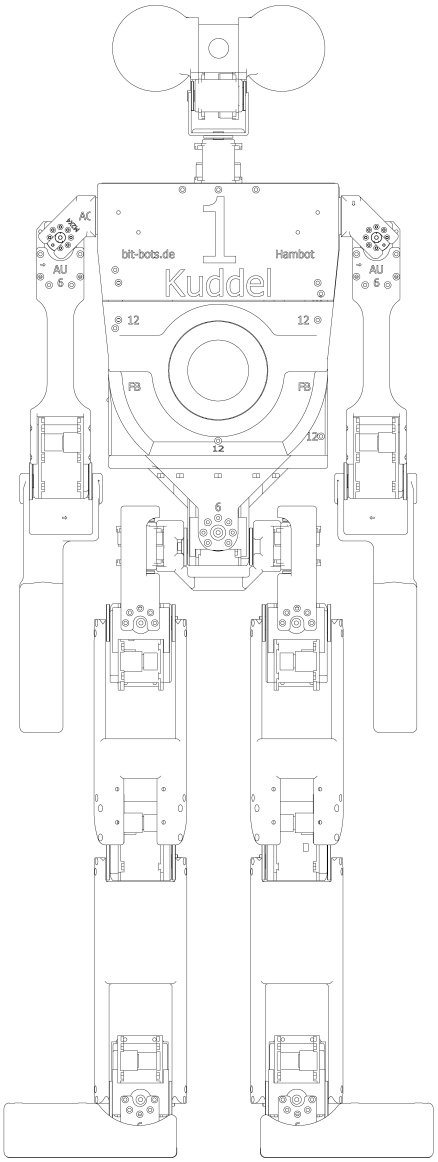
Hambot Documentation

Version 0.1



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Contents

This is a pre-version of the documentation. The pictures are still missing and some things will may change.

Chapter 1

Introduction

Hambot is a 87cm tall humanoid robot. Its main propose is the use in RoboCup Soccer but it can also be used in other research fields which are connected to humanoid robotic. This is the overall documentation for the robot.
For more details about the motors see *http://support.robotis.com/en/*.
The documentation for our electronic is available at *github.com/bit-bots/*.
There is also a paper called "Hambot: An Open Source Robot for RoboCup Soccer".

If you have any questions please write to *info@bit-bots.de*

1.1 Overall Layout

The Hambot is divided into eight section, which are easily separable: Head, shoulders, right arm, left arm, torso, waist, right leg, left leg. The right and left sides are also individually detachable to allow direct access to the electronics.

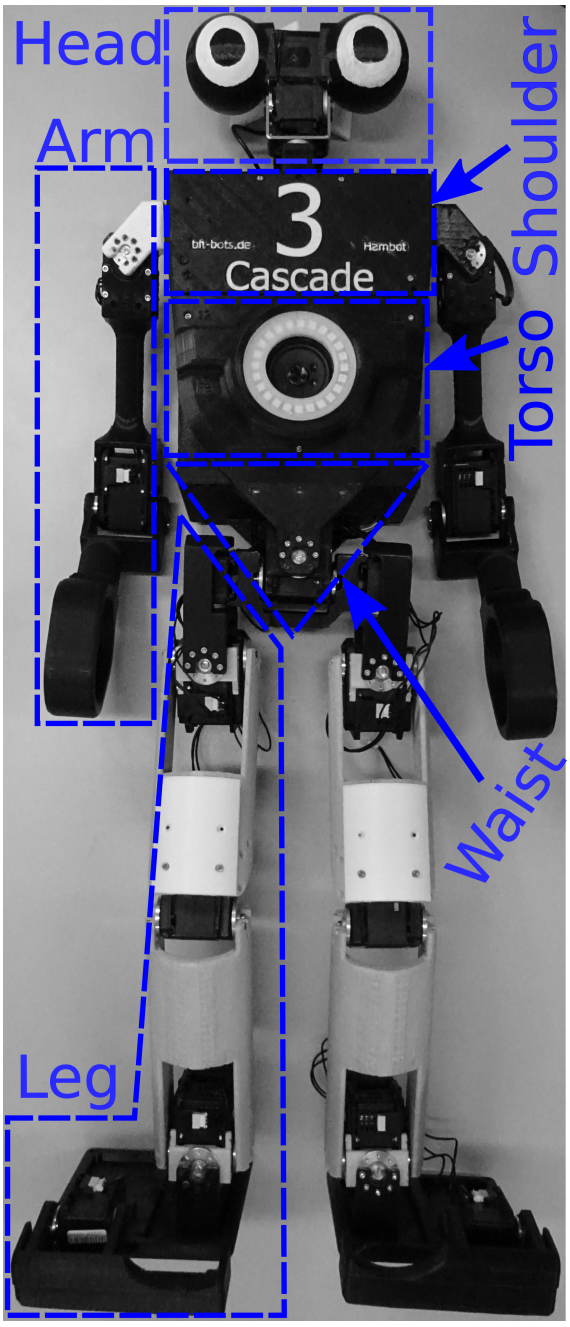


Figure 1.1: A fully assembled Hambot with marked sections.

ID	Name	Type
1	RShoulder Pitch	MX-64
2	LShoulder Pitch	MX-64
3	RShoulder Roll	MX-28
4	LShoulder Roll	MX-28
5	RElbow	MX-64
6	LElbow	MX-64
7	RHipYaw	MX-28
8	LHipYaw	MX-28
9	RHipRoll	MX-64
10	LHipRoll	MX-64
11	RHipPitch	MX-106
12	LHipPitch	MX-106
13	RKnee	MX-106
14	LKnee	MX-106
15	RAnklePitch	MX-64
16	LAnklePitch	MX-64
17	RAnkleRoll	MX-64
18	LAnkleRoll	MX-64
19	HeadPan	MX-28
20	HeadTilt	MX-28
27	RToe	MX-28
28	LToe	MX-28
29	WaistRoll	MX-64
30	WaistPitch	MX-106

Table 1.1: IDs, Names and Types of the Motors.

Chapter 2

Production

The production of a Hambot requires only a 3D printer and basic tools. The following chapter will tell you what tools and material you have to buy and guide you through the production process.

2.1 Required Tools and Material

2.1.1 3D Printer

First you need a 3D printer or access to one. I would recommend the purchase of at least one, because it is much easier if you have direct access to it. Also the price is relatively low compared to the total price. Basically any consumer printer is usable. But due to the size of some parts at least one printer with a build volume of 20x20x10 cm is needed.

There are many different possible printing materials available, even for consumer printer. The two most common are ABS (acrylonitrile butadiene styrene) and PLA (polylactic acid). While ABS is a bit harder and quite more heat resistant, PLA was also used successfully in a Hambot. Both have the same cost but PLA is easier to print. First tests with printed nylon were made and showed good results, especially in bonding between layers. But further tests are necessary to investigate the performance of nylon in Hambot. If you have results in this direction please share them.
Until now the Hambot was printed successfully on following printers (please add yours if you have used another one):

Ultimaker 2, RepRap Industrial

Some other cheap printers which should be able to print the Hambot, but were not tested yet:

Prusa i3, ...

Printer type	FDM
Build volume	20x20x10cm
Printable material	PLA or ABS (or Nylon)
Number of extruders	1 (2 is better)
Heatable print bed	If you print ABS

Table 2.1: Requirements for the printer.

SLS (selective laser sintering) should also work, but was not tested yet, because it is substantial more expensive.

2.1.2 Tools

Only basic tools are needed, which should be available in the next hardware store or online shop

- Hammer ca 500g
- Hexwrench 1.5, 2, 2.5
- Slotted screwdrivers, different small sizes
- Superglue / instant adhesive
- Gripper
- Rotary tool ("Dremel")
- File (maybe different sizes)

If you want to make the electronics on your own to, you will also need

- Soldering iron
- "Molex Spox" tongs
- Wire cutter
- Multimeter

2.1.3 Material

2.2 Production of the Parts

2.2.1 Slicing

In order to print the parts you have to slice them first to get the .gcode which is needed by any 3D printer. I recommend using Slic3r. It is open source, runs on all systems and is currently the most powerful free slicing engine.

Section	Name	Amount
Screws DIN 912 [1]		
	M2 X 4	100
	M2,5 X 6	100
	M2,5 X 8	150
	M2,5 X 10	100
	M2,5 X 12	100
	M2,5 X 16	50
	M2,5 X 20	50
	M2,5 Nut	500
	M3 X 6	50
	M3 X 12	50
	M3 Nut	50
Robotis Dynamixel		
	MX-28	8
	MX-64	10
	MX-106	4
	HN05-1	12
	HN07-i101	5
Electronics		
	Odroid XU3-lite	1
	Subboard or CM730	1
	Powerboard	1
	NeoPixel Ring 24*	1
	Speaker*	1
	MPU 6050	1
	Amplifier*	1
	Language chip*	1
	USB Wifi dongle	1
	Logitech C910	1
	Fan 30x30mm	2
	Buttons*	8
	Tamiya Crimp Male	6
	3-cell LiPo with Tamiya connector	2

Table 2.2: Needed materials for one Hambot. See the documentation of the custom boards, if you want to build them on your own. Parts marked with * are not absolutely necessary. The amount of screws is roughly estimated. More explicit information about some parts will follow soon.

Section	Name	Abbreviation	Quantity	Support	Infill
Head	Head Eye Left	HEL	1	No	30
	Head Eye Right	HER	1	No	30
	Head Connector	HC	1	No	70
Shoulders	Shoulder Top	ST	1	No	70
	Shoulder Bottom	SB	1	No	70
	Shoulder U3_Spacer	SU	4	No	100
Back	Back Cover	BC	1	No	70
	Back Number	BN	1	No	30
	Back Handle	BH	1	10	70
Front	Front Top	FT	1	No	50
	Front Bottom	FB	1	10	50
	Front Teammarker	FM	2	No	30
	Front Speaker	FS	1	No	100
	Front Ringholder	FR	1	No	100
	Front Defuser	FD	1	No	30
Torso	Torso Front	TF	1	No	70
	Torso Back	TB	1	No	70
	Torso Left	TL	1	No	50
	Torso Right	TR	1	10	50
	Torso Battery Bar	TA	3	No	100
	Torso Center	TC	1	No	70
	Torso Plug	TP	1	No	30
Arm	Arm Connector	AC	2	No	100
	Arm Upper	AU	2	30	70
	Arm Lower Left	ALL	1	10	70
	Arm Lower Right	ALR	1	10	70
Waist	Waist Top	WT	1	No	70
	Waist Front	WF	1	No	70
	Waist Back	WA	1	No	70
	Waist Bottom	WB	1	10	70
	Waist Bearing	WE	1	10	100
	Waist Center	WC	1	30	100
Leg	Leg Yaw Connector Left	LYL	1	No	70
	Leg Yaw Connector Right	LYR	1	No	70
	Leg Upper	LU	2	30	70
	Leg Lower	LL	2	30	70
	Leg Roll Connector	LR	8	10	100
	Leg Bearing	LB	4	10	100
	Leg Foot Connector	LC	2	No	70
	Leg Foot Left	LFF	1	No	70
	Leg Foot Right	LFR	1	No	70
	Leg Toes Left	LTL	1	30	70
	Leg Toes Right	LTR	1	30	70
	Leg Teammarker	LT	2	30	30
Battery	Battery Cage	CC	>2	60	70
	Battery Lid	CL	>2	No	70

Table 2.3: Table of 3D printed parts.

Printing with support structure takes fundamentally more effort, because the holes for the screws and nuts have to be cleared manually. Try the settings from table 2.3, even if it looks not possible for the printer. They will (at least in Slic3r) provide good results. The support structure will maybe be modeled manually in the future. If you have a printer with dual extrusion, you can also use dissolvable filament in the second extruder for the support structure. I would recommend HIPS when printing ABS and PVA for printing with PLA. For more detailed information about Slic3r look at *http://slic3r.org/*

2.2.2 Post-Processing

After printing a bit of work is needed before using the parts. First any support structure and brim has to be removed. Then deburr the edges. Redrill all screw holes with either a drill or a screwdriver to ensure that the screw shaft and head have enough space to fit fully in the part. Remove any material that is still present in the holes for the nuts. Insert nuts in all holes (except for the *Bearing* parts, see section 2.2.2) and put screws in them. Pay attention that the screw is long enough to go completely through the nut. Then use a low viscous glue, e.g. superglue. The glue should flow into the holes and fix the nut in its place, but not fix the screw into the nut or fill the thread. Wait until the glue is completely dry and unscrew the screws. Now your part is ready for a long time of use.

Special Parts

Some parts need additional work to prepare them.

Torso Plug Insert into each hole a male Tamiya crimp with an attached cable. The cable should be around 15 cm and should be large enough for 10A continuous load. The other end of the cable has to be uninsulated because it will be inserted into the *Backbone*.

Waist Bearing and Leg Bearing Mount a *Robotis HN05-i1* bearing on the front and fix it with a M3x12 screw and a M3 Nut.

Chapter 3

Assembly

In this section you will learn to assemble the Hambot. Please prepare all parts like explained in section 2.

Note: If you use the RS485 version of the Dynamixel motors (e.g. MX-64R), replace all TTL cables with RS485 cables.

Attention: Generally all motor horns have to face into the front or inside direction when assembling. The direction of the three points have to be like it is shown on the parts.

3.1 Parts

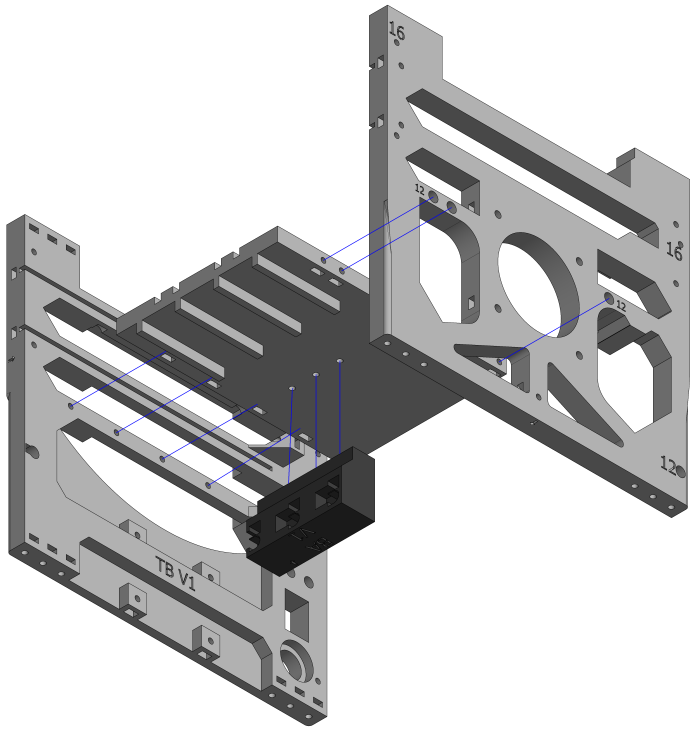
We will assemble the different parts of the robot. At the beginning of each step is a table with the needed parts for this step. Then follows a description of the actions with pictures to as an illustration.

3.1.1 Torso

	Part		No.
Printed	Torso Front	TF	1
	Torso Back	TB	1
	Torso Center	TC	1
	Torso Plug	TP	1
Electronics	Backbone Board		1
	Power Switch		1
	Power Outlet		1

The torso consists out of three main parts: *Front*, *Back* and *Center*. These build a cage like structure which is the center of the robot and will be normally never be disassembled. We will only assemble this at the beginning to have better access during the assembly. The rest will be assembled at the end.

First assemble the *Torso Plug* with the *Torso Center* . Use the three holes in the *Torso Center* to install the Plug so that it is on the same side like the railing.



Fix the *Power Switch* and *Power Outlet* in the *Torso Back* and add wires to the *Power Outlet*. Now assemble the Front and the Center as shown in the picture. Finally assemble also the *Torso Back* . Now the mechanical structure is complete. The *Backbone* can be installed. Therefore screw the board in the shown direction into its place and connect the wires from the *Power Outlet*. Also connect the wires from the *Torso Plug* to the *Power Switch* and then to the *Backbone*.

3.1.2 Shoulders

	Part		No.
Printed	Shoulder Top	ST	1
	Shoulder Bottom	SB	1
	Shoulder U3_Spacer	SU	4
Motors	MX-64		2
	TTL cable	25cm	2
Electronics	U3 Board		1

First use the *Spacers* to assemble the *U3 Board* to the *Shoulder Top* . The LAN-port has to face the outside. Plug the cables into the MX-64s and assemble them to the *Torso Back* . Assemble the *Shoulder Top* on the motors. Finally assemble the finished shoulder section to the torso and connect the TTL cable to the *Backbone* (arm left and arm right).

3.1.3 Waist

	Part		No.
Printed	Waist Top	WT	1
	Waist Front	WF	1
	Waist Back	WA	1
	Waist Bottom	WB	1
	Waist Bearing	WE	1
	Waist Center	WC	1
Motors	MX-64		1
	MX-106		1
	TTL cable	10cm	2
Electronics	MPU 6050		1
	MPU Cable	10cm	1

First assemble the *MPU 6050* into the predefined hole in the *Waist Top* . Then fix the *Waist Back* and *Waist Front* on *Waist Top* . Connect the motors with the *Waist Center* and add the *Waist Bearing* . Fix the *Waist Bottom* to the MX-106 motor. Finally assemble the finished waist section to the torso and connect the TTL cable to the *Backbone* (right leg and left leg).

3.1.4 Front

	Part		No.
Printed	Front Top	FT	1
	Front Bottom	FB	1
	Front Speaker	FS	1
	Front Ringholder	FR	1
	Front Defuser	FD	1
Electronics	NeoPixel Ring 24		1
	Speaker		1
	Language Chip		1
	Amplifier		1

Fix the *Language Chip* and the *Amplifier* inside the torso with glue and connect them (Note: This will be changed in the next version to a direct assembly on the *Backbone*). Assemble the *Front Speaker* and the *Speaker* into the *Torso Front* . Insert the *NeoPixel Ring* in the *Front Defuser* and glue the *Front Ringholder* on the back. Fix the *Front Ringholder* on the *Front Speaker* . Finally screw the *Front Bottom* and the *Front Top* to the *Torso Front* .

3.1.5 Back

	Part		No.
Printed	Back Cover	BC	1
	Back Number	BN	1
	Back Handle	BH	1
Electronics	Button		8
	LCD Board		1

Assemble the *Back Handle* and the *LCD Board* to the *Back Cover* . Assemble the result to the *Torso Back* .

3.1.6 Head

	Part		No.
Printed	Head Eye Left	HEL	1
	Head Eye Right	HER	1
	Head Connector	HC	1
Motors	MX-28		2
Electronics	Camera C901		1
	TTL Cable	15cm	1
	TTL Cable	10cm	1

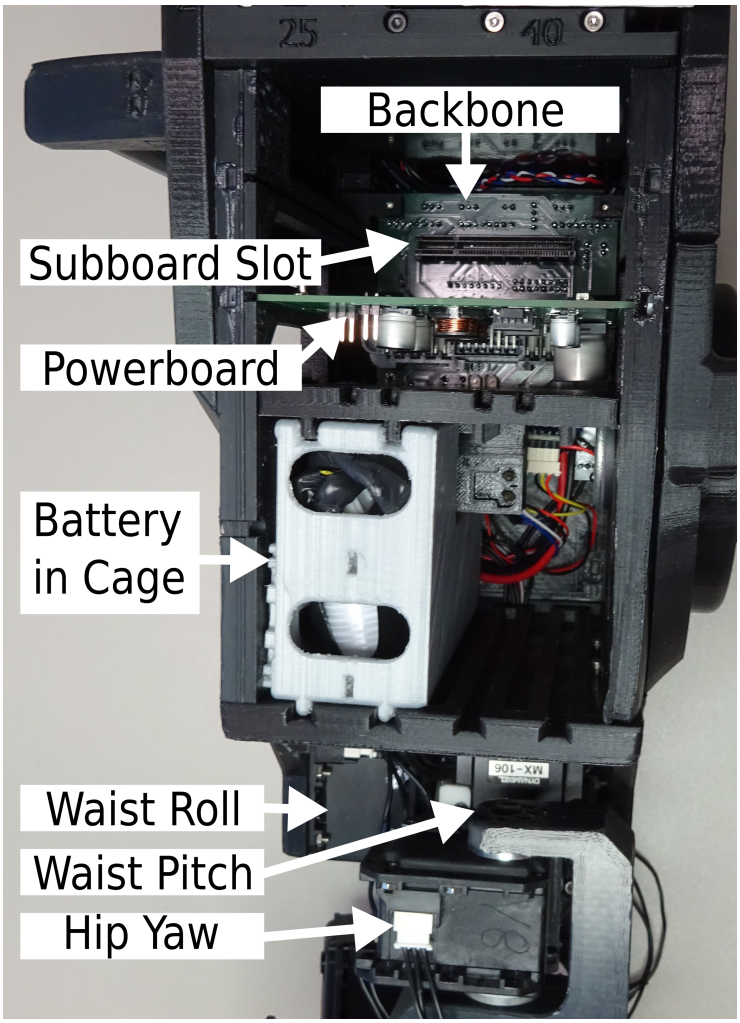


Figure 3.1: View from the left side without cover. The subbboard and one of the batteries are missing. The newly introduced waist joint is visible at the bottom.

Assemble the two motors with the *Head Connector* and connect them with the 10cm TTL cable. Mount the camera on the upper motor. Fix the two eyes around the camera. Finally assemble the product to *Shoulder Top* . Connect the lower motor with the 15cm TTL cable to the *Backbone* (head). The USB cable of the camera is directly plugged into the Odroid U3.

3.1.7 Arms

	Part		No.
Printed	Arm Upper	AU	2
	Arm Lower Left	ALL	1
	Arm Lower Right	ALR	1
	Arm Connector	AC	2
Motors	MX-28		2
	MX-64		2
Electronics	TTL Cable	15cm	2
	TTL Cable	10cm	2

Connect the MX-64 with *Arm Lower Left* and *Arm Upper* . Put the 15cm TTL cable through *Arm Upper* and connect it. Assemble the MX-28 on *Arm Upper* and then the *Arm Connector* on the MX-28. Then fix the other side of the *Arm Connector* to the MX-64 motor in the shoulder section. Assemble the right arm accordingly.

3.1.8 Legs

	Part		No.
Printed	Leg Yaw Connector Left	LYL	1
	Leg Yaw Connector Right	LYR	1
	Leg Upper	LU	2
	Leg Lower	LL	2
	Leg Roll	LR	2
	Leg Bearing	LB	4
	Leg Foot Connector	LC	8
	Leg Foot Left	LFL	1
	Leg Foot Right	LFR	1
	Leg Toes Left	LTL	1
	Leg Toes Right	LTR	1
Motors	MX-28		4
	MX-64		6
	MX-106		4
Electronics	TTL Cable	15cm	1
	TTL Cable	10cm	1

Assemble one MX-104 with a *Leg Bearing* and two *Leg Roll Connector* like it is shown in the picture. Connect one MX-28 motor inside the *Leg Yaw Connector Left* and attach a MX-64 on the back of *Leg Yaw Connector Left* . Now assemble the MX-106 with the *Leg Bearing* and *Leg Roll Connector* to the *Leg Yaw Connector Left* . Fix the *Leg Upper* on the MX-106 and connect another MX-106 on the other side of the *Leg Upper* . Connect the *Leg Lower* to the knee motor. Assemble the *Leg Foot Connector* to a MX-64. Assemble a MX-64 with a *Leg Bearing* and two *Leg Foot Connector* . Connect this to the *Leg Foot Connector* . Connect this to the *Leg Lower* and the *Leg Foot Left* . Connect the *Leg Toe Left* to a MX-28 and assemble it on the *Leg Foot Left* .

The finished leg can be connected to *Waist Bottom* . Do this a second time for the right leg.

3.1.9 Battery

	Part		No.
Printed	Battery Cage	CC	1
	Battery Lid	CL	1
Electronics	3-cell LiPo Battery		1

Store the battery in the *Battery Cage* and put the Tamiya plug in the hole, so that the connector is fixed. Assemble the lid onto the battery. Be careful to don't act pressure onto the battery. The lid should only prevent the battery from falling out and not push the battery. Do this another time for the second battery.

3.1.10 Completion

	Part		No.
Printed	Torso Right	TR	1
	Torso Left	TL	1
	Torso Battery Bar	TA	1
Electronics	3-cell LiPo Battery		1

To complete the assembly the side plates of the torso have to be assembled. Make sure all cables inside the robot are connected and assemble the side plates. Then insert the two *Battery Cage* with batteries inside the torso and fix them with the *Torso Battery Bar* . Therefore the *Torso Battery Bar* has to be inserted and then turned in counter clockwise orientation. If you want you can also add the *Teammarker* to the robot. Congratulations, your Hambot is finished! You can try to turn it on.

Chapter 4

Software

You can run your own software on the Hambot, if you want to, or you can use our framework, which is open source.

4.0.11 Own Software

We recommend to use our Debian system image available at:
http://data.bit-bots.de/1503-goal.img.tar.gz
You can also use another version of Linux but this is much more work. Then you can access it via *ssh* and run your code. For more information regarding the communication with the subboard, please have a look at the documentation of the subboard.

4.0.12 Hamburg Bit-Bots Framework

You can also use the open source framework of the Hamburg Bit-Bots. The newest version will be released after the world championship. In the near future we will change to ROS and provide normal ROS packages for the use of the Hambot. If you want to know how far we are, please write us at *info@bit-bots.de*.

Chapter 5

Development

Content for this section will be provided soon.
If you have any suggestions, critic or questions please email to:
info@bit-bots.de.