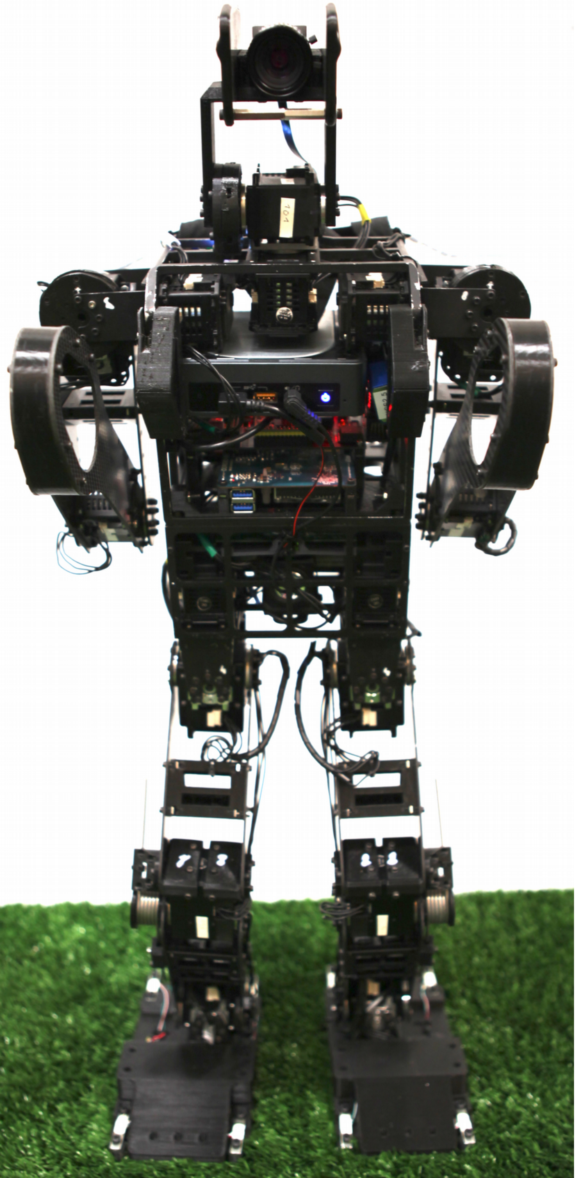
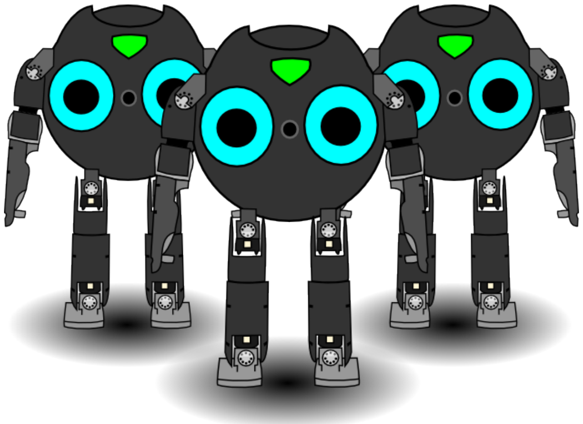


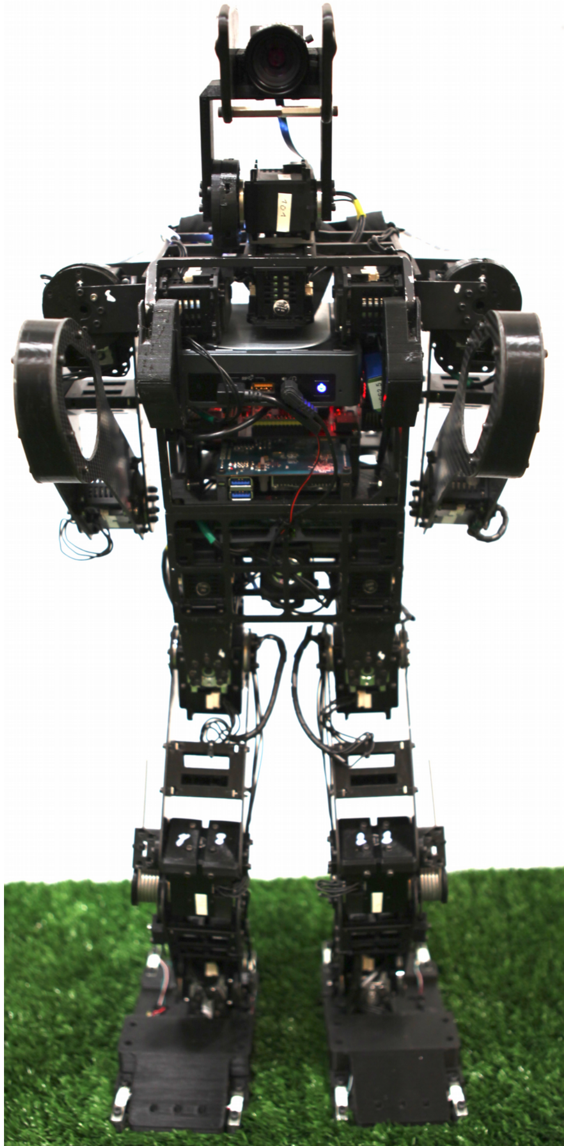
Hamburg Bit-Bots Wolfgang OP

Jasper Güldenstein



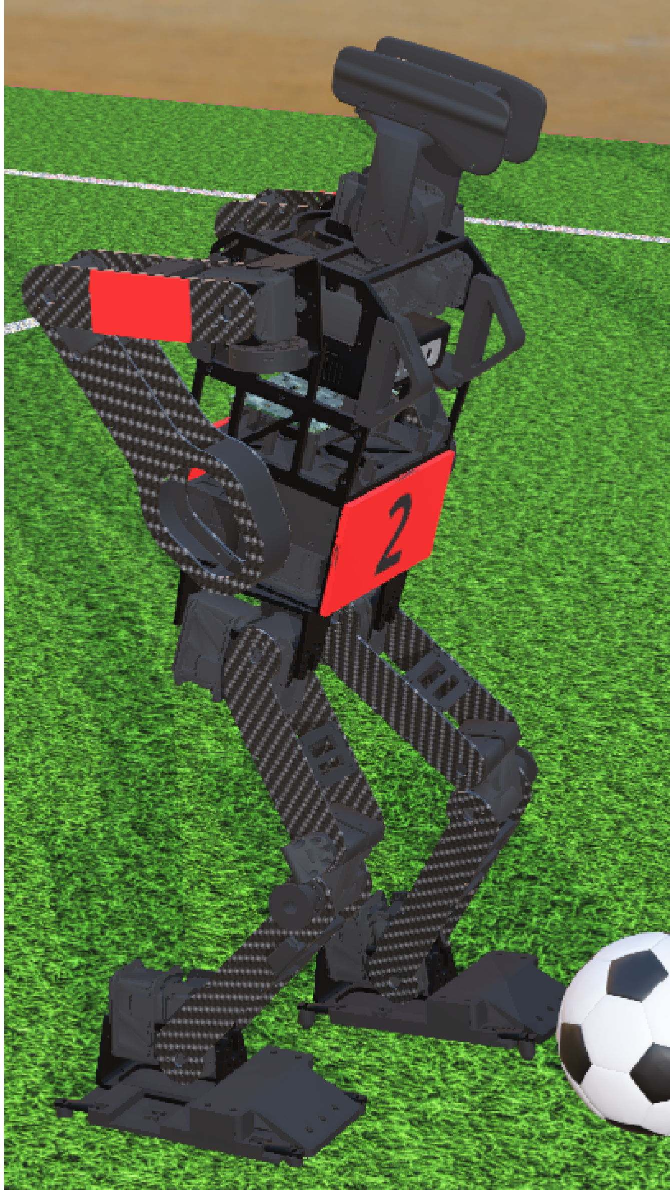
Real World Wolfgang OP

- 20 DOF Humanoid Robot
- Descendant of the Nimbro OP
- 3D printed elastic elements
- Parallel Elastic Actuator (PEA) in the knees
- Focus on robustness
- 715 Hz Control loop
- Publications
  - Wolfgang-OP: A Robust Humanoid Robot Platform for Research and Competitions (Humanoids 2021)
  - High-Frequency Multi Bus Servo and Sensor Communication Using the Dynamixel Protocol (Robocup Symposium 2019)



Wolfgang OP Simulation Model

- Fully Open Source
- Modeled after real robot
  - Actuators
  - PEA
  - IMUs
  - Force Sensors
- Onshape → URDF → PROTO
  - Accurate physical properties
- Full Bounding Objects collision



Wolfgang OP Simulation Model

- Fully Open Source
- Modeled after real robotfile
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  - PEA
  - IMUs
  - Force Sensors
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  - Accurate physical properties
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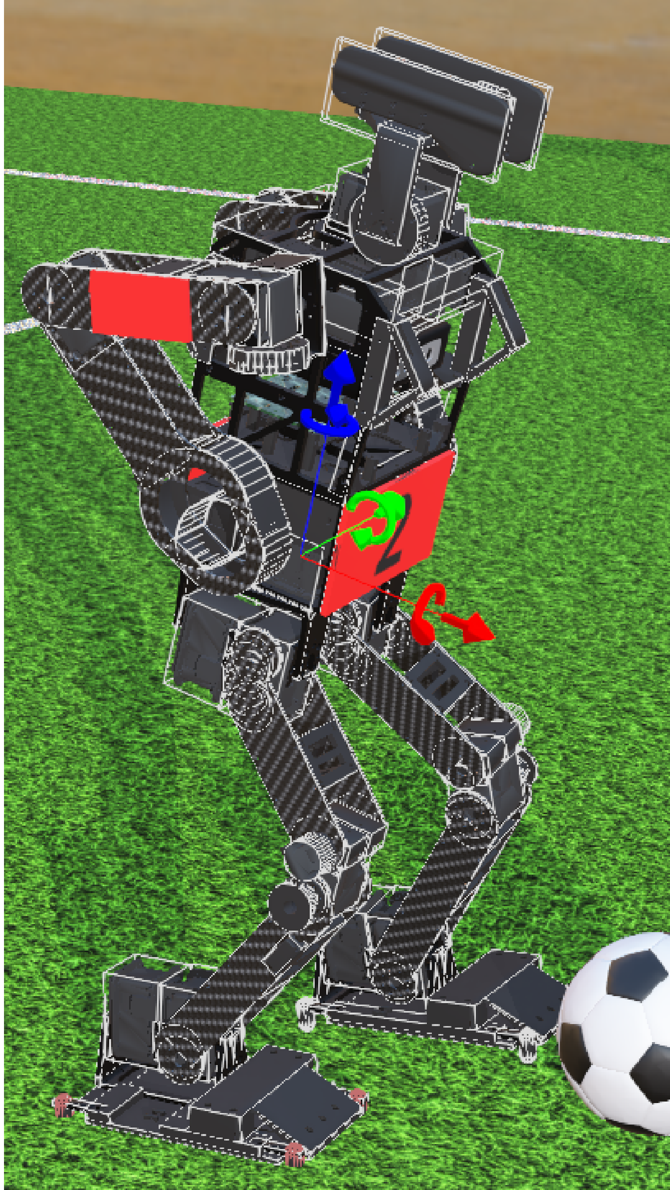
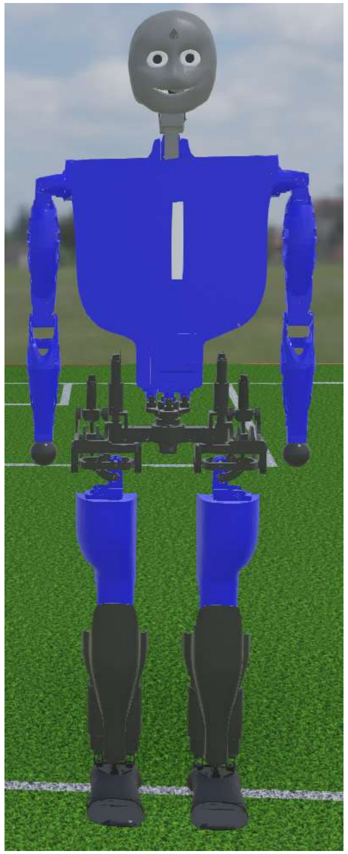


Contributions to the league

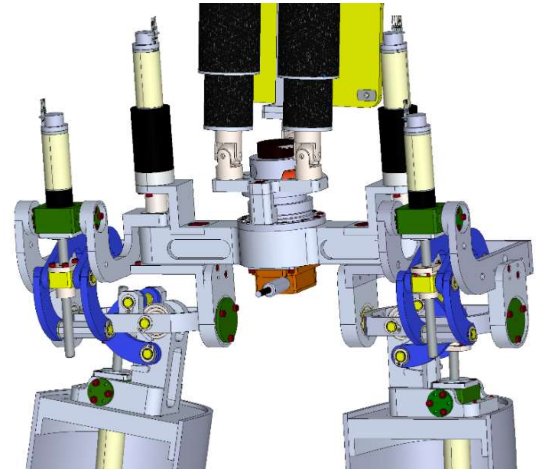
- Strong involvement in model specifications
- 2 tools for creating collision models
  - Manual 3D model → Bounding object
  - Automatic rotated bounding boxes
- Several contributions to urdf2webots

Robot Model - Team Sweaty

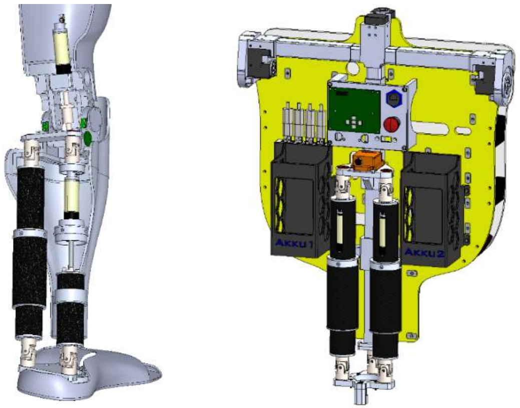
Contribution for the Best Robot Model Award in RoboCup 2021



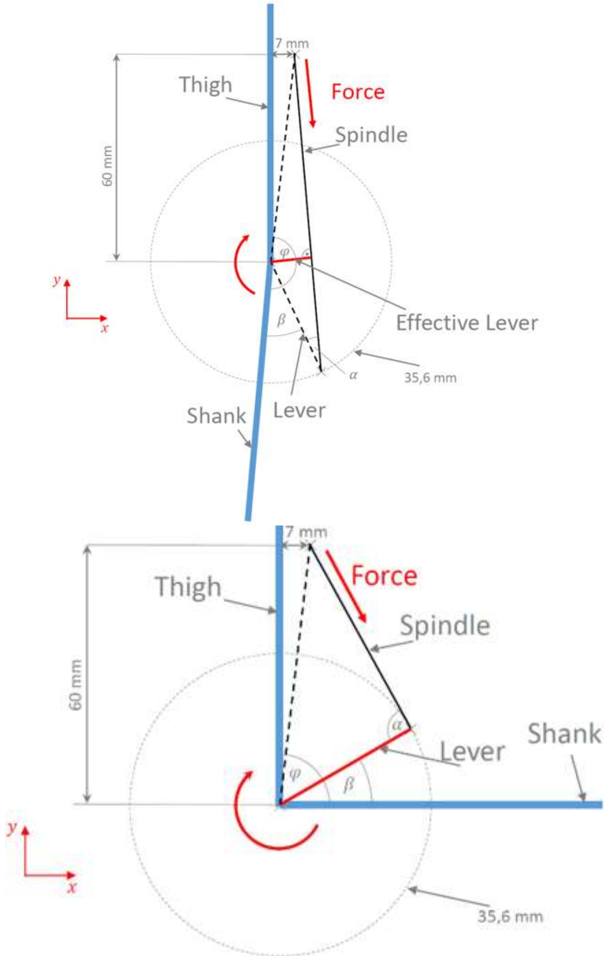
Coupling Mechanism for high torque and low backlash

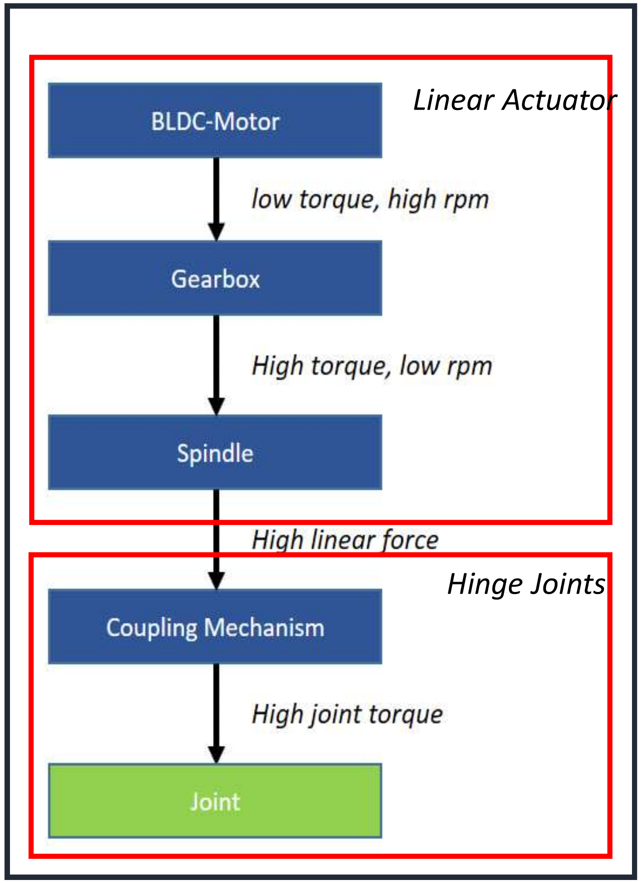


Back view of Sweaty´s hip. Coupling Mechanisms are used for pitch and roll



Joint Mechanism for Knee, Ankle and lower Back

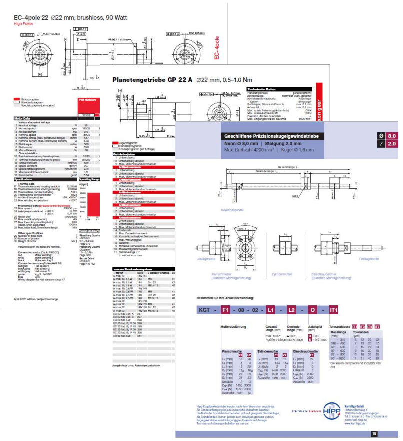




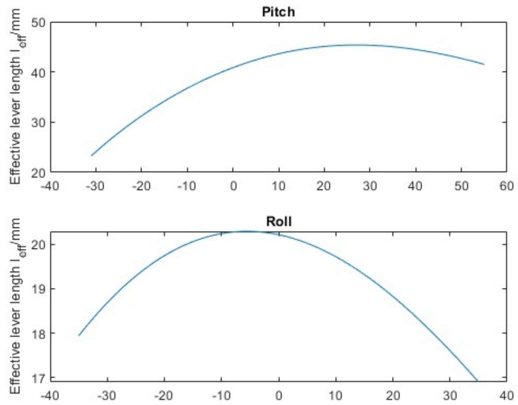
LinearMotor combined with multiple HingeJointWithBacklash
→ Simulation time 0.1
HingeJointWithBacklash and a RotationalMotor
→ Simulation time 1.0

Modeling of the HingeJointWithBacklash and the RotationalMotor

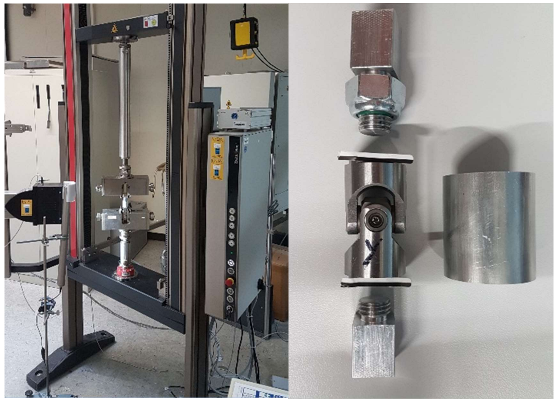
Datasheets

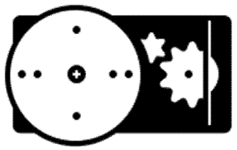


Coupling Data



Measurement Data

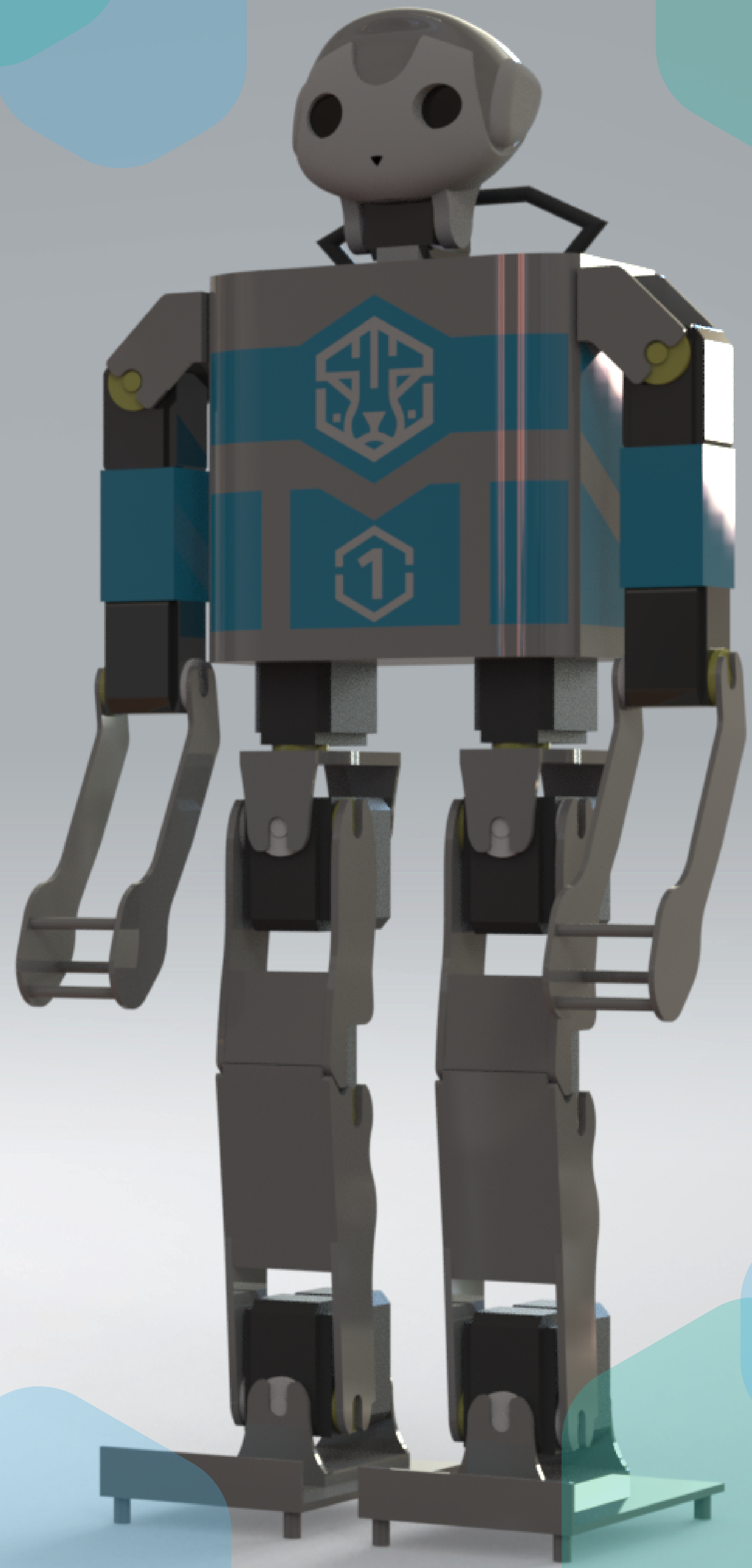




HingeJointWithBacklash
RotationalMotor

MRL-HSL Robot

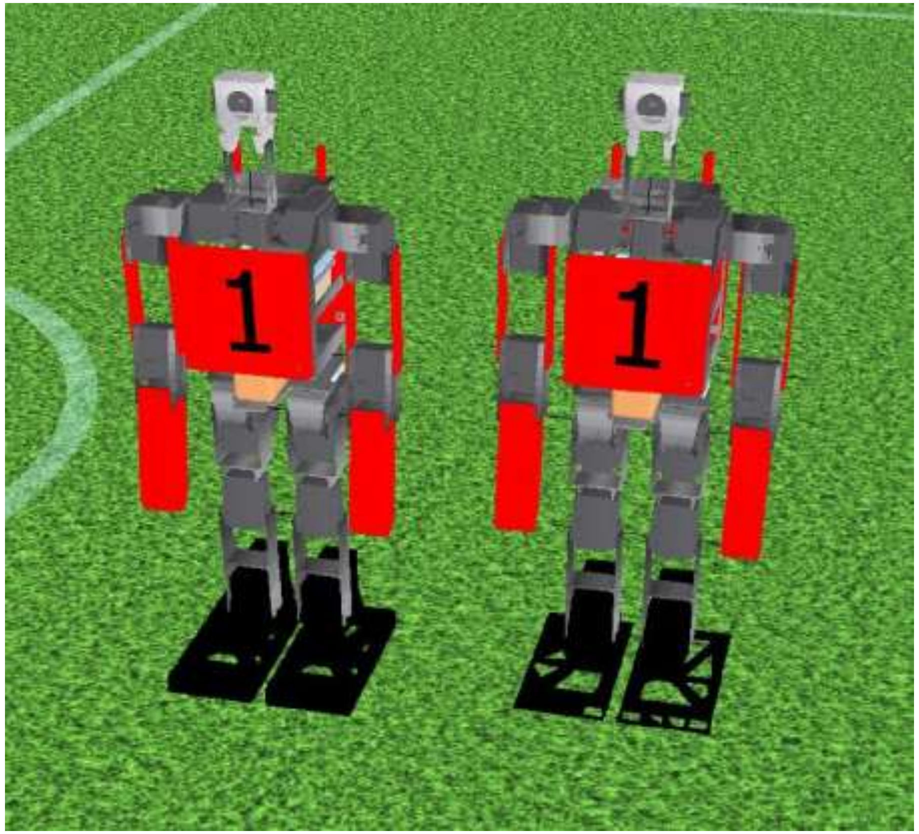
- Avoiding Complexity
  - Simplification of the parts
  - Using geometric shapes as bounding object
  - Removing unnecessary components
- Accuracy
  - Validated physical characteristics
  - Optimum bounding objects
  - Perfect physical Collision
- Appearance

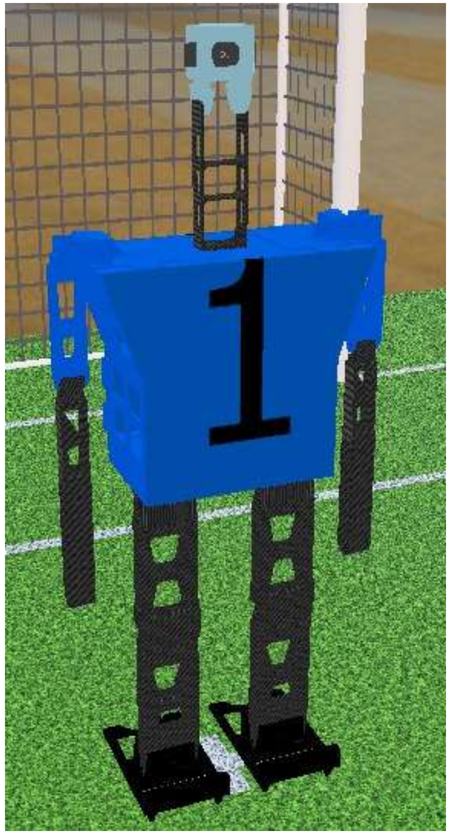


@mrl_humanoid

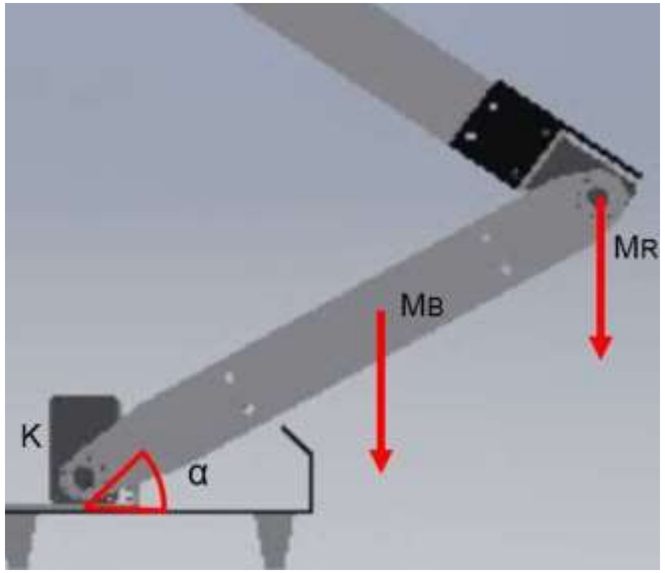
Robot Model Competition

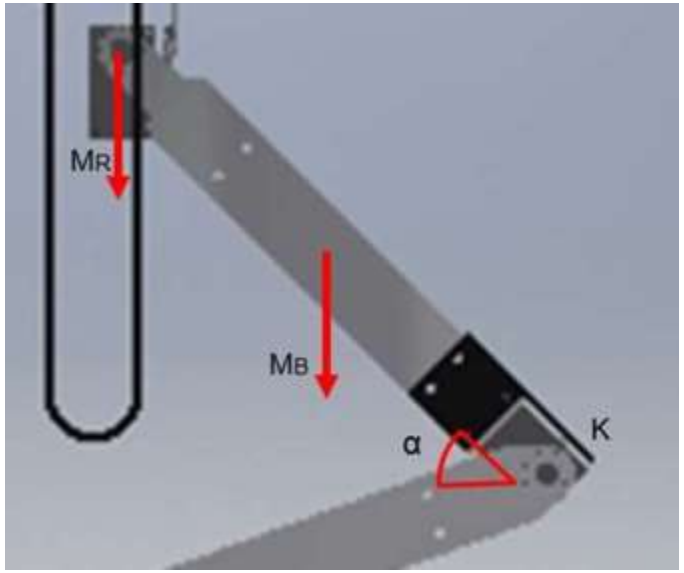
RoboFEI

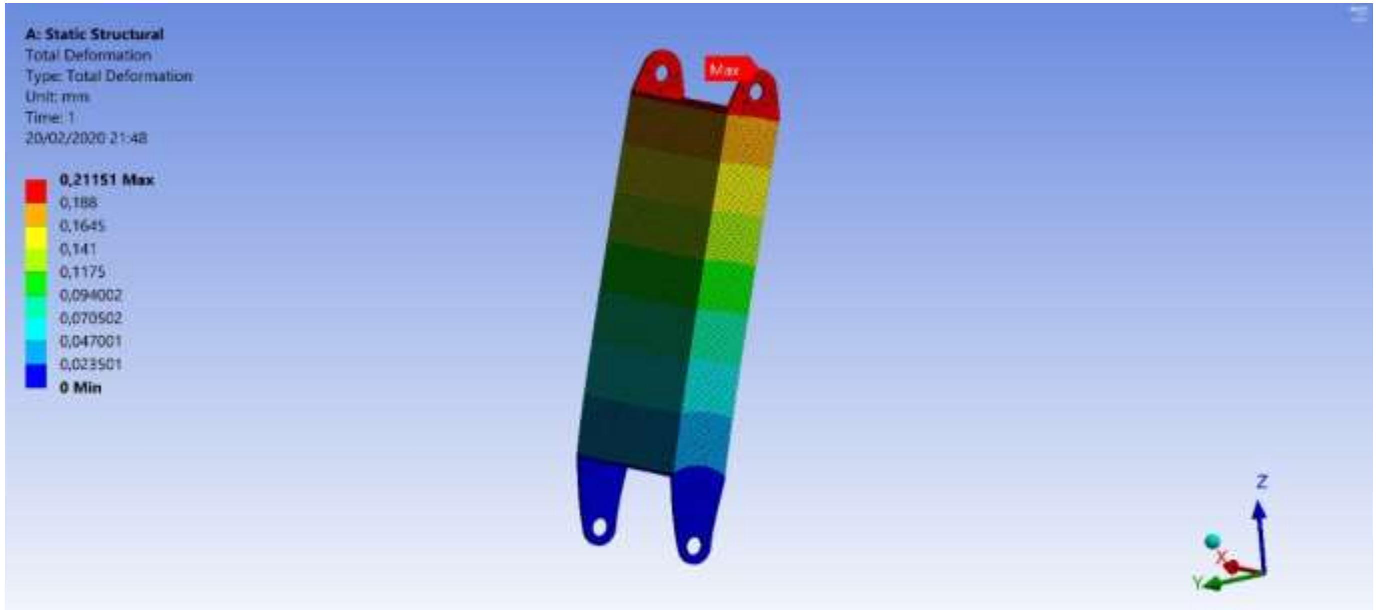




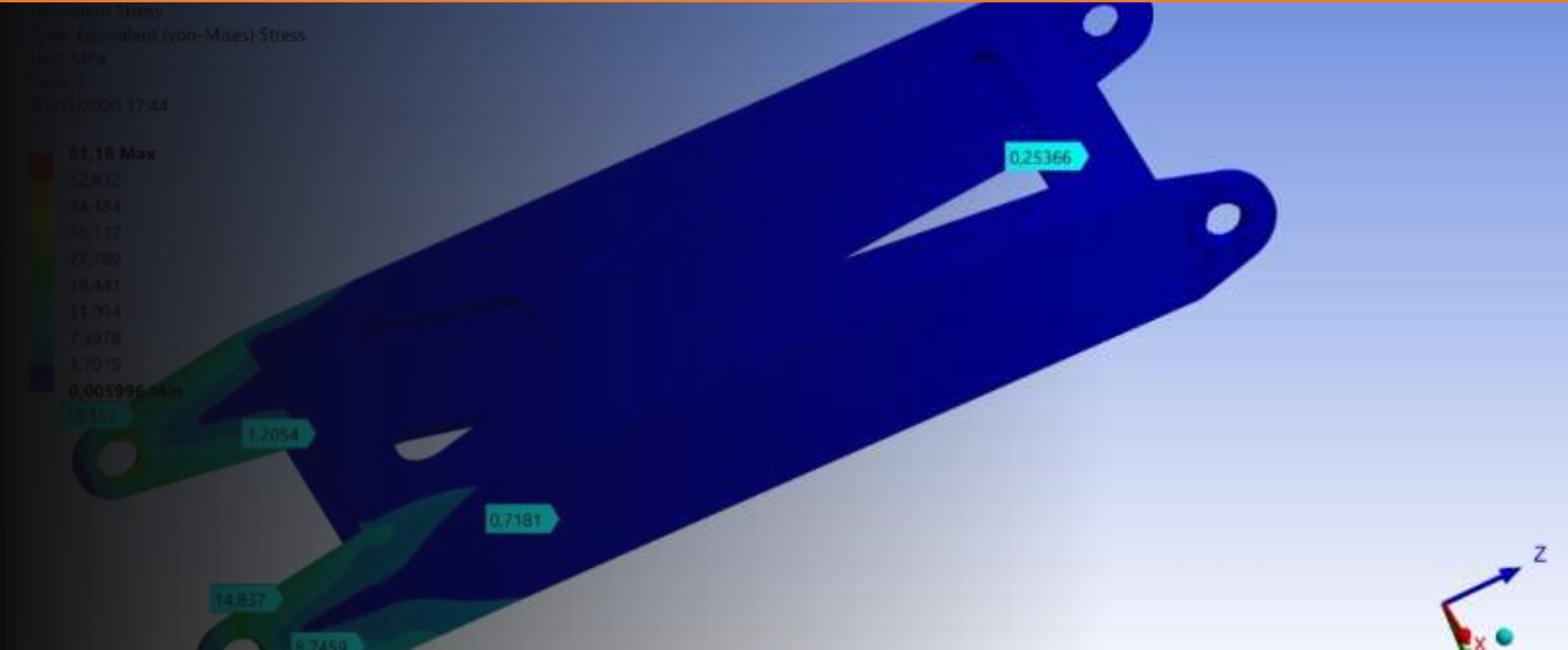
Starting with the basics...

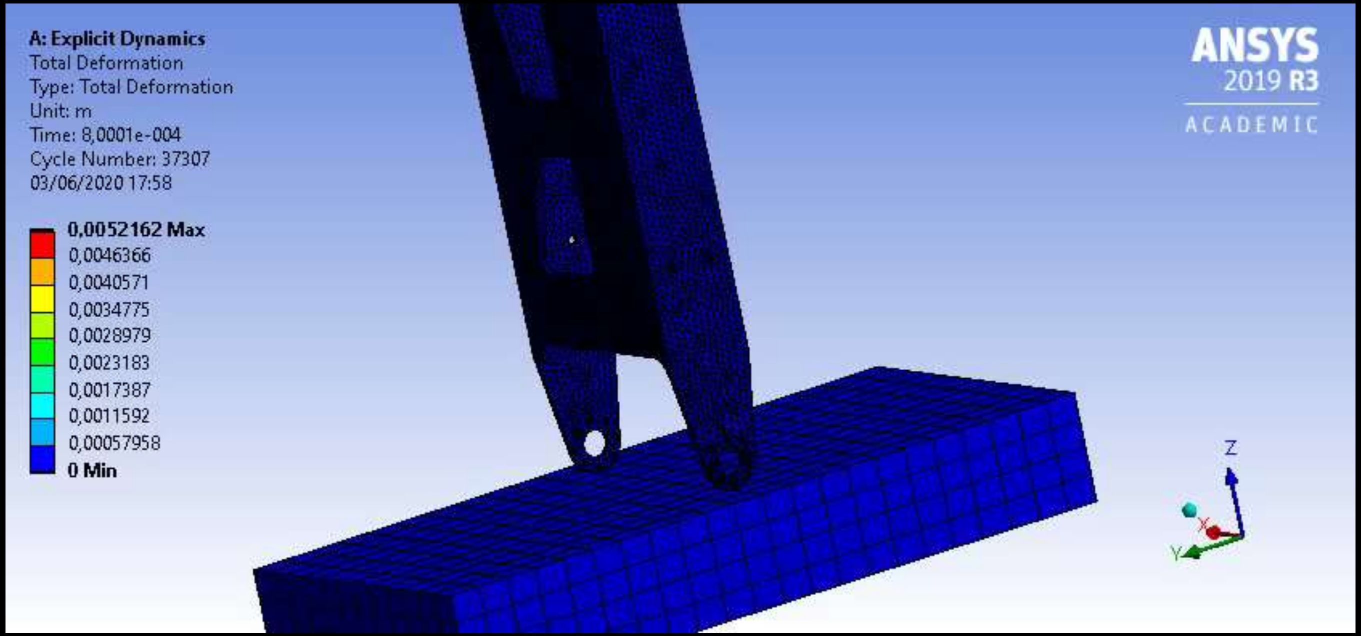






Topology Optimization process

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Type: Total Deformation
Unit: m
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03/06/2020 17:58
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0,0040571
0,0034775
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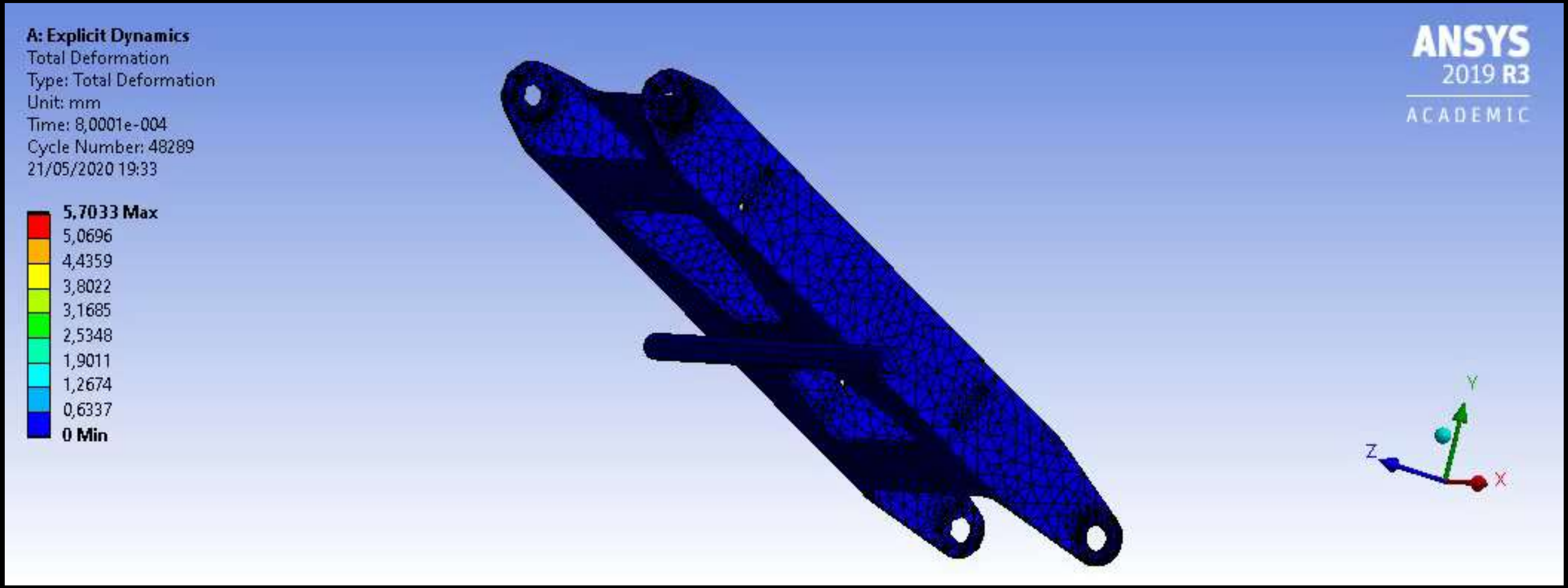
0,0017387
0,0011592
0,00057958
0 Min
ANSYS
2019 R3
ACADEMIC
Z
X
Y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2,5348
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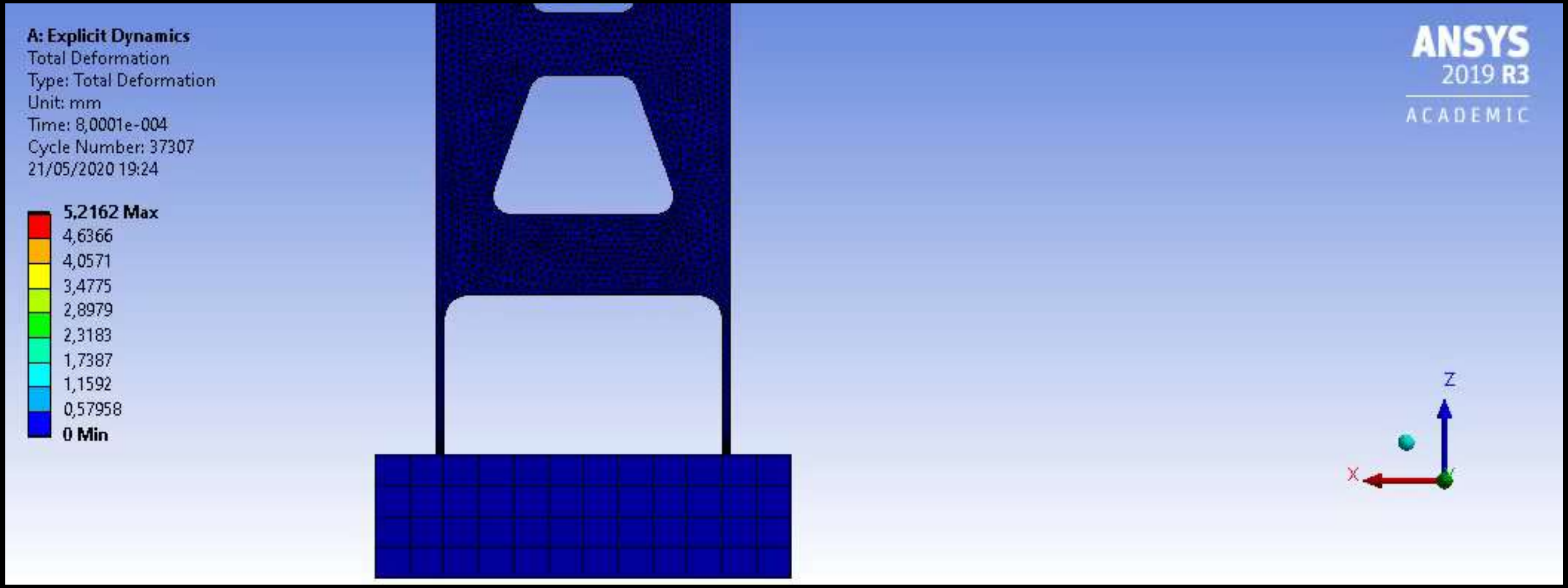
0 Min
ANSYS
2019 R3
ACADEMIC
Y
Z
X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Total Deformation
Type: Total Deformation
Unit: mm
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Cycle Number: 37307
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4,0571
3,4775
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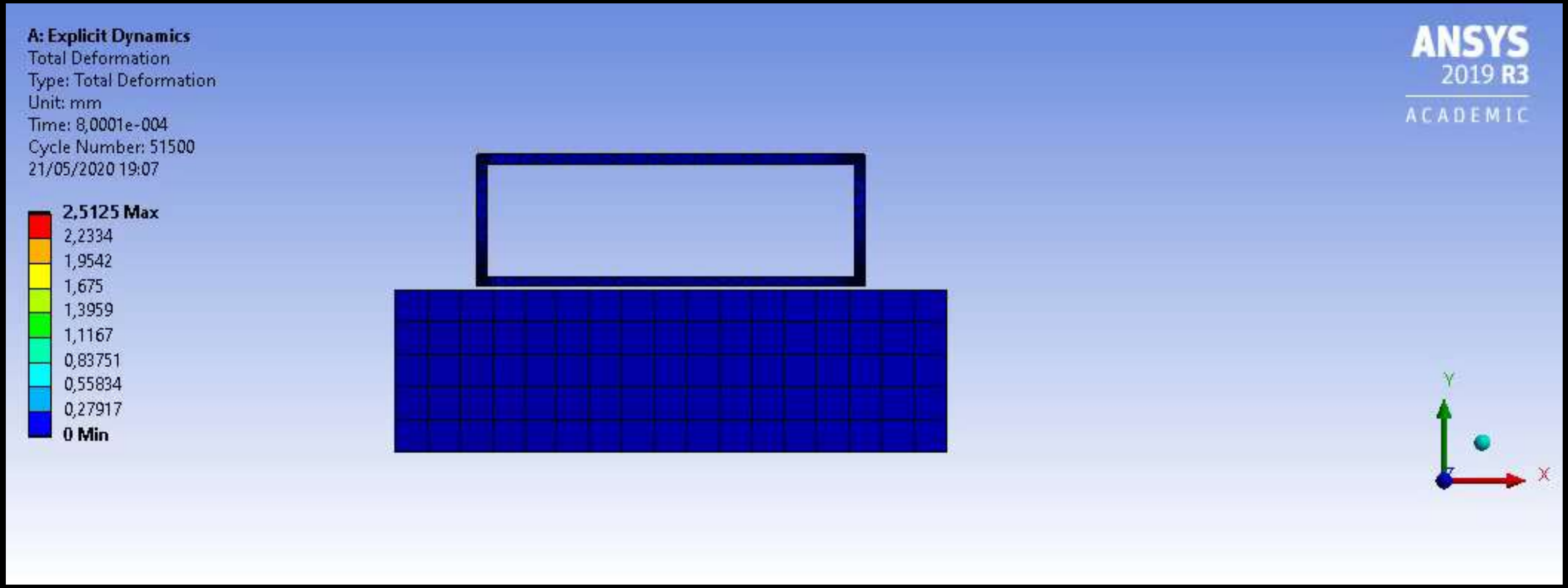
1,7387
1,1592
0,57958
0 Min
ANSYS
2019 R3
ACADEMIC
Z
X


A: Explicit Dynamics
Total Deformation
Type: Total Deformation
Unit: mm
Time: 8,0001e-004
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2,2334
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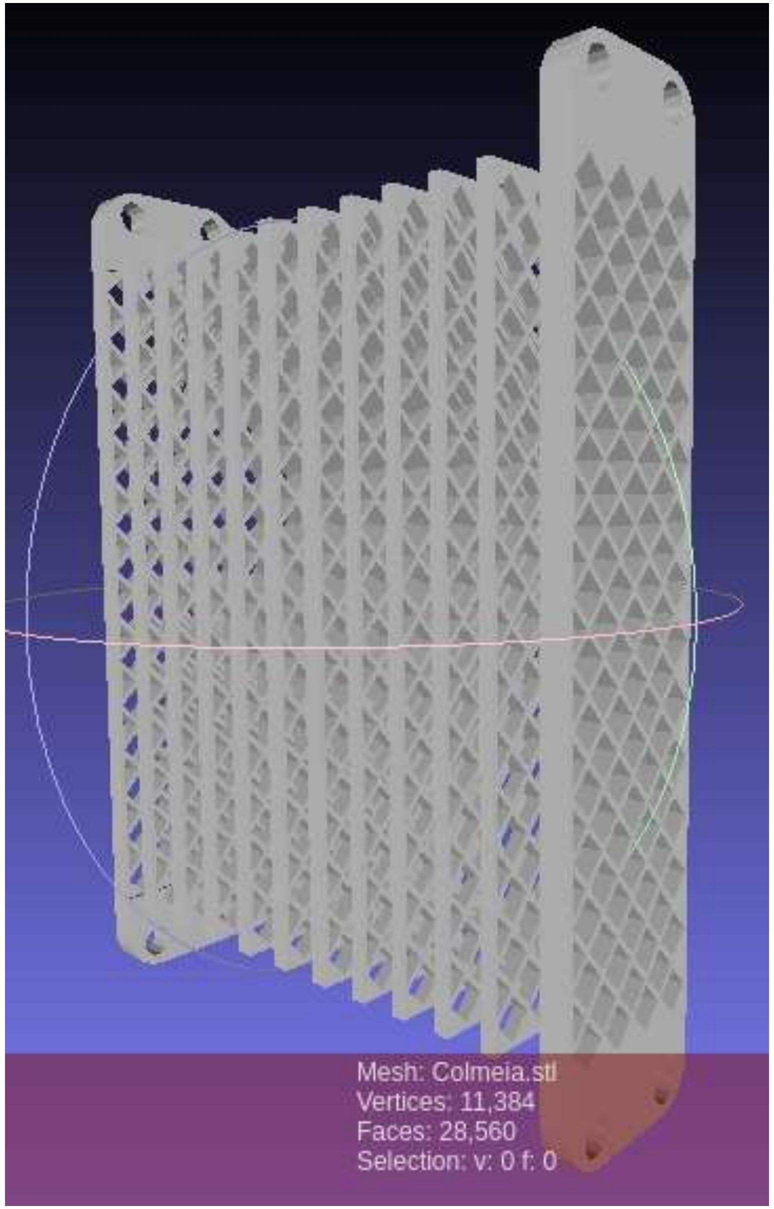
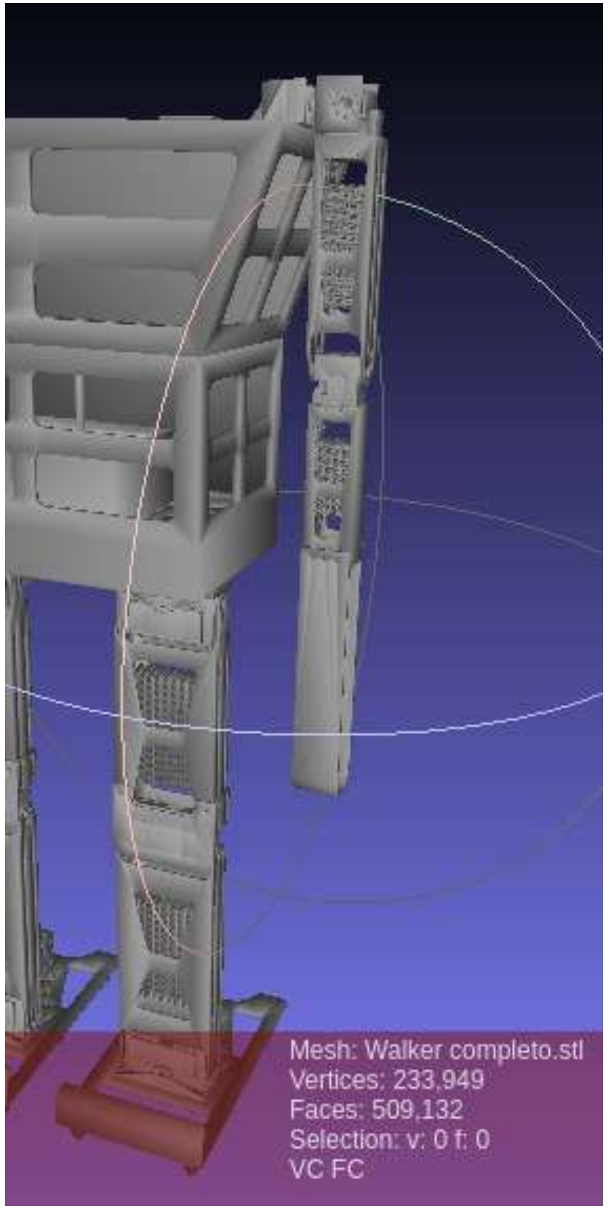
1,675
1,3959
1,1167
0,83751
0,55834
0,27917
0 Min
ANSYS
2019 R3
ACADEMIC
Y
X

Colmeias (hives)

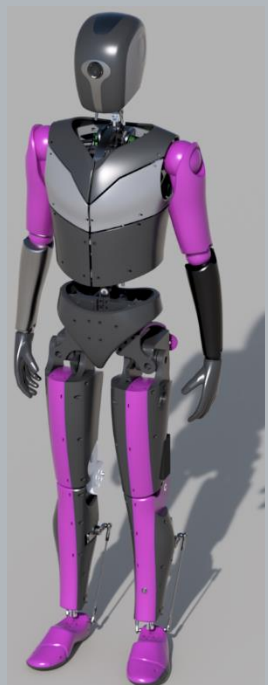




Some difficulties... 😐

01. RFC Robot Model Vision

The Mickey Plattform Gen 2021



OVERVIEW

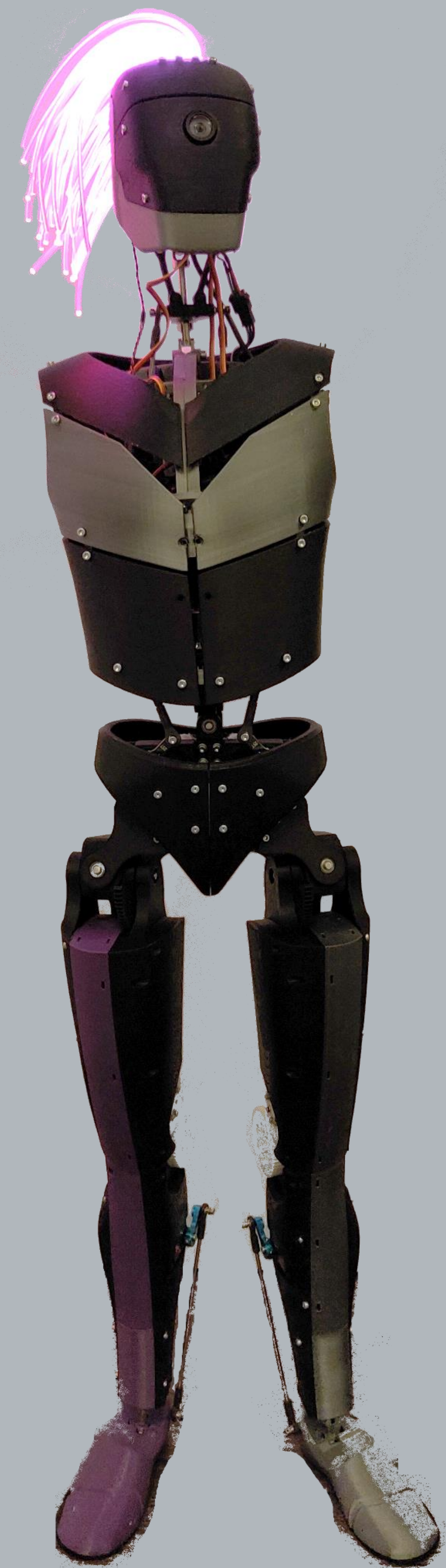
- 32 DoF
- Height = 1 m
- Weight = 6 kg
- Shoe size = 25 EU
- Customizable hairstyles
- Costs below 2000 €

GOAL

- Cost reduction
- 3D printed
- Custom smart actuators
- Indirectly driven joints

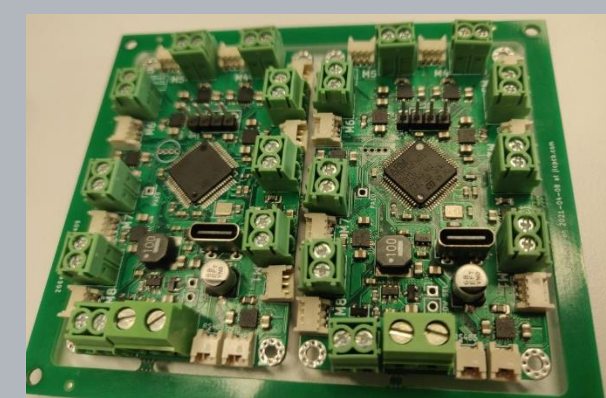
3D PRINT

- Based on premade robot model integrated our needs
- FDM printable
- Prints fit on 22*22 cm² build plate
- Printed on cheap private 3d printer



SMART ACTUATORS

- Custom electronics
- 8 motors connected to one servo board
- 60 € per board
- Gear boxes from RC servos
- Current controlled 5 A motor drivers
- Sophisticated motor control loops



WEBOTS CHALLENGES

- 32 DoF
- Custom smart actuators
- Loopy structures
- No arms
- Missing hair physics

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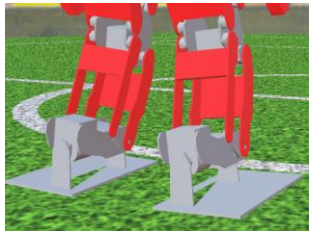
01. RFC BERLIN

CIT Brains

Gaku Kuwano, Yasuo Hayashibara, Hideaki Minakata, Kiyoshi Irie, Naoki Takahashi, Koki Matsumoto, Ryoko Shiojima, Takehiro Hasegawa, Satoshi Inoue, Kiyoshiro Kawanabe, Hayato Kambe, Masato Kubotera, Dan Sato, Hiroki Noguchi, Yuta Mibuchi, Riku Yokoo, Ryodai Arai, Naoki, Iwasawa, Haruki Ogawa, Yuki Shigematsu, Yugo Nishio, Riko Bato, Keita Mori, Yuto Aiba, Ikuo Shige, Misaki Sekitori, Kenta Tsukino, Takuya Nagamine, Kengo Nishi, Taiki Fukuda, Kenzo Fujisaki, Shun Hoshina, Hikaru Maeda, Yusaku Matsuyama, Kaito Miyawaki

Reproduction of the real environment

Closed links (real)



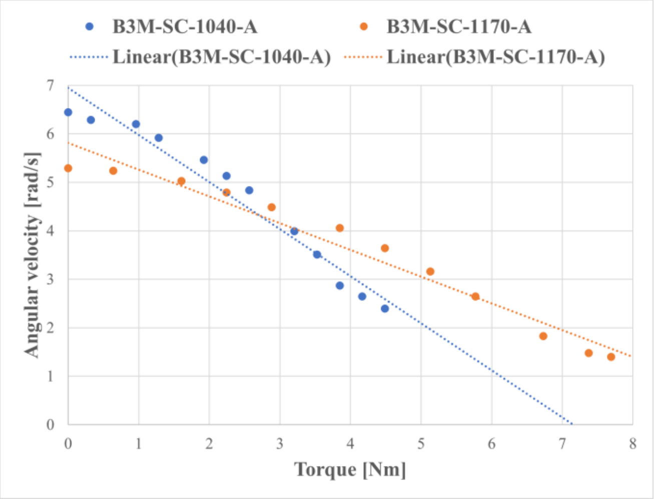
Closed links (webots)

Implementation of closed links

Implemented a closed link mechanism to reproduce the symmetric behavior of a real robot.

Motor characteristic experiment

To use Kondo's B3M series servo motors, we conducted a unique experiment using powder brakes. By using the values obtained in the experiment, we were able to reproduce accurate motion closer to real use than the nominal values.

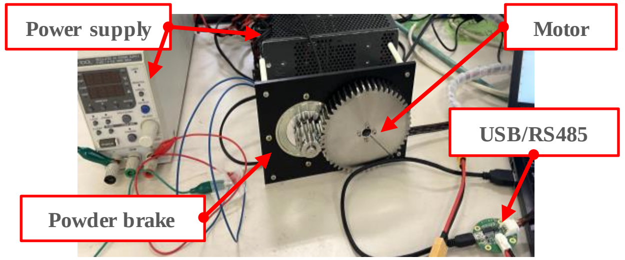


N-T Characteristics

Using **nominal value**

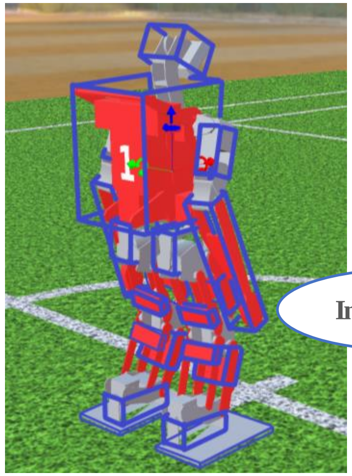
Using **experimental value**

Real environment



Experimental device

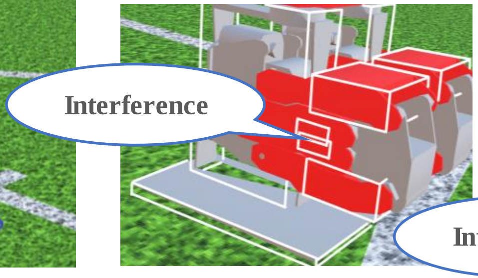
Reduced computational load



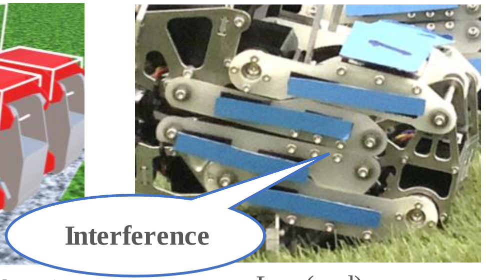
Overall bounding box

Simplifying the bounding box

The bounding box consists of the minimum required to simulate the model. The total is 20, which can reduce the computational load of the model.



Leg bounding box(webots)



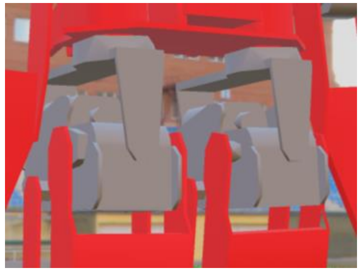
Leg (real)

Reduction of polygons

To simplify the model, we filled all hole shapes, used Autodesk Inventor's feature Shrinkwrap, replaced complicated forms with the cuboid, removed parts that are not related to movement.

Design model
approx. 1,490,000 polygons

Simplification



Reduction model
approx. 7,500 polygons

Support 千葉工業大学 CHIBA INSTITUTE OF TECHNOLOGY **Model released** https://github.com/citbrains/GankenKun_webots **Team website** http://www.cit-brains.net/

HERoEHS Robot Model Presentation

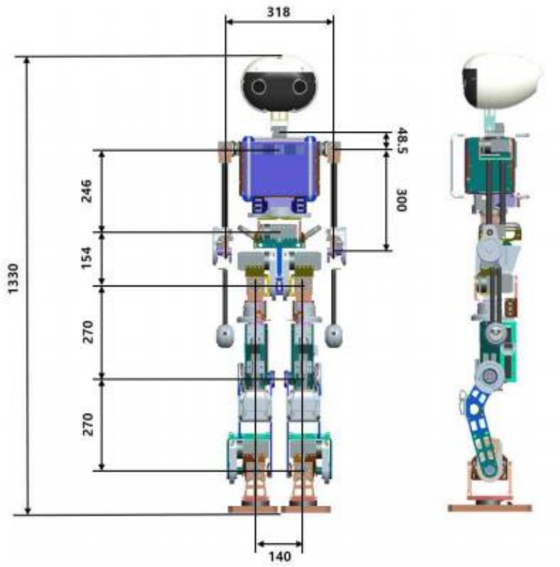
RoboCup 2021
Virtual Humanoid Soccer Competition

HANYANG UNIVERSITY
HEROEHS

INDEX

I . Specification of ALICE

Hardware Structure



Ratio of ALICE

- Robot name : ALICE 3
- Degrees of freedom : 22 DOF
- Height of robot : 133 cm
- Weight of robot : 24.6 kg
- Type of motors :

  Robotis Dynamixel XH540-V270-R

  Robotis Dynamixel Pro PH42-020-S300-R

  Robotis Dynamixel Pro PH54-100-S500-R

XH540-V270-R

PH42-020-S300-R

PH54-100-S500-R

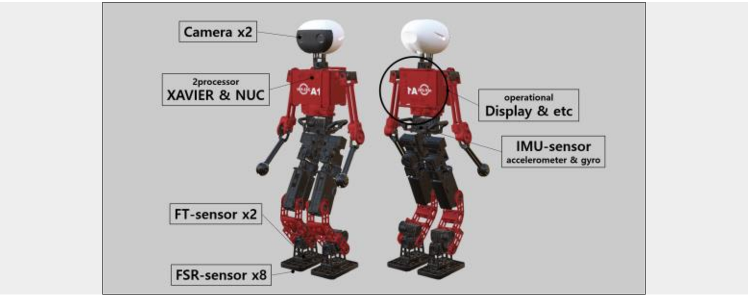
Ⅰ. Specification of ALICE

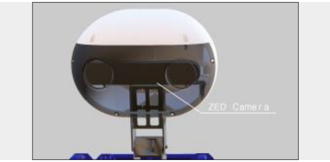
Computing Units

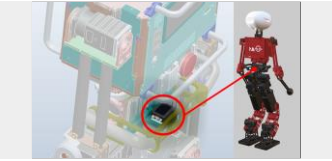
- NVIDIA Jetson AGX Xavier 32GB
- Intel NUC 10th Core i5

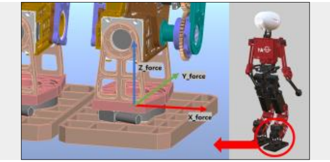
Type of Sensors

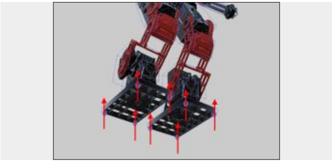
- ZED stereo camera (It replace RGB cameras in webot)
- LORD IMU sensor (It separate Gyro and Accelerometer in webot)
- ROBOTOUS Force-Torque 6-axis sensors (It don't use Torque 3-axis in webot)
- SingleTact FSR CAL 15MM DIAMETER, 450N/100LB FORCE (It just use in webot)





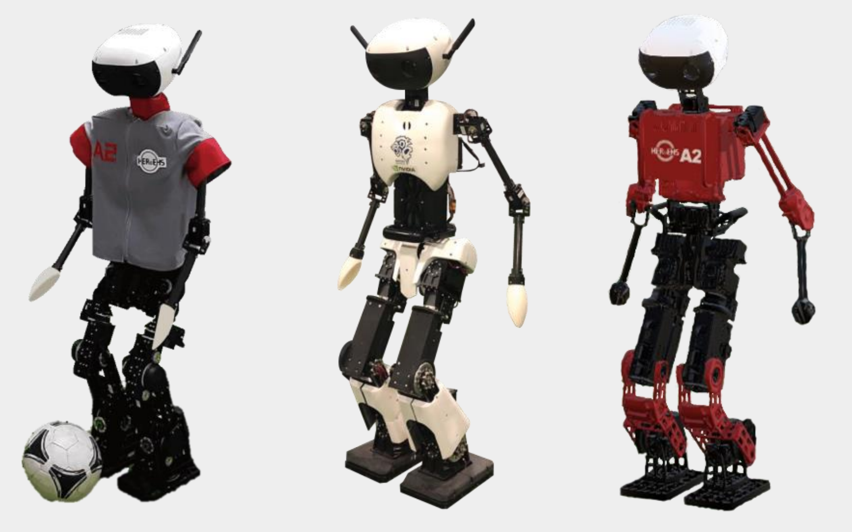






Ⅱ. Design of ALICE

ALICE Design Philosophy



<ALICE1> 2018 <ALICE2> 2019 <ALICE3> 2021

- Female-type design determined through preliminary survey.
- A moderately human-like design that doesn't fall into Uncanny Valley.
- Implementing human-like curved design.
- A height of about 130cm that an adult person can look down on while feeling psychologically comfortable.

ALICE is designed to be a human-friendly robot.

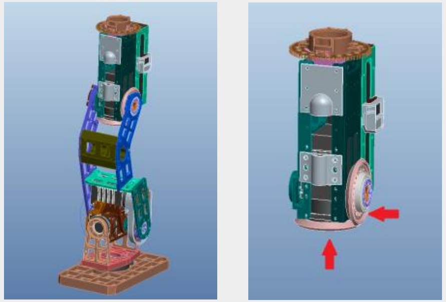
Ⅱ. Design of ALICE

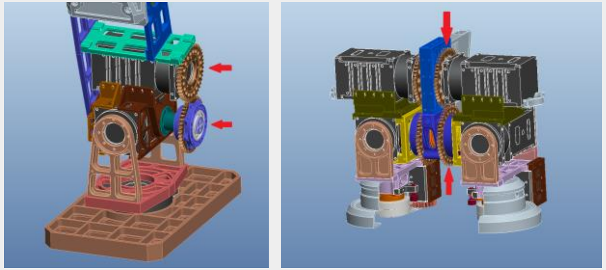
Safety handle

- It can be hold easy by handler at emergency.
- It protects the computing units from direct collision.

Ⅲ. Mechanical features of ALICE

Axial alignment and overcoming spatial constraints





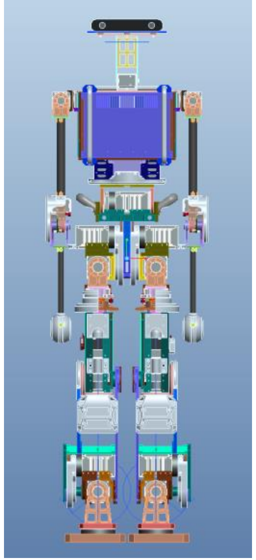
- Using bevel gears to make legs slimmer.
- Using a gear train to align the two rotation axes at the ankle joint.
- Using a gear train to align the three rotation axes at the hip joint.

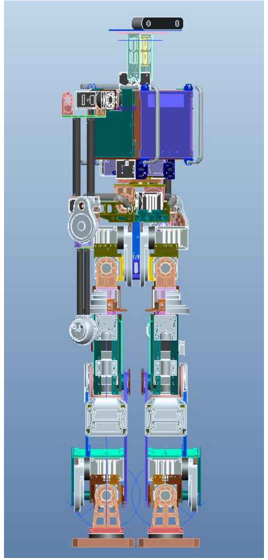
Ⅲ. Mechanical features of ALICE

Standing up motion using the waist pitch joint

- ALICE can stand up using the waist pitch joint like a human does.

Searching motion using the waist yaw joint

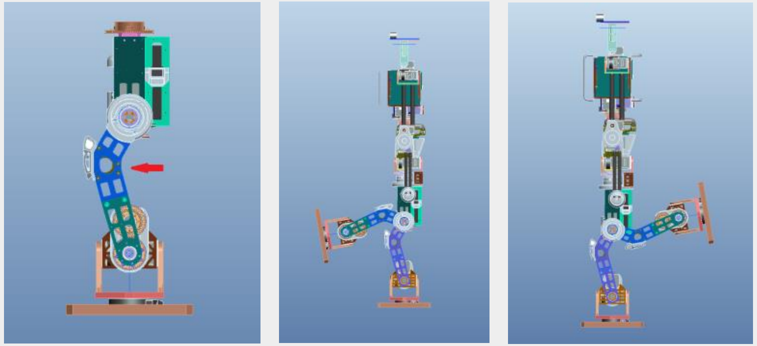




- ALICE can search widely and fast by using the waist yaw joint.

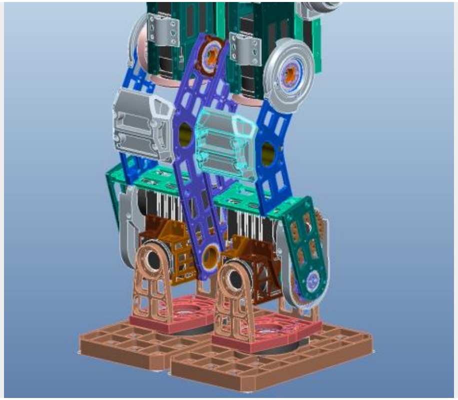
Ⅲ. Mechanical features of ALICE

Curved legs for ROM expansion



- It can move 80 degrees forward and 100 degrees backward.

Foot design features

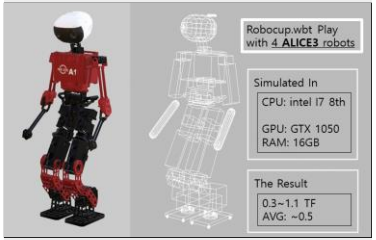


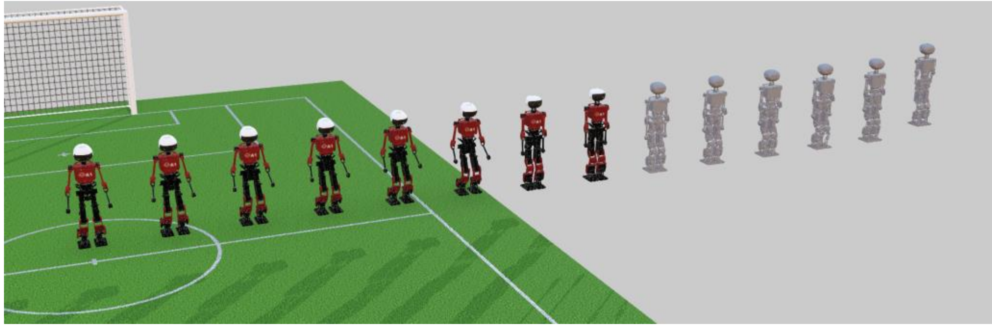
- It is designed as wide as possible to increase the ZMP space.
- A lot of pockets make the feet light weight.
- Designed with a thin vertical frame to adapt well to soft grass.

IV. Proto model of ALICE

- Fully implemented visual model and beautiful coloring.
- A low-complexity collision model using geometric primitives.
- Reliable base pose preset by PROTO.

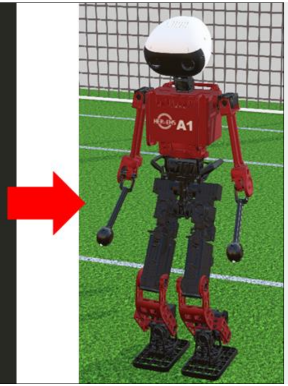
Alice3.proto	the Num of boundingObject		
SHAPE	VERTICES	COUNT	ALL
Capsule	130	12	1560
Cylinder	36	2	72
Box	8	35	280
SUM			1912





PROTO model history

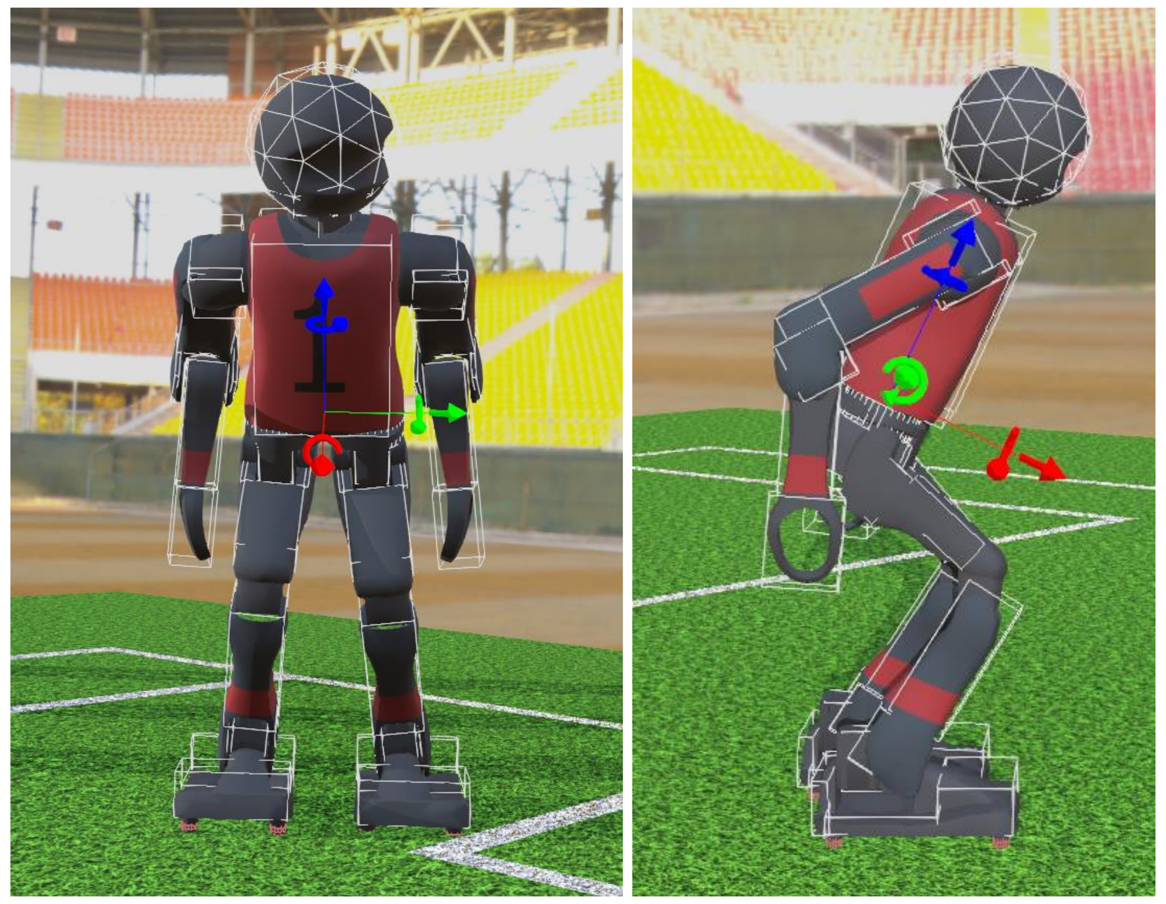
```
-- Base pose
DEG2RAD = 3.1415926 / 180
local l_shoulder_pitch_BP = 0.0 * DEG2RAD
local r_shoulder_pitch_BP = 0.0 * DEG2RAD
local l_shoulder_roll_BP = 10.0 * DEG2RAD
local r_shoulder_roll_BP = -10.0 * DEG2RAD
local l_elbow_pitch_BP = 45.0 * DEG2RAD
local r_elbow_pitch_BP = -45.0 * DEG2RAD
local head_pitch_BP = 20.0 * DEG2RAD
local head_yaw_BP = 0.0 * DEG2RAD
local waist_yaw_BP = 0.0 * DEG2RAD
local waist_pitch_BP = 0.0 * DEG2RAD
local l_hip_pitch_BP = 27.6432 * DEG2RAD
local r_hip_pitch_BP = -27.6432 * DEG2RAD
local l_hip_roll_BP = 2.14682 * DEG2RAD
local r_hip_roll_BP = -2.14682 * DEG2RAD
local l_hip_yaw_BP = -1.10918 * DEG2RAD
local r_hip_yaw_BP = 1.10918 * DEG2RAD
local l_knee_pitch_BP = -55.3482 * DEG2RAD
local r_knee_pitch_BP = 55.3482 * DEG2RAD
local l_ankle_pitch_BP = -27.6415 * DEG2RAD
local r_ankle_pitch_BP = 27.6415 * DEG2RAD
local l_ankle_roll_BP = -2.41342 * DEG2RAD
local r_ankle_roll_BP = 2.41342 * DEG2RAD
```




감사합니다
Thank you
HANYANG UNIVERSITY
HER EHS

NUBOTS NUgus Virtual Model

THE UNIVERSITY OF NEWCASTLE AUSTRALIA



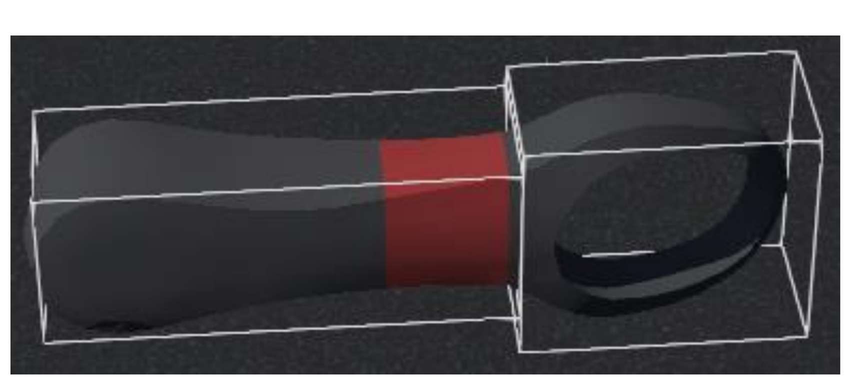
Overview

RoboCup Worldwide 2021 was held virtually in simulation. As a participant, the NUbots team from the University of Newcastle created a virtual model of the NUgus platform for the Webots Simulation Environment. The process of converting the physical model to a virtual model required modifications to various parameters and values, to match the operation of the virtual model to the physical one in the real world as close as possible.

Mesh Implementation

To generate the mesh and define physical descriptions such as the mass and joints of the NUgus platform, the NUgus URDF was converted to a Webots PROTO file using the urdf2webots utility [1]. The NUgus URDF file is based upon the robot developed by the University of Bonn in collaboration with the Germany company igus® GmbH in 2015 [2].

To improve simulation performance, the collision boxes of the virtual model were constructed from Webots geometric primitives. These bounding boxes maintain the general structure of the NUgus model and ensure all joints still have their full range of motion.



Accelerometer and Gyroscope

Webots accelerometer and gyroscope sensor nodes are used to model the NUgus robot. Both simulated devices are modified to represent the *LIS331DLH* [3] and *L3G4200D* [4] devices respectively, to a satisfactory level of accuracy. The adjustable parameters of the accelerometer and gyroscope sensor nodes are modified to match the physical NUgus platform.

The resolution of the accelerometer and gyroscope is calculated by:

$$resolution = \frac{size\ of\ range}{4095}$$

Accelerometer	Gyroscope
$\frac{78.48}{4095} \approx 0.01916$	$\frac{17.4533}{4095} \approx 0.0042621$

A lookup table (LUT) is used to indicate how values measured by Webots are mapped to values returned by the sensor.

Noise values are calculated using the following equation for both sensors.

$$noise\ min = \frac{stddev}{min + DC\ offset}$$

$$noise\ max = \frac{stddev}{max + DC\ offset}$$

LUT for Accelerometer

Measured Value [m/s^2]	Return Value [m/s^2]	Noise [%]
-39.24	60.76	0.000704
39.24	139.24	0.000307

LUT for Gyroscope

Measured Value [rad/s]	Return Value [rad/s]	Noise [%]
-8.72665	91.238	0.0001151
8.72665	108.72	0.000096541

Motor Implementation

The arms and head of the NUgus robot use *Dynamixel MX64AR* servos, with two in each shoulder, one in each elbow, and two in the neck. The legs use *Dynamixel MX106* servos, with two in each ankle, three in each hip, and one in each knee.

In Webots, all the active joints are implemented using *HingeJointWithBacklash*. The backlash parameter supplied in the Dynamixel data sheet is 0.33° (approx. 0.0058 [rad]). However, a value of 0.01 [rad] was used, due to the limitations of modelling small backlash values in Webots.

As the physical NUgus robot operates at roughly 14v, the voltage parameters for the Dynamixel motors are set to 14.8v in Webots.

Motor Type	Parameter	Variable Name	Value
MX106	maxTorque	MX106-torque	10.00
MX106	maxVelocity	MX106-vel	5.76
MX106	dampingConstant	MX106-damping	1.23
MX106	staticFriction	MX106-friction	2.55
MX64	maxTorque	MX64-torque	7.30
MX64	maxVelocity	MX64-vel	8.17
MX64	dampingConstant	MX64-damping	0.65
MX64	staticFriction	MX64-friction	1.73

The Dynamixel motors use a 12-bit rotary encoder. For each motor, a *PositionSensor* is used with a resolution of 0.0015.

Camera Implementation

In the physical robot, there are two FLIR BlackFly S BFS-U3-13Y3C-C cameras [5] with Lensation BF10M19828S118C lenses [6]. Due to the lack of full spherical lens support in Webots, the lenses are implemented with rectilinear projection.

The field of view is reduced to $\frac{\pi}{2}$ since the rectilinear lens cannot support a field of view of more than $\frac{2\pi}{3}$ and values between these had an undesirable zoom effect.

The resolution of the cameras is 640x480px. On the physical robot the resolution is 1280x1024px, however this value was lowered due bandwidth limitations.

Noise has been set to 1e-9 as there is little noise on the physical cameras. Motion blur is set to 10, as the physical cameras run at 100fps, with very little motion blur. Since rectilinear projection is being used, the spherical field and lens parameters are set to their defaults. The lens of the real camera has a fixed focus, so focus parameters are left at their default values. The focal length is set to 1.98mm, the focal length of the physical cameras.

References

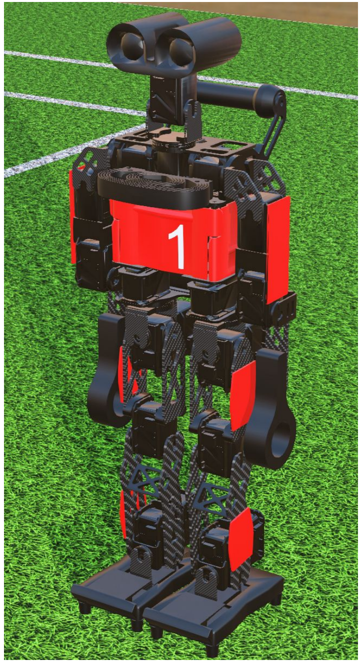
[1] Cyberbotics. (2020) urdf2webots. [Online]. Available: https://github.com/cyberbotics/urdf2webots HumanoidOpenPlatform
[2] P. Allgeuer, H. Farazi, M. Schreiber and S. Behnke, "Child-sized 3D printed igus humanoid open platform", *IEEE-RAS 15th International Conference on Humanoid Robots* (Humanoids), 2015.
[3] STMicroElectronics: MEMS digital output motion sensor ultra low-power high performance 3-axes "nano" accelerometer. https://www.st.com/resource/en/datasheet/cd00213470.pdf
[4] STMicroElectronics: L3G4200D: three axis digital output gyroscope. https://www.elecrow.com/download/L3G4200AN3393.pdf
[5] FLIR: BlackFly S BFS-U3-13Y3C-C: Camera http://softwareservices.flir.com/BFS-U313Y3/latest/Model/spec.html
[6] Lensation: Lensagon BF10M19828S118C: S-Mount lens https://www.lensation.de/pdf/BF10M19828S118C.pdf

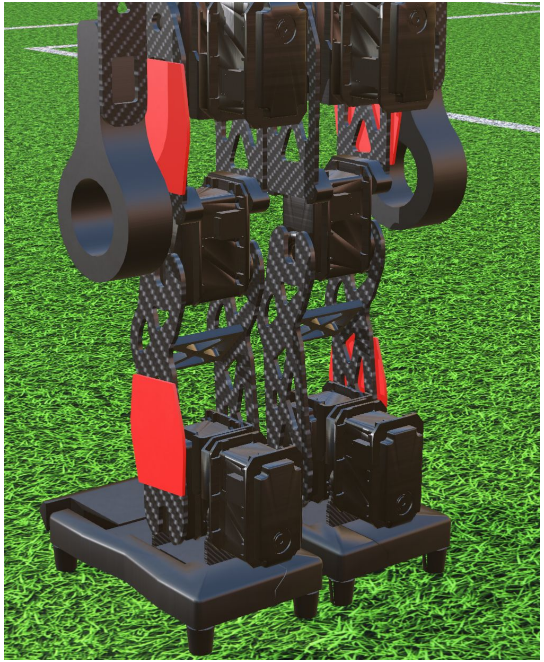
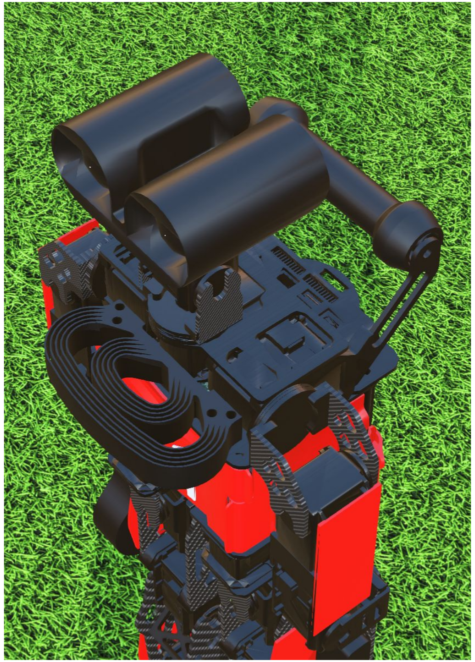
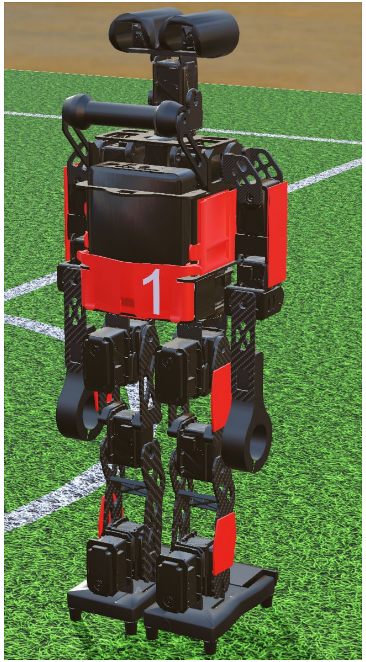
SAHR

(Starkit Autonomous Humanoid Robot)

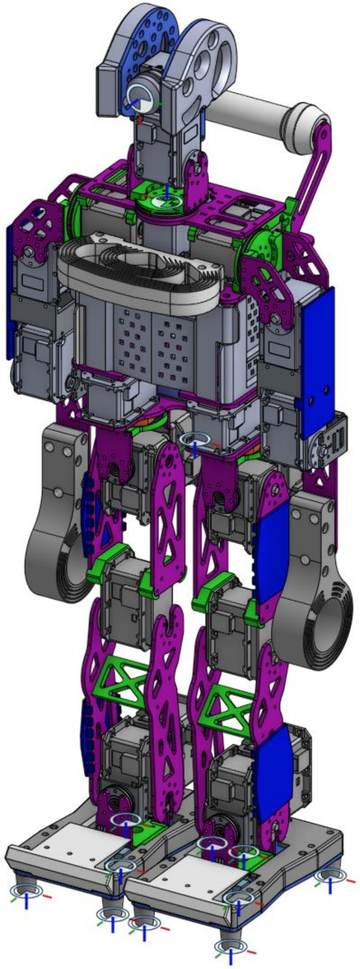
Origin

SolidWorks -> URDF -> Proto

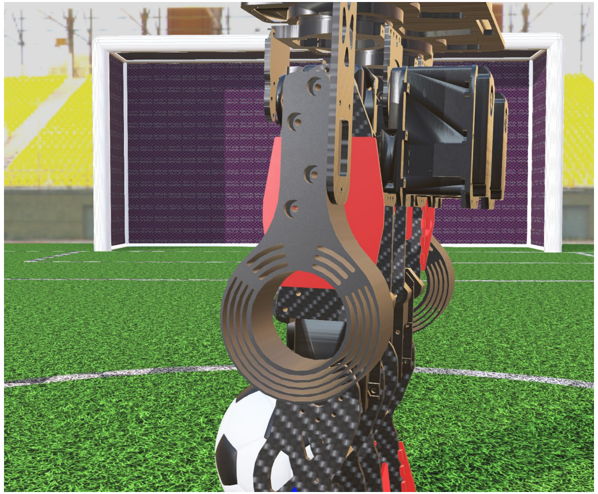


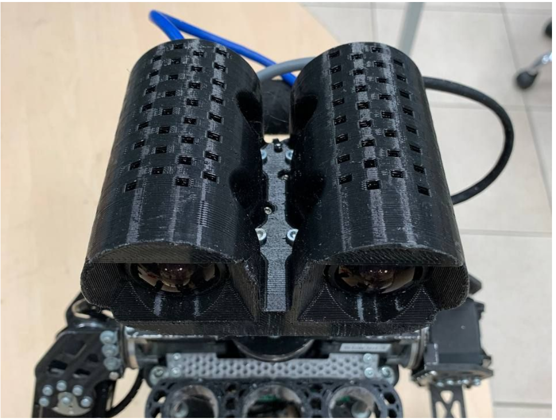
OnShape model

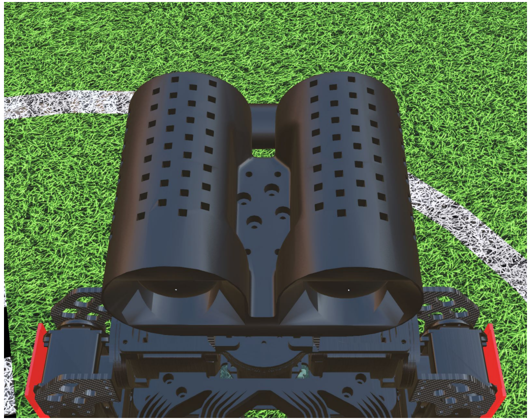


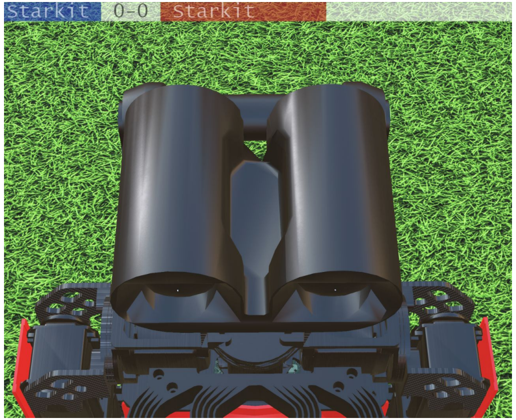
Simplifying hands



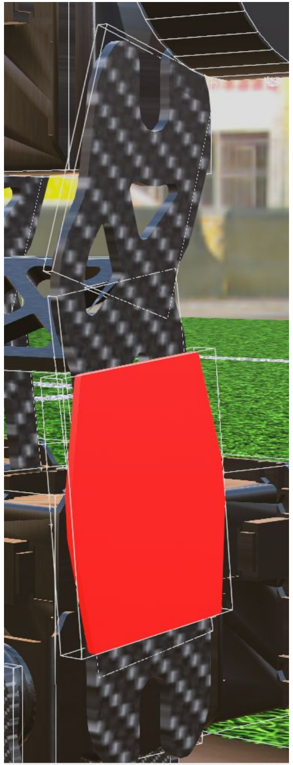
Simplifying head

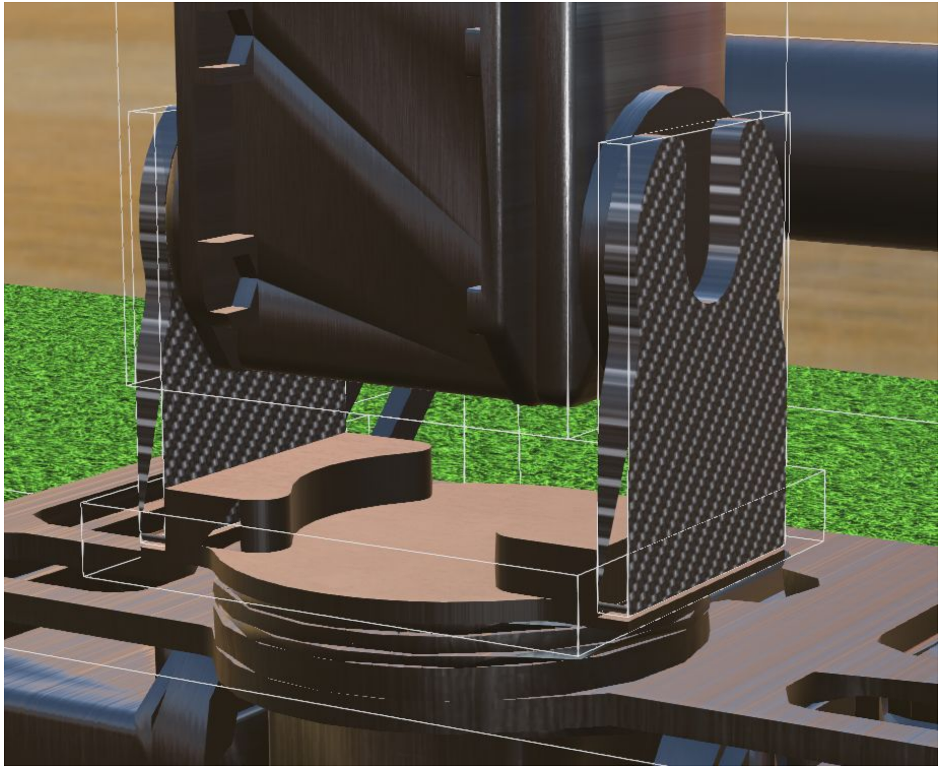


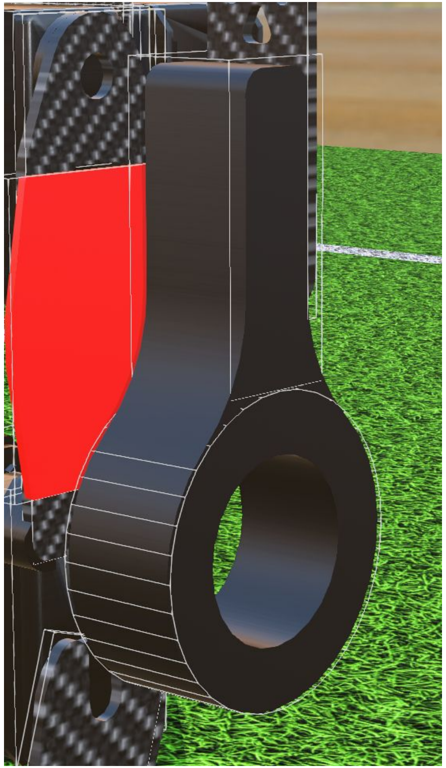




Bounding Objects



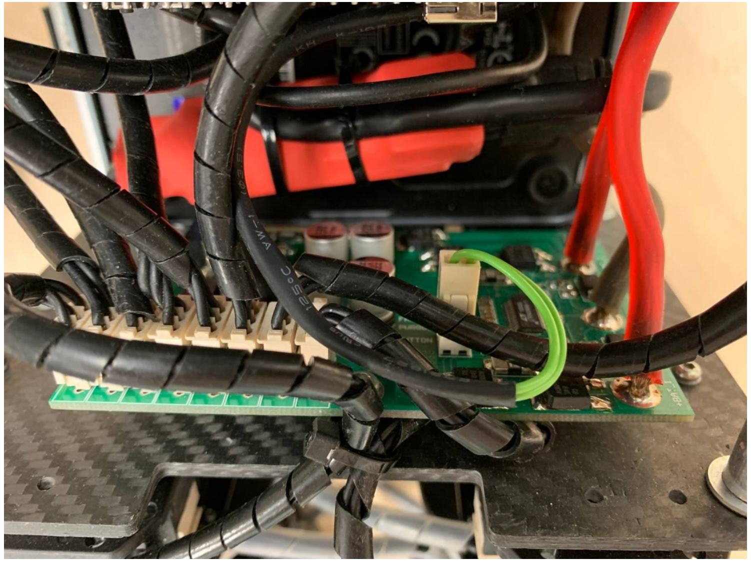


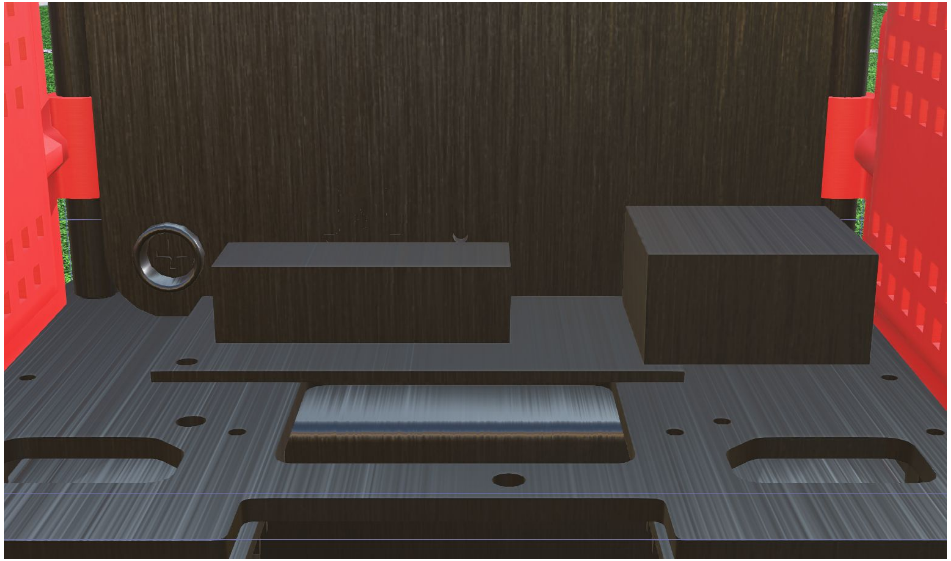


Power

No emergency button

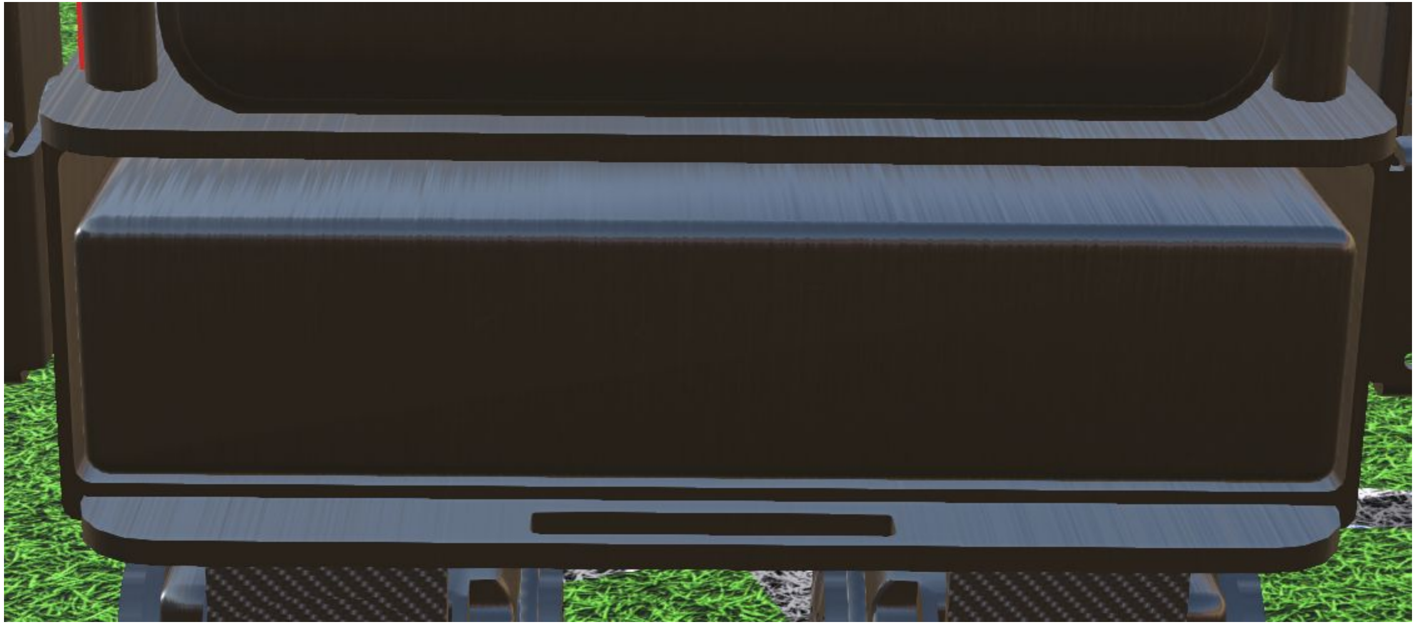
PowerBoard





Battery

Almost 6% of robot weight



Servos

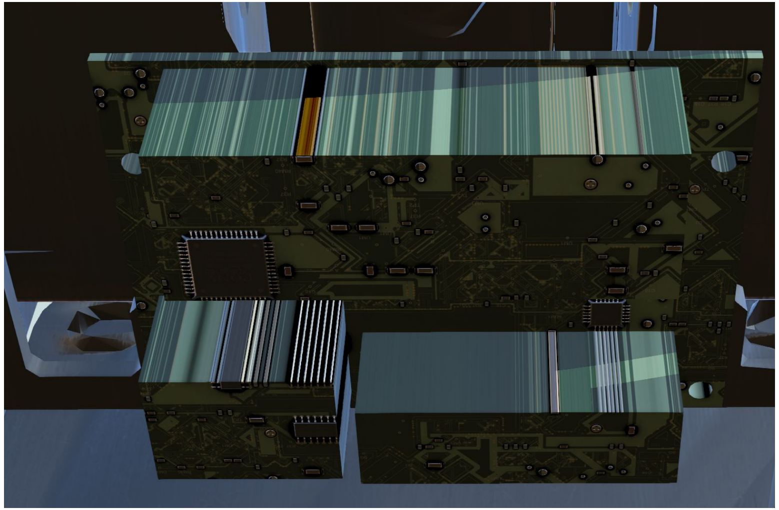
8 Dynamixel MX64-AT (head, arms)

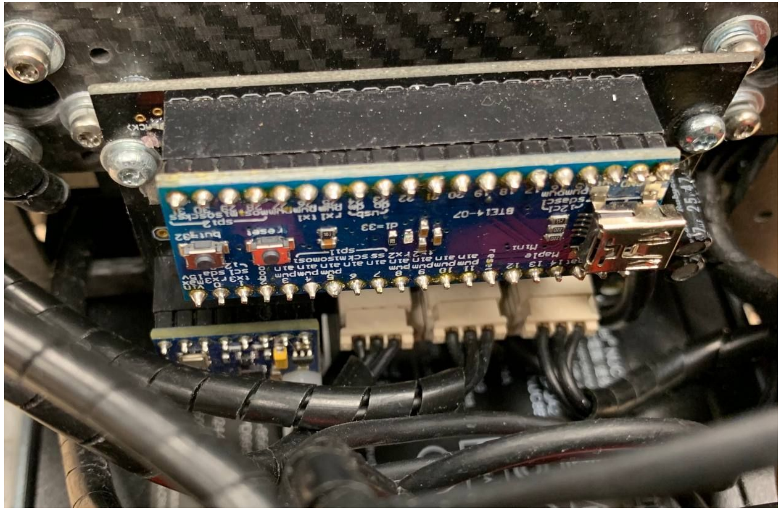
12 Dynamixel MX106-T (legs, shoulders)

Voltage 14.8V

DXLBoard

Accelerometer (MPU-6050), Gyro (MPU-6050), Change sensor range inside the proto, PCB texture :)

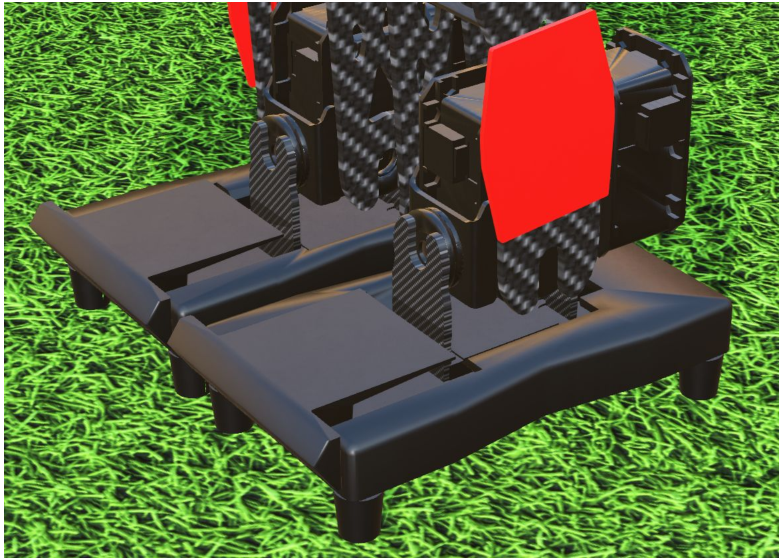




ForceFoot

8 touch sensors (HL-703 Strain gauge with HX711 ADC)

Redesign of Rhoban ForceFoot (add 3d printed cover)



Cameras

Stereo pair of 2 FLIR BlackFly S

resolution: 1440x1080 720x540

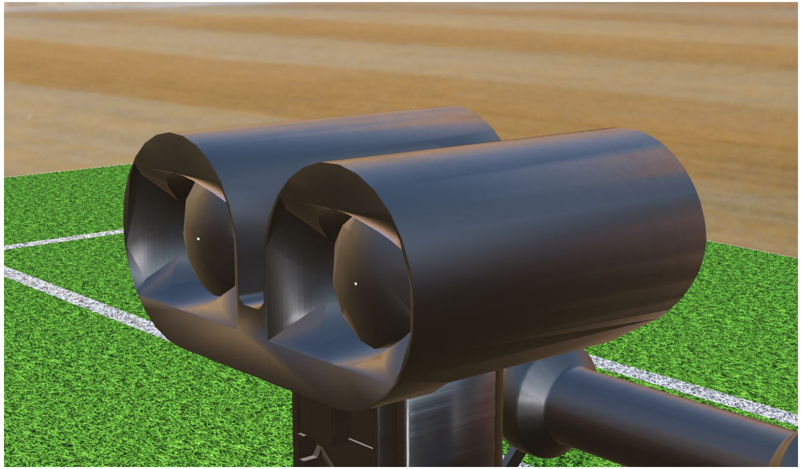
Wideangle cameras (1.762 FOV)

Lens:

center 0.5 0.5

radialCoefficients -0.26 -0.26

tangentialCoefficients 0 0



Materials

Brushed aluminum, Carbon fiber, Plastic