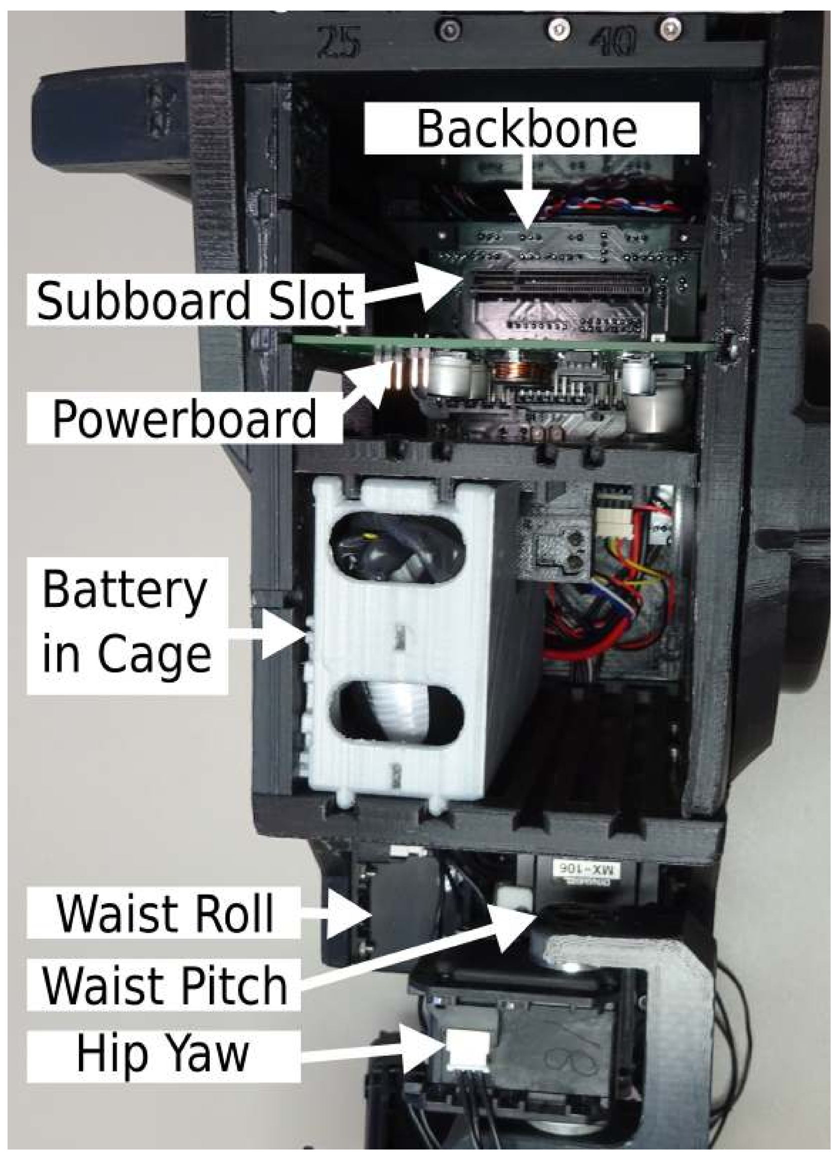

Figure 1: *View from the left side without cover. The subbboard and one of the batteries are missing. The newly introduced waist joint is visible at the bottom.*

Problems in the Humanoid League

From our point of view the RoboCup Humanoid League has currently the following problems:

- Almost just the same DOF-layout as the Darwin-OP
  - No movement in the torso, feet are only flat boards
- Robots are hard to build on your own
  - Need of expensive machines or materials, need of experience
- To much effort for maintenance
  - Battery change, chaotic cable management, part replacement
- Difficult to work with the robot
  - Sharp edges, no interaction or debug possibilities on the robot

Body Composition

Feet The capability to control the toes extends the feet by another DOF, potentially improving both walking stability and standing up movements. The toes can also be changed to enable a better high kick. They can be bend up to $90°$.

Legs The legs are designed in a pipe-like shape. This has advantages compared to the U-profile composition, which is often used with sheet metals. Cables are routed directly through these pipes, preventing abrasion of the wires. Besides, it looks more human and is more comfortable to touch and hold.

Waist An additional joint with two DOF has been added at the waist, which allows the robot to move its upper body independently from the legs. The joint should be similar to the lumbar spine and the lower thoracic spine of humans, but only in two directions. This flexibility is necessary for human walking because the upper body moves and rotates during every step [2]. With the roll axis of the new waist joint this movement is possible. Furthermore it allows to move the center of mass over the supporting leg during a kick. The pitch axis improves standing up and picking up the ball. With this joint we can move the upper body about $45°$ to left and right, $35°$ to the front and $12°$ to the back.

Torso The torso consists of a cage-like structure with detachable side plates for easy access. The upper torso holds the electronics and in the lower torso the batteries. Each battery has an own printed case which can be slid into the robot and locked with a bolt, thus enabling a fast change, approximately 13s for both batteries (Fig. 2). LEDs on the side are showing the current battery charge levels and which battery is currently used.

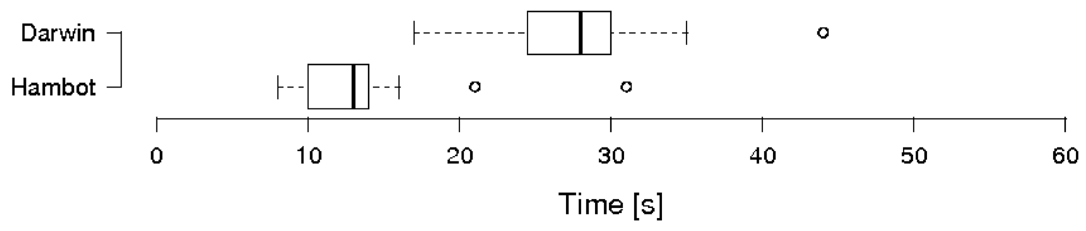

Figure 2: *Time for battery change, tested by a group of trained and untrained test persons. Median time: Darwin 28s, Hambot 13s.*

Electronics

The electronics consist of the main computer board (Odroid XU3 lite [1]), a power management board and a subboard, which controls the motors an other peripheral electronics. These two boards can be slided into a backbone board, which is located at the side of the robot and replaces the cables, which would normally run through the torso. Therefore, no cables are necessary inside the torso, which simplifies maintenance. The robot uses two standard 12V lithium polymer batteries, which can be hot swapped.

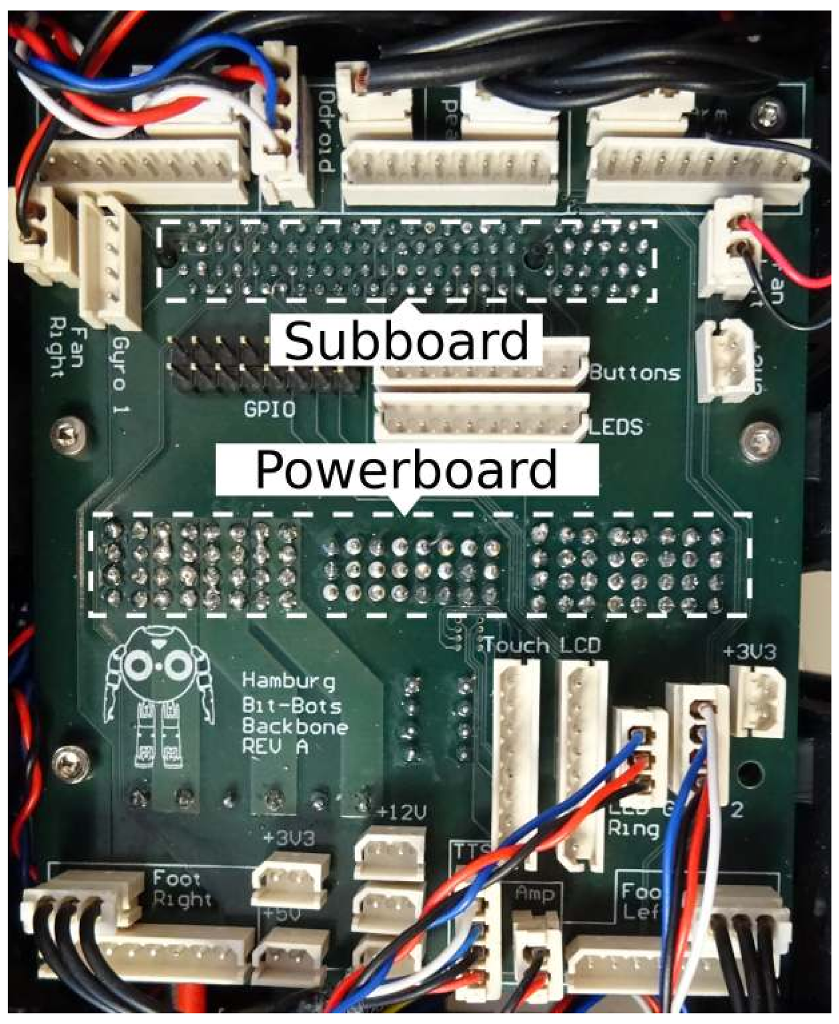

Figure 3: *View from the right side without cover. All cables are centrally connected to the backbone, resulting in a orderly layout. The connectors to the other boards and batteries are on the back.*

Interaction

The Hambot has eight free programmable buttons on the back, which are equipped with LEDs to indicate their state. There is a LCD touch display in the back for laptop free interaction. A ring of RGB LEDs is embedded into the front. Every LED can be individually controlled. This is handy to express the robots current beliefs, e.g. the position of the ball. The audio output is also used for debugging. Therefore, a dedicated text-to-speech chip and a speaker with a human resonance frequency is installed to ensure good speech quality.

3D Printing

All parts were designed to be printable with a low cost fused deposition modeling (FDM) consumer printer, e.g. Prusa i3 (~600 €). The two most used plastic print materials are acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA) which can be printed by almost all consumer printers. While it is possible to build the robot with both materials, ABS is preferred due to its better strength and heat resistance. The printing direction is important for the stability of prints. Therefore, all parts are printed in a direction that maximizes the plane between two layers and improves adhesion. Every part has a small arrow engraved on it to show in which direction it should be printed. Standard socket cap screws (ISO 4762 12.9) and nuts (ISO 4032) were used to connect the parts. Steel nuts are inserted into prepared holes and sealed with glue to obtain resistant threads. Thus all screws can be tightened without a wrench and the parts can be reassembled multiple times. The estimated print time for a complete Hambot is two weeks with a single consumer FDM printer. Parallel printing with multiple printers reduces this time.

Figure 4: *Example of a printed part with engraved information to simplify assembling. WB denotes the name of the part (waist bottom), V2 is the version, 8 indicates the required screw lengths (M2,5x8) and the little arrow shows the direction in which the part should be printed.*

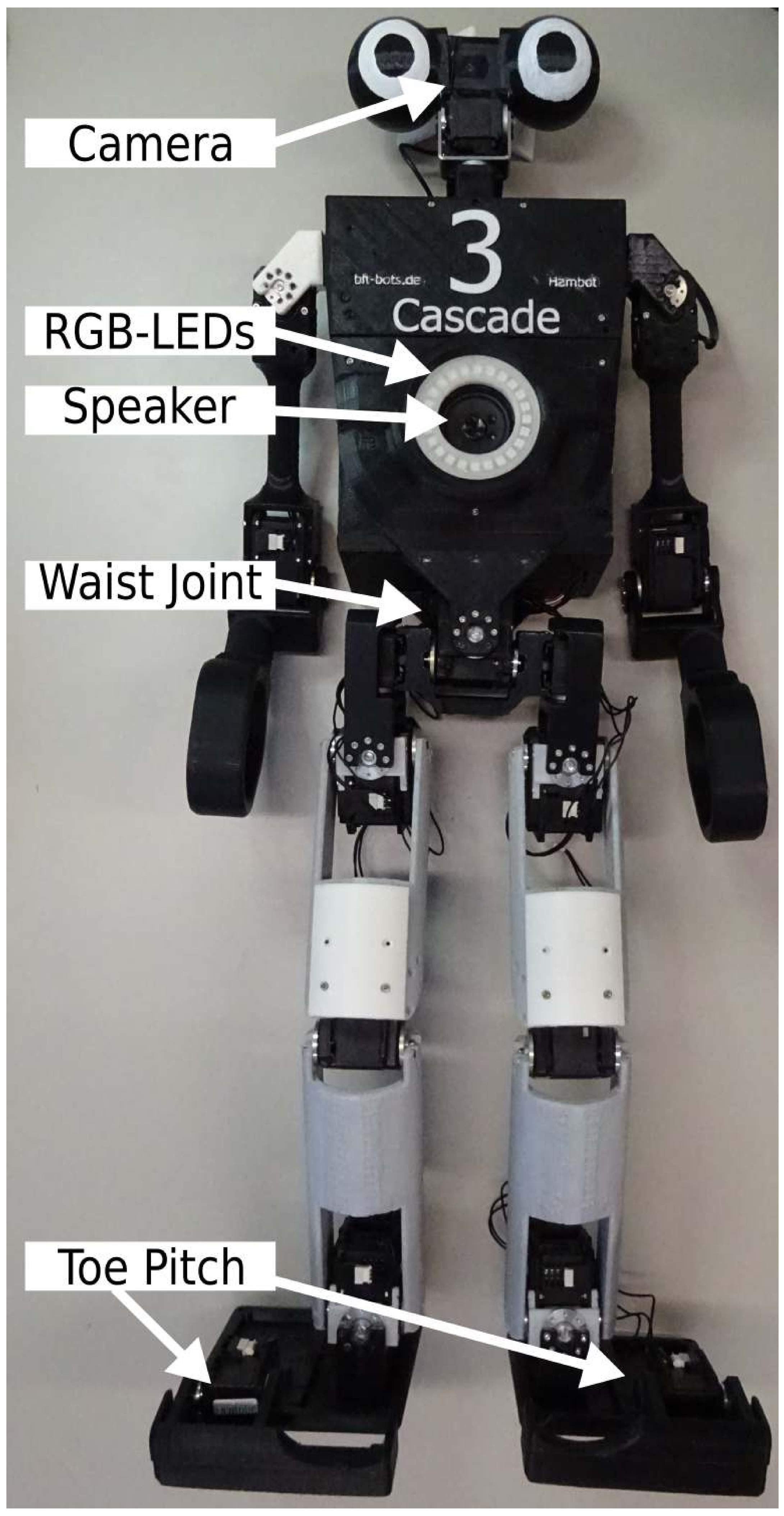

Figure 5: *A fully assembled Hambot.*

	Complete	Upgrade
Filament	100 €	100 €
Odroid XU3 lite	120 €	120 €
Logitech C910	60 €	60 €
Other electronics	550 €	550 €
Dynamixel servos	6800 €	3520 €
Total	7630 €	4350 €

Table 1: *Estimated hardware costs for one Hambot (**left**) and for an upgrade from a Darwin (**right**).*

Conclusion and Further Work

The Hambot is a low-cost platform for Humanoid Kid- and Teen-Size League. It's design and the 3D-printed nature lead to easy further hardware developments. Self production is easy and possible everywhere, because only a simple consumer 3D-printer is needed. The platform will be further developed by the Hamburg Bit-Bots. Our next steps include the development of more human feet and a better camera system with global shutter. But we highly encourage other teams to join our development and bring new ideas.

All necessary files and documentation can be found at: **https://github.com/bit-bots**

References

[1] Hardkernel co., Ltd. ODROID-XU3 Lite product specification, 2015.

[2] Simon Mochon and Thomas A McMahon. Ballistic walking. *Journal of biomechanics*, 13(1):49–57, 1980.

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