# Project Ballbot

**Florian MÃijller**
**Markus Lamprecht**
**Michael Suffel**

TECHNISCHE UNIVERSITÄT DARMSTADT

TU Darmstadt, RTM

## Inhaltsverzeichnis

## 1 Item - List

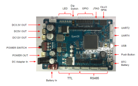
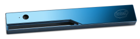
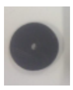
| Item | # | W.[g] | Weblink | Picture |
|---|---|---|---|---|
| OpenCR Board (Controlling the motors, IMU) | 1 | 60 | *github_wiki* |  |
| UpBoard (Main PC) | 1 | 96 | *127€* |  |
| Intel RealSense R200 | 1 | 9.4 | *datasheet, 84.15€* |  |
| Laser Distance Sensor | 1 | 124 | *specs, 100€* |  |
| Battery: LI-PO 11.1 1800mAh LB-12 19 | 1 | 132 | *44.90€* |  |
| Turtlebot3 Layers() | 4 | | | |
| XM430-W350-R Dynamixel (Motors) | 3 | 72 | *robotis,250€* |  |
| Ball(alum., dia.: 140mm, material thickness 2.5mm) | 1 | 400 | *ball-tech gmbh,40€.* |  |
| Omni wheels(dia: 60mm, thickness:25mm) | 3 | 46 | *10.38€* |  |
| Kreisring (PLA, 3D printeted) | 1 | 28 | |   |
| Halterung (PLA, 3D printeted) | 3 | 18 | |  |
| Mitnehmer (PLA, 3D printeted) | 3 | 8 | |  |
| Plain washer (Beilagscheibe),(PLA, 3D printeted) | 3 | 0.8 | |  |
| M3 (Mutter-Halterung-Kreisring-Layer) | 9 | | | |
| M2.5 (Kreisring-Layer) | 2 | | | |
| M3x8mm Halterung | 6 | | Zylinderkopf (Imbus) | |
| M3x22mm Layer | 3 | | Zylinderkopf (Imbus) | |
| M2.5x22 (Motoren-Halterung) | 12 | | Sechskant | |
| M2.5x38 (Motoren-Rad) | 3 | | Zylinderkopf (Imbus) | |
| M2.5x24 (Layer) | 2 | | Zylinderkopf (Imbus) | |
| M2x6mm (Mitnehmer-Motor) | 12 | | Zylinderkopf (Imbus) | |

**Tabelle 1.1:** My caption

| Type | Size | Amount | Place |
|---|---|---|---|
| Cylinderhead screw | M3 x 11mm | 8 | Motor mounts |
| Cylinderhead screw | M2,5 x 22mm | 16 | Motor plate |
| Cylinderhead screw | M2 x 6 mm | 18 | Wheel shaft |
| Cylinderhead screw | M2,5 x 36 mm (38 mm) | 5 | Wheel shaft cover |
| Cylinderhead screw | M3 x 20 mm (21mm) | 4 | Layer mounting |
| Nut | M2 | 5 | Layer mounting |
| Cylinderhead screw | M2,5 x 22mm (23mm) | 4 | Layer mounting |

**Total Cost: 1176€ + Cost of opencr board and all plastic (incl. tb3 structure) and scrwes**
TODO:

1. Abmessungen von einer struckture layer
2. upboard1-link noch eintragen

## 2 Simulation

### 2.1 Launch

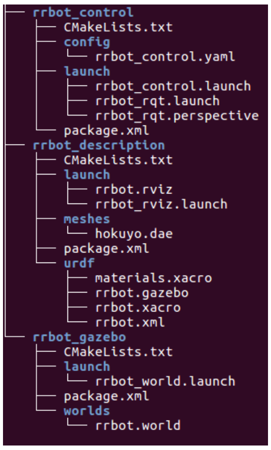
These files are executed one after another:

1. bb_simulation: ballbot.launch
2. bb_description: bb_description.launch
3. bb_description -> urdf: bb.xacro
4. bb_description -> urdf: bb.urdf.xacro
5. bb_description -> urdf: common_properties.xacro
6. bb_description -> urdf: bb.gazebo.xacro

### 2.2 Simulation design

Ballbot SDF Reference: *Ballbotmodel*

We use not the sdf but the xacro description as in this example *here*.




Gazebo uses different physics engines:

- Open Dynamics Engine (ODE) (Default)
- Bullet
- Dynamic Animation and Robotics Toolkit (DART)
- Simbody

which all have different friction etc. models.

Files:

- bb.urdf.xacro: Link's: Visual description of the Robot and its collision model(STL file). Pose Mass and Inertias. Joint's: Pose,axis,effort and velocity limits, friction.

- common_properties.xacro: Macros for color definition.
- bb.gazebo.xacro: gazebo references dynamics of the links: friction parameters (mu1,mu2),

Gazebo Parameter's List:

| name(xacro) | description | value | sdf group |
|---|---|---|---|
| mu1 | is the Coulomb friction coefficient for the first friction direction | 1.0 | ode |
| mu2 | is the friction coefficient for the second friction direction (perpendicular to the first friction direction) | 2.0 | ode |
| kp | spring constant equivalents of a contact as a function of SurfaceParams::cfm and SurfaceParams::erp | | ode |
| kd | spring damping constant equivalents of a contact as a function of SurfaceParams::cfm and SurfaceParams::erp. | | ode |
| cfm | Constraint Force Mixing parameter. | | ode |
| erp | Error Reduction Parameter. | | ode |
| min_depth | Minimum depth before ERP takes effect. | | ode |
| max_Vel | Maximum interpenetration error correction velocity. If set to 0, two objects interpenetrating each other will not be pushed apart. | | ode |
| slip1 | Artificial contact slip in the primary friction direction | | ode |
| slip2 | Artificial contact slip in the secondary friction dirction. | | ode |

See: *ODESurfaceParams*

## 2.3 Gazebo Parameters

```
git@git.sim.informatik.tu-darmstadt.de:TurtleBot/jsonlab.git
git@git.sim.informatik.tu-darmstadt.de:TurtleBot/octave_rosbridge.git
```

## 2.4 Control

sobald diff drive plugin angeschaltet drehen sich die raeder viel zu schnell ....

### 2.4.1 Plugins

- gazebo-ros-control
- diff drive

### 2.4.2 Launch

```
roslaunch rrbot_control rrbot_control.launch
```

These files are executed one after another:

1. load config
2. controller_spawner

## 2.5 Sensors

### 2.5.1 IMU

We want to simulate the IMU of the opencr board. STRG+T to see imu topic values! *Imu of opencr board simulated*

Simulate like this: rviz rviz dann als fixed frame nimm: imu_link. Und add topic imu und waehle als topic ballbot/sensor/imu

bbbb

## 3 Model

### 3.1 Composition

The Ballbot consists of three parts, which are depicted in Figure 3.1.

- Body with motors
- 3 omni-directional wheels
- Ball

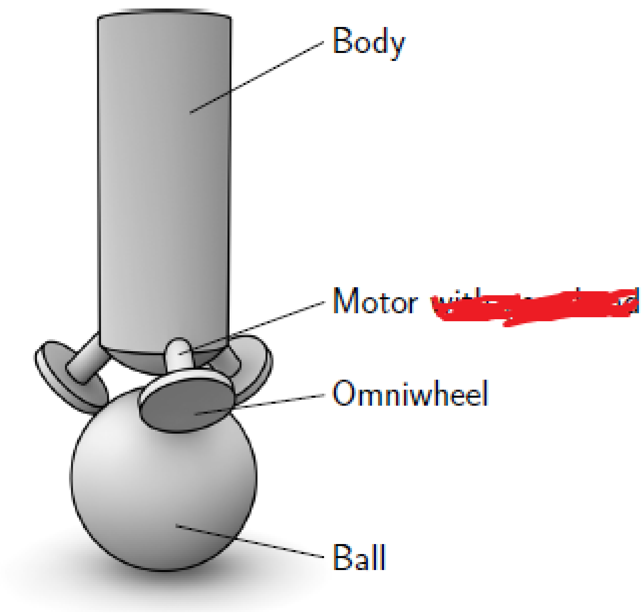



**Abbildung 3.1:** Parts for the 3D-Model

### 3.2 Assumptions

To reduce the complexity of the system, the following assumptions are made:

- **No slip** between the contact points between the ball/ground and wheels/ball
- **No friction**; except the friction, which occurs at the rotation of the ball around the z-axis
- **No deformation**
- **Fast motor dynamics**; The controlling of the motor is much faster than the controller of the Ballbot
- **Ball moves only horizontal**

### 3.3 Model Parameters

**Tabelle 3.1:** My caption

| Parameter | Variable | Value | Source |
|---|---|---|---|
| Mass of the ball | $m_K$ | 0,4 $kg$ | Datasheet |
| Mass of the body | $m_B$ | 1,646 $kg$ | SolidEdge |
| Mass of the virtual wheel | $m_{VW}$ | 0,384 $kg$ | Measured |
| Radius of the ball | $r_K$ | 0,07 $m$ | Datasheet |
| Radius of the body | $r_B$ | 0,0703 $m$ | Measured |
| Radius of the Wheels | $r_W$ | 0,03 $m$ | Datasheet |
| Height of the center of gravity | $l$ | 0,24045 $m$ | SolidEdge |
| Height of the body | $h$ | 0,34294 $m$ | SolidEdge |
| Inertia of the Ball | $\Theta_K$ | 0,00131 $kgm^2$ | Computed |
| Inertia of the Body (x-axis) | $\Theta_{Bx}$ | 0,08751 $kgm^2$ | SolidEdge |
| Inertia of the Body (y-axis) | $\Theta_{By}$ | 0,08788 $kgm^2$ | SolidEdge |
| Inertia of the body (z-axis) | $\Theta_{Bz}$ | 0,00329 $kgm^2$ | SolidEdge |
| Inertia of the body (xy plane) | $\Theta_{Bxy}$ | -0,00001 $kgm^2$ | SolidEdge |
| Inertia of the body (xz plane) | $\Theta_{Bxz}$ | 0,00203 $kgm^2$ | SolidEdge |
| Inertia of the body(zy plane) | $\Theta_{Bzy}$ | 0,00018 $kgm^2$ | SolidEdge |
| Gear ratio | $i$ | 353,5 | Datasheet |
| Gravitational acceleration | $g$ | 9,81 $m/s^2$ | BachelorThesis |