Project Ballbot

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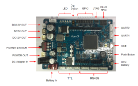
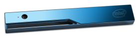
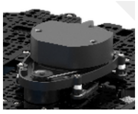
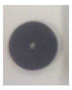
Inhaltsverzeichnis

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(125cmx125cm)	4			
XM430-W350-R Dynamixel (Motors)	3	82	robotis,250€	
Ball(alum., dia.: 140mm, material thickness 2.5mm)	1	400	ball-tech gmbh,40€ .	
Omni wheels(dia: 60mm, thickness:25mm)	3	51.46	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	0.45		
M3 (Mutter-Halterung-Kreisring-Layer)	9			
M2.5 (Kreisring-Layer)	2			
M3x8mm Halterung	6		Zylinderkopf (Imbus)	
M3x22mm Layer	3	1.34	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)	
Distanzbolzen	???		???	

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

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

TODO:

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

2 Simulation

TODO: check if controller works
check why imu fails

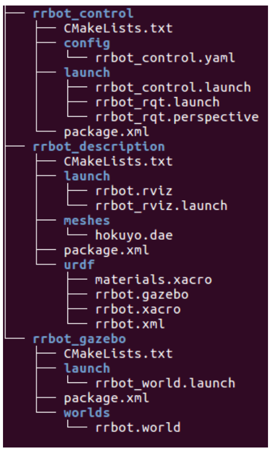
2.1 Launch

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
fdir1	3-tuple specifying direction of mu1 in the collision local reference frame.	0 0 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

Urdf Parameter's List: JOINT TAGS:

name(xacro tag)	description	value
axis	this is the axis around the joint is revolting or linear	xyz="0 1 0"
dynamics	set the friction and the damping	friction="0.7" damping = "0.0"

2.3 Gazebo Parameters

2.4 Control

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

Diff Drive in ballbot.launch an oder ausschalten.

in bb.gazebo.xacro transmission und controller festlegen.

zudem yaml file(currently I use: effort_controllers/JointVelocityController)

Effort Joint Interface as Hardware Interface is used.

Do this example first: `http://gazebosim.org/tutorials/?tut=ros_control`

Also try this bb8 gazebo tutorial: `https://www.youtube.com/watch?v=j5qC9l448p8`

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

The simulated IMU outputs values like: orientation (x,y,z,w), angluar velocity(x,y,z), linear velocity(x,y,z), linear acceleration(x,y,z).

The opencr real IMU gives values like: orientation(x,y,z,w), angular velocity(x,y,z), linear acceleration(x,y,z) see http://turtlebot3.readthedocs.io/en/latest/appendix_opencr.html

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

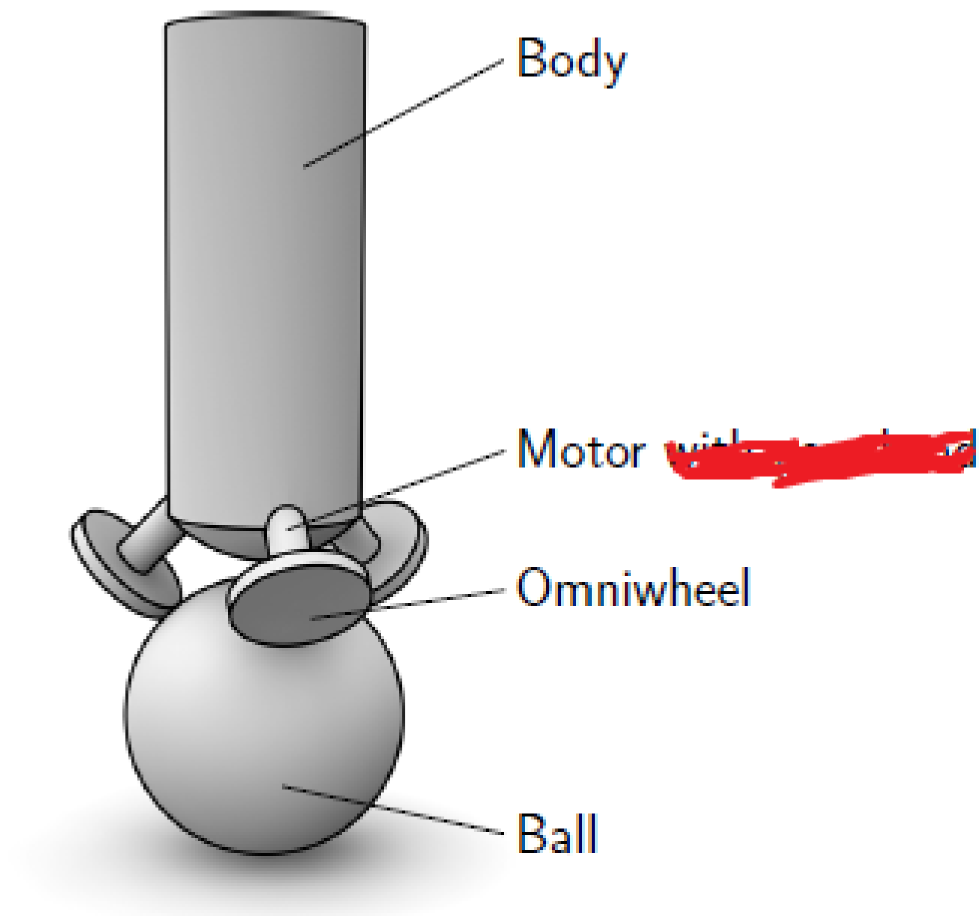


Abbildung 3.1: Parts for the 3D-Model

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

Traegheitsmoment kugel Hohlzylinder: $J = m\frac{r_i^2+r_a^2}{2} = 0.4 * \frac{65^2+70^2}{2} kg * 10^{-6} m^2 = 1.825 * 10^{-3} kgm^2$
Traegheitsmoment wheel Vollzylinder: $J = m\frac{1}{2}r^2 = 0.05146 * 0.020^2 = 1.0292 * 10^{-4} kgm^2$

Tabelle 3.1: My caption

Parameter	Variable	Value	Source
Mass of the ball	m_K	0,4 kg	Datasheet
Mass of the ball	m_K	0,397 kg	Measured
Mass of the ball	m_K	0,631 kg	SolidEdge
Mass of the body, complete (with motors/wheels)	m_B	?	Measured
Mass of the body, complete (with motors/wheels)	m_B	1,785 kg	SolidEdge
Mass of the body (without motors/wheels)	m_B	?	Measured
Mass of the body (without motors/wheels)	m_B	1,394 kg	SolidEdge
Mass of Omniwheel	m_{OW}	0,050 kg	Measured
Mass of Omniwheel	m_{OW}	0,046 kg	SolidEdge
Mass of the virtual wheel	m_{VW}	0,384 kg	Measured
Mass of the substructure, complete (with motors/wheels)	m_S	0,506 kg	Measured
Mass of the substructure, complete (with motors/wheels)	m_S	0,457 kg	SolidEdge
Mass of plate	m_P	0,078 kg	Measured
Mass of plate	m_P	?	SolidEdge
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	Θ_K	0,00131 kgm^2	Computed
Inertia of the Body (x-axis)	Θ_{Bx}	0,08751 kgm^2	SolidEdge
Inertia of the Body (y-axis)	Θ_{By}	0,08788 kgm^2	SolidEdge
Inertia of the body (z-axis)	Θ_{Bz}	0,00329 kgm^2	SolidEdge
Inertia of the body (xy plane)	Θ_{Bxy}	-0,00001 kgm^2	SolidEdge
Inertia of the body (xz plane)	Θ_{Bxz}	0,00203 kgm^2	SolidEdge
Inertia of the body(zy plane)	Θ_{Bzy}	0,00018 kgm^2	SolidEdge
Inertia of the rotor (motor)	Θ_M	0,444e-6 kgm^2	Adoption
Inertia of Omniwheel	Θ_{OW}	0.000023157 kgm^2	Computed
Inertia of the actuating wheel in yz/xz	Θ_W	0,058873 kgm^2	Computed
Inertia of the actuating wheel in xy	Θ_{Wxy}	0,16656 kgm^2	Computed
Gear ratio	i	353,5	Datasheet
Gravitational acceleration	g	9,81 m/s^2	BachelorThesis