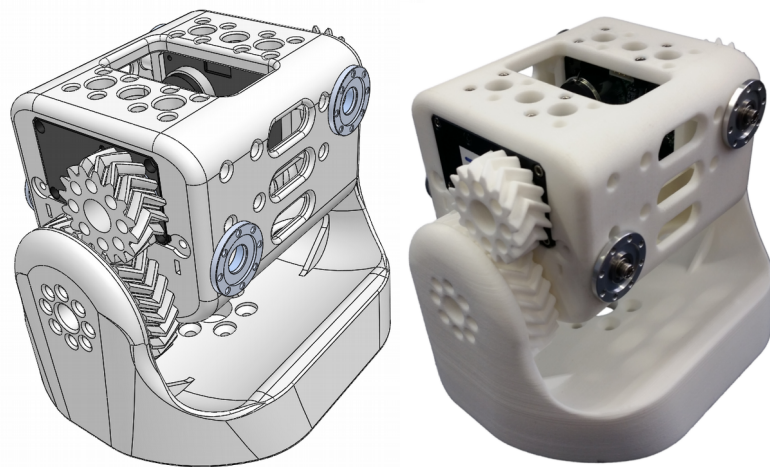
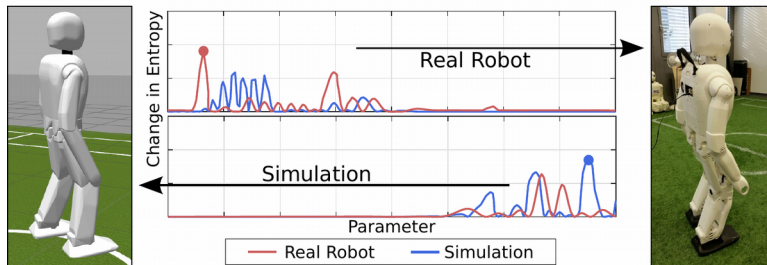
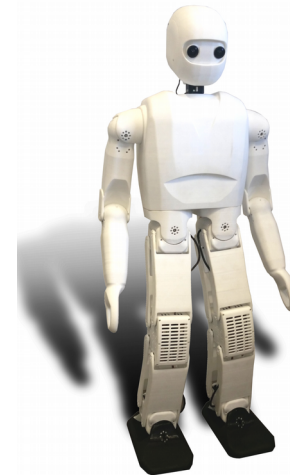
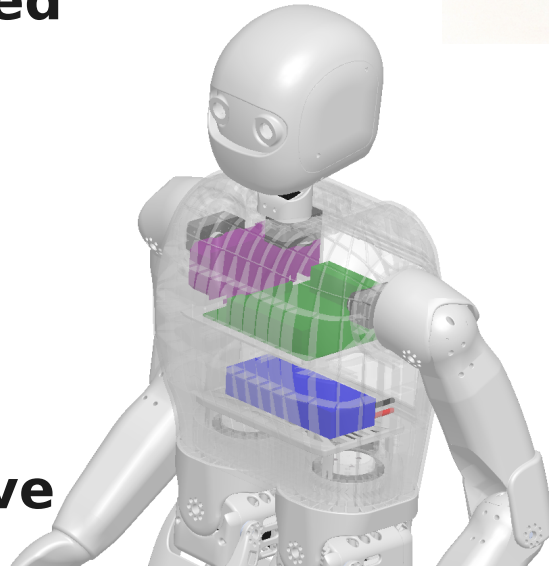
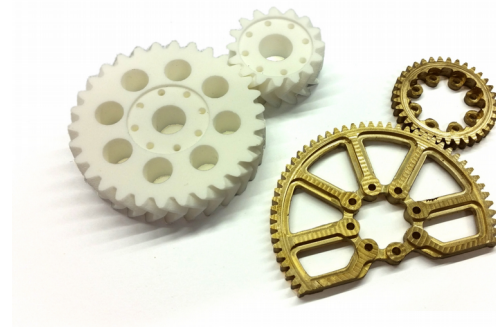


# NimbRo-OP2X: Adult-sized Open-source 3D Printed Humanoid Robot



# Main hardware features

- off-the-shelf components
- standard miniITX PC
- GPU-enabled
- completely 3D printed structure
- parallel kinematics
- tried and tested
- open source
- modifiable
- relatively inexpensive

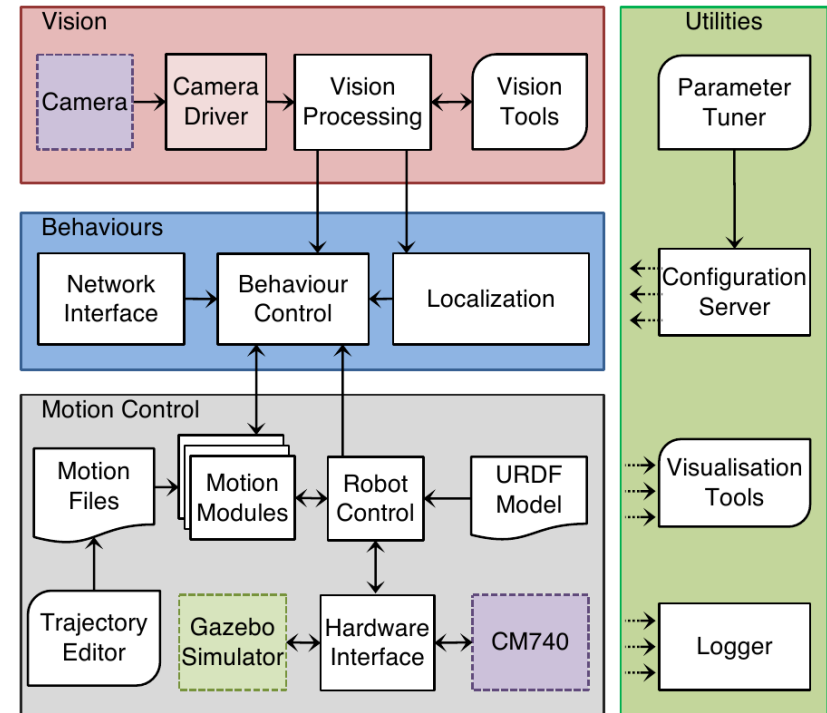


# Hardware specifications

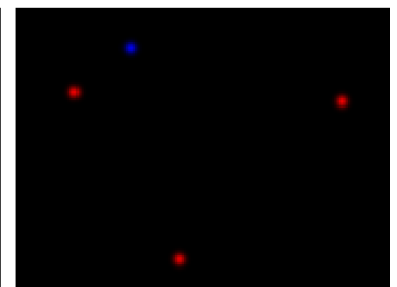
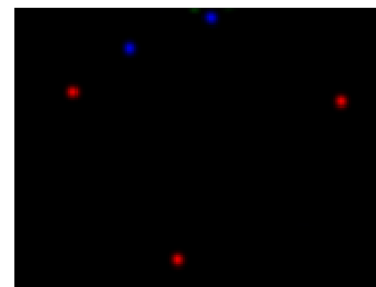
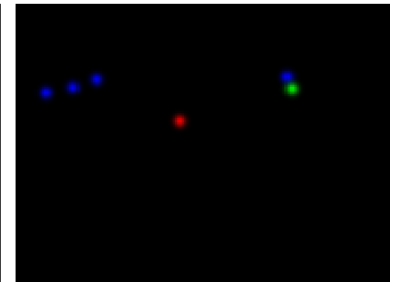
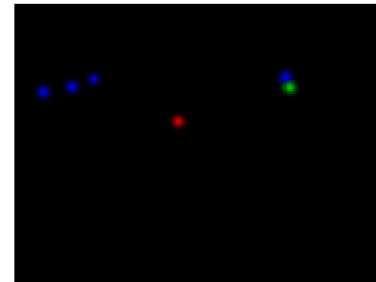
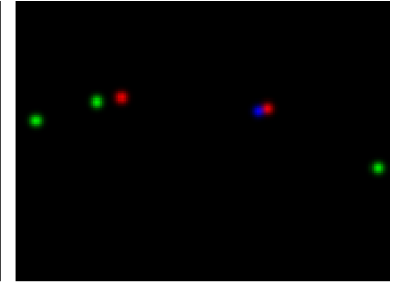
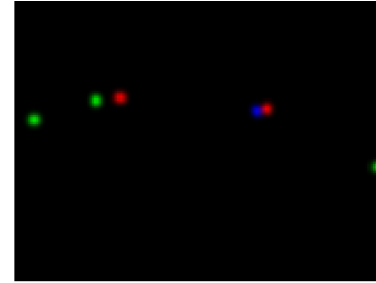
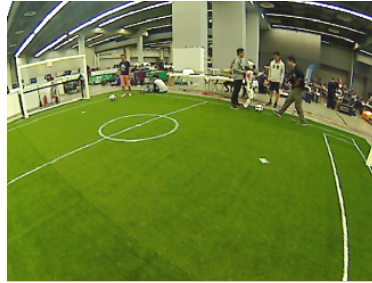
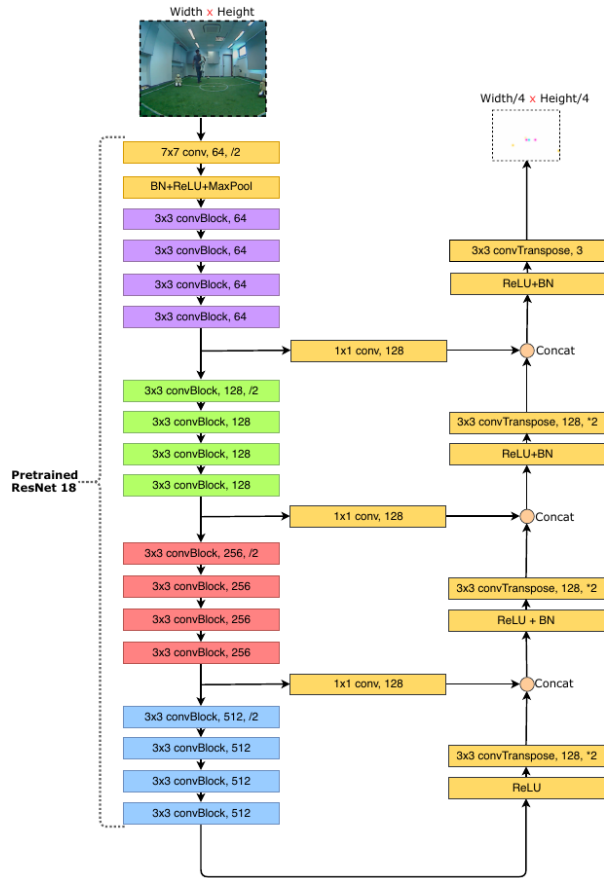
Type	Specification	Value
General	Height & Weight	135 cm, 19 kg
	Battery	4-cell LiPo (14.8 V, 8.0 Ah)
	Battery life	20–40 min
	Material	Polyamide 12 (PA12)
PC	Mainboard	Z370 Chipset, Mini-ITX
	CPU	Intel Core i7-8700T, 2.7–4.0 GHz
	GPU	GTX 1050 Ti, 768 CUDA Cores
	Memory	4 GB DDR4 RAM, 120 GB SSD
	Network	Ethernet, Wi-Fi, Bluetooth
	Other	8 × USB 3.1, 2 × HDMI, DisplayPort
Actuators	Total	34 × Robotis XM-540-W270-R
	Stall torque	12.9 Nm
	No load speed	37 rpm
	Control mode	Torque, Velocity, Position, Multi-turn
Sensors	Encoders	12 bit/rev
	Joint torque	12 bit
	Gyroscope	3-axis (L3G4200D chip)
	Accelerometer	3-axis (LIS331DLH chip)
	Camera	Logitech C905 (720p)
	Camera lens	Wide-angle lens with 150° FOV

# Main software features

- ROS-based open source software
- modular framework
- optimized omnidirectional gait
- compliant servo-actuation
- attitude estimator
- motion designer
- Gazebo simulator
- CNN-based vision

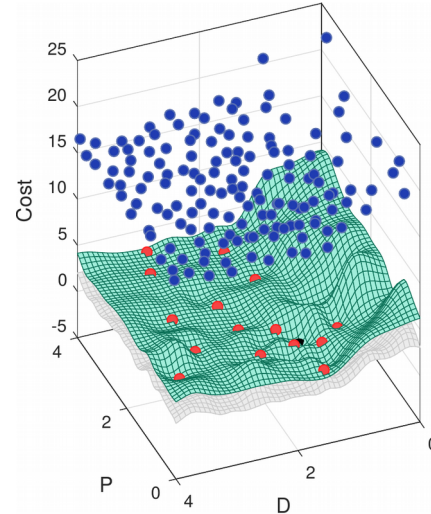
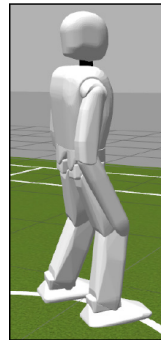
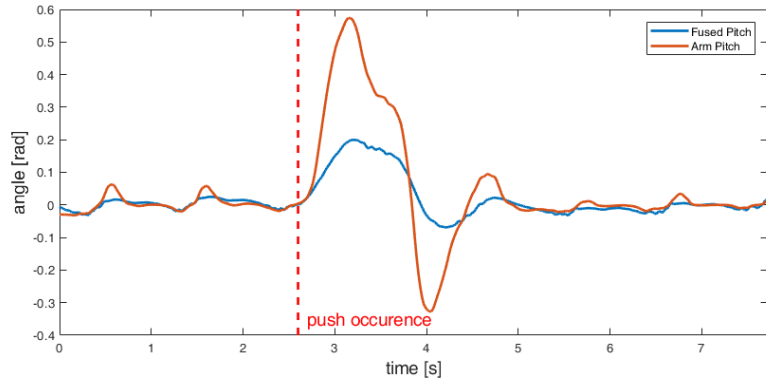


# CNN-based vision



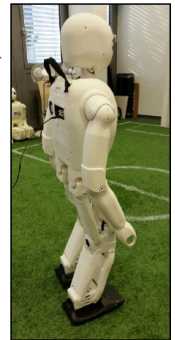
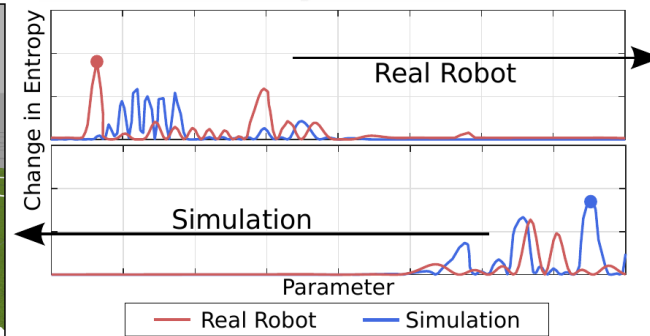
# Optimized omnidirectional gait

- speeds of up to 0.5m/s
- tuning not required
- parameters are a result of combining simulation and real world experiment results



$$J_{\alpha}(\mathbf{x}) = \int_0^T \|e_{P\alpha}(\mathbf{x})\|_1 dt + \nu(\mathbf{x})$$

$$J_{\beta}(\mathbf{x}) = \int_0^T \|e_{P\beta}(\mathbf{x})\|_1 dt + \nu(\mathbf{x})$$





# Performance

- RoboCup 2018 Soccer Competition winner
- RoboCup 2018 Technical Challenge winner
- RoboCup 2018 Best Humanoid Award winner

