UiO : Department of Informatics
University of Oslo

Photo from PAL Robotics

Who is TIAGo?

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Why TIAGo?

A robot that could be applied to different areas of robotics research, including human-robot interaction, robot control, robot sensing, etc., and be suitable for user studies.

	Lio	Generation Robots	TIAGo
Robotics research	✗	✓	✓
User studies	✓	✗	✓

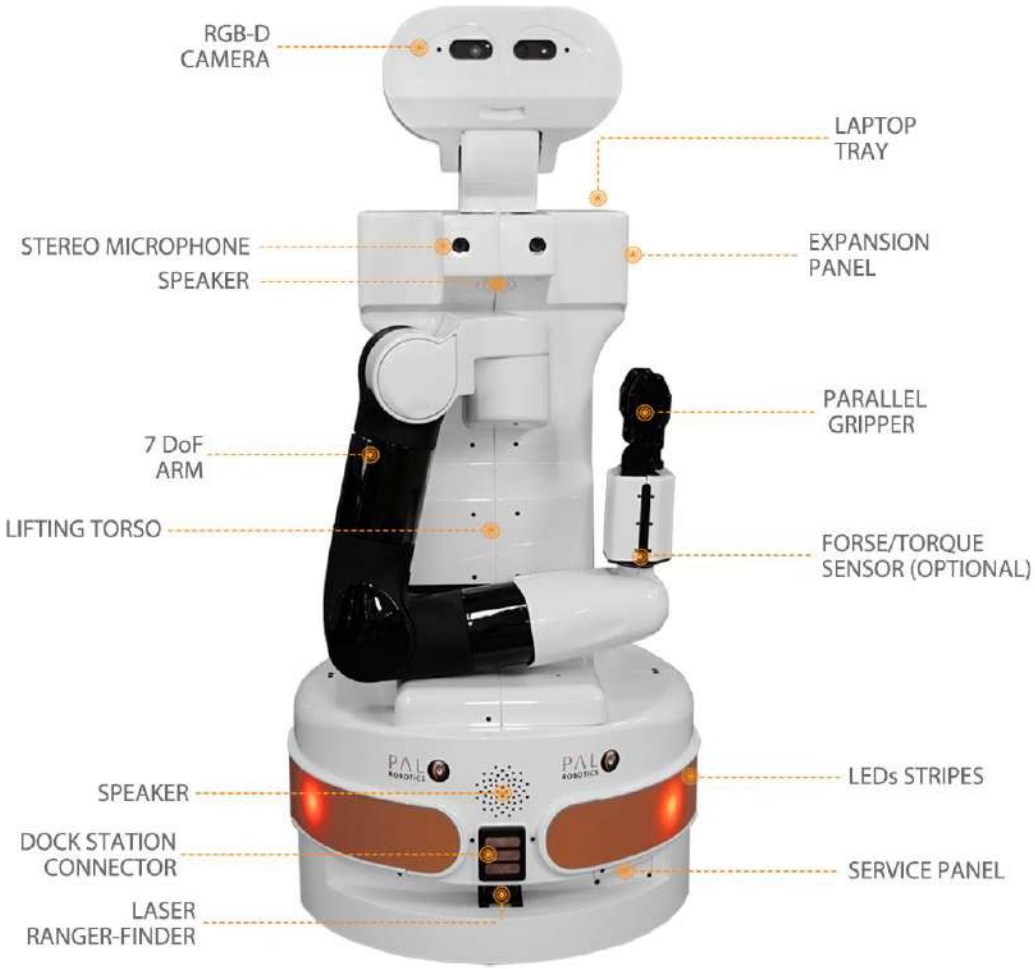
REF: fp-robotics.com

REF: clearpathrobotics.com

TIAGo at first glance

TIAGo is a mobile manipulator designed to work in indoor environments. It has an extendable torso and an arm manipulator to grab tools and objects. Its sensor suite allows it to perform a wide range of perception, manipulation, and navigation tasks.

Dimensions	Height	110 – 145 cm
	Weight	72 Kg
	Base footprint	Ø 54 cm
Degrees of freedom	Mobile base	2
	Torso lift	1
	Arm	4
	Wrist	3
	Head	2
	Hey5 hand	19 (3 actuated)
	PAL gripper	2
Mobile base	Drive system	Differential
	Max speed	1 m/s
Torso	Lift stroke	35 cm
Arm	Payload	2 Kg
	Reach	87 cm
Electrical features	Battery	36 V, 20 Ah
Sensors	Base	Laser range-finder
		Sonars
		IMU
	Torso	Stereo microphones
	Arm	Motors current feedback
	Wrist	Force/Torque
	Head	RGB-D camera



Hardware - Mobile base

TIAGo's mobile base is provided with a differential drive mechanism and contains an onboard computer, batteries, power connector, laser-range finder, three rear sonars, a user panel, a service panel, and two WiFi networks to ensure wireless connectivity.

Hardware - Mobile base

Laser range-finder (2D lidar)

Located at the front of the base. This sensor measures distances in a horizontal plane. It is a valuable asset for navigation and mapping.

Manufacturer	SICK
Model	TIM561-2050101
Range	0.05 - 10 m
Frequency	15 Hz
Field of view	180°
Step angle:	0.33°

Sonars

These sensors are capable of measuring from low to mid-range distances. In robotics, ultrasound sensors are commonly used for local collision avoidance. Ultrasound sensors work by emitting a sound signal and measuring the reflection of the signal that returns to the sensor.

Manufacturer	Devantech
Model	SFR05
Frequency	40 kHz
Measure distance	0.03 - 1 m

Inertial measurement unit (IMU)

This sensor unit is mounted at the center of TIAGo and can be used to monitor inertial forces and provide the attitude

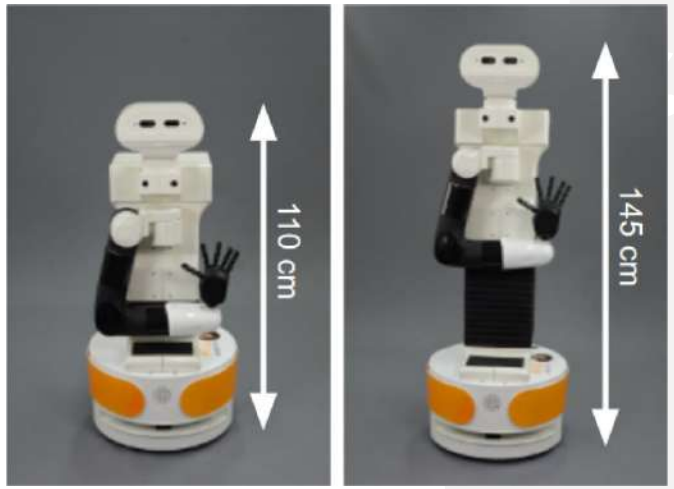
Manufacturer	InvenSense
Model	MPU-6050
Gyroscope	3-axis
Accelerometer	3-axis

Hardware - Torso

TIAGo's torso is the structure that supports the robot's arm and head, and is equipped with an internal lifter mechanism that allows the user to change the height of the robot. Furthermore, it features an expansion panel and a laptop tray. The lifter is able to move at 50 mm/s and has a stroke of 350 mm.

Stereo microphones

There are two microphones that can be used to record audio and process it in order to perform tasks like speech recognition.



Hardware - Arm manipulator

TIAGo 's arm is composed of four M90 modules and one 3 DoF wrist, M3D

Weight	10 Kg					
Payload	2.8 Kg					
Joints	7					
Onboard control modes	Modules	Position, velocity and current				
	Wrist	Position and velocity				
Actuators	Description	Reduction	Max speed [rpm]	Nominal torque [Nm]	Encoders (bits) Motor	Absolute
	1st module	100:1	18	39	12	12
	2nd module	100:1	18	39	12	12
	3rd module	100:1	22	22	12	12
	4th module	100:1	22	22	12	12
	Wrist 1st DoF	336:1	17	3	11	12
	Wrist 2nd DoF	336:1	17	5	11	13
	Wrist 3rd DoF	336:1	17	5	11	13

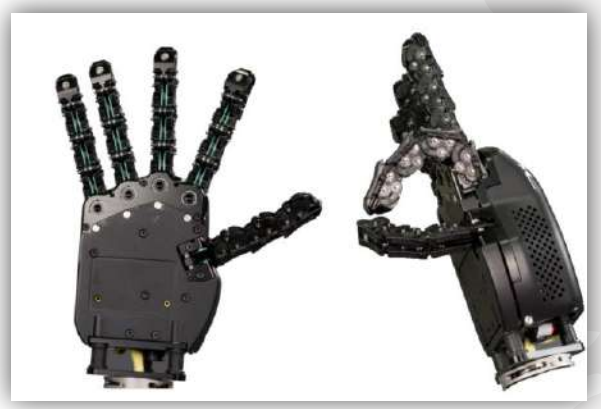
Force/torque sensor

TIAGo has a force/torque sensor integrated on the end-point of the wrist

Physical Specs	Weight	Diameter	Height	
	0.0917 Kg	45 mm	15.7 mm	
	Fx, Fy	Fz	Tx, Ty	Tz
Sensing ranges	290 N	580 N	10 Nm	10 Nm
Resolution	1/8 N	1/8 N	1/376 Nm	1/752 Nm

Hardware - Arm manipulator - End effector

TIAGo 's end-effector is one of the modular features of the robot. TIAGo can be used with three interchangeable end-effectors: the Hey5 hand, the PAL parallel gripper and the Schunk WSG32 industrial gripper.



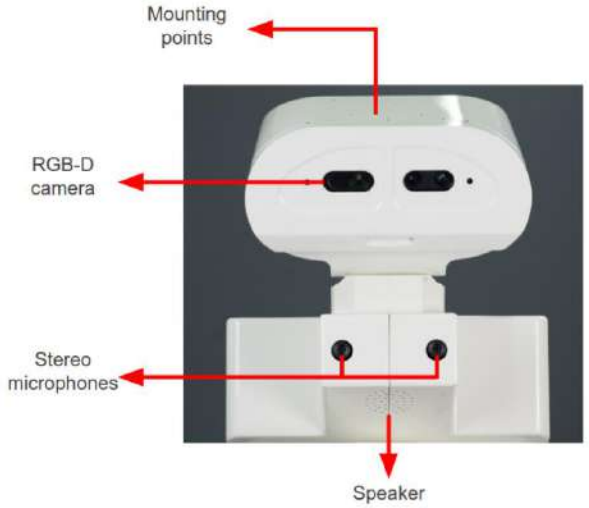
Model	WSG 032-068-C
Weight	550 g
Payload	2 kg
Interchangeable fingers	Yes
Stroke per jaw	34 mm
Min. gripping force	5 N
Permanent gripping force (100% continuous duty)	50 N
Max. speed	400 mm/s

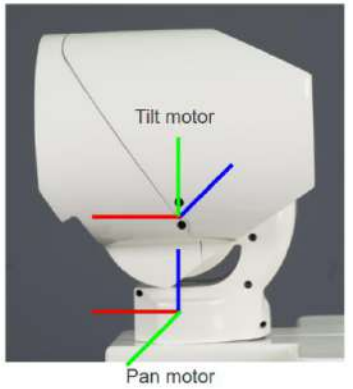
Weight	800 g				
Payload	2 kg				
interchangeable fingers	Yes				
Actuators	Description	Reduction	Max speed [rpm]	Max torque [Nm]	Absolute encoder
	Left finger	193:1	55	2.5	12 bits
	Right finger	193:1	55	2.5	12 bits

Weight	720 g		
Payload	1 Kg		
Joints	19		
Actuators	Description	Max speed [rpm]	Max torque [Nm]
	Thumb	32	0.23
	Index	32	0.23
	Middle+right+little	34	0.45

Hardware - Head

TIAGo's head is equipped with a pan-tilt mechanism, i.e. 2 DoF, and an RGB-D camera. Furthermore, on top of the head, there is a flat surface with mounting points to allow the user to add new sensors or equipment.





RGB-D camera

Manufacturer	Orbbec
Model	Astra S
Field of view	60° H, 49.5° V, 73° D
Interface	USB 2.0
Color stream modes	QVGA 320x240 @ 30 fps, VGA 640x480 @ 30 fps, 1280x960 @ 10 fps
Depth stream modes	QVGA 320x240 @ 30 fps, VGA 640x480 @ 30 fps, 160x120 @ 30 fps
Depth sensor range	0.4 - 2 m

Hardware - Onboard computer and processor

Onboard computer

Component	Description
CPU	Intel i5 / i7
RAM	8 / 16 GB
Hard disk	250 / 500 GB SSD
Wi-Fi	802.11 a/b/g/n/ac
Bluetooth	Smart 4.0 Smart Ready

Development computer

Any computer supporting ROS (directly or through containers) could be easily integrated with TIAGo's onboard computer.

NVIDIA Jetson TX2

Suitable for implementing ML/DL/RL models

Hardware - Joystick

Joystick

The motions of the mobile base, torso, head, and opening/closing of the end-effector could be controlled using the joystick.
To control the arm manipulator (6 DoF of the end-effector) one should first run the WBC motion planner.

Software - Robot Operating System (ROS)

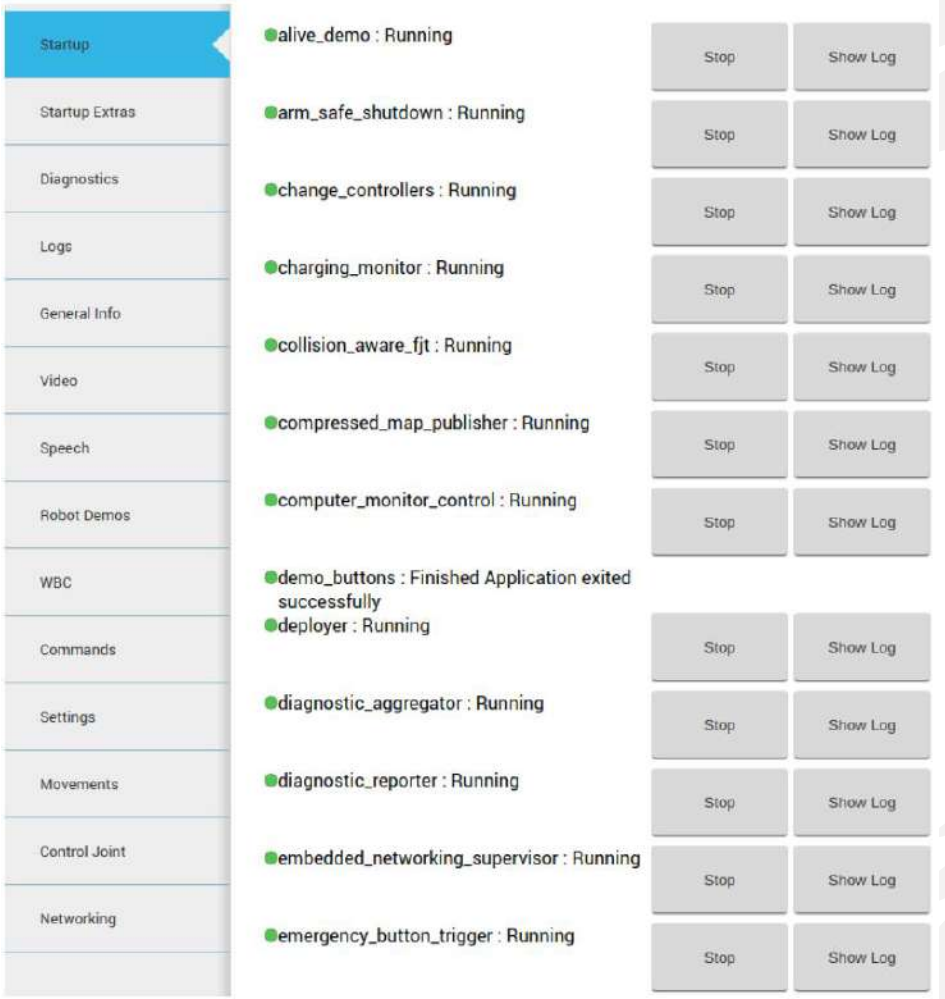
TIAGo is programmed based on ROS.
The comprehensive list of ROS packages used in the robot are classified into three categories:

- Packages belonging to the official ROS distribution melodic.
- Packages specifically developed by PAL Robotics, which are included in the company's own distribution, called ferrum.
- Packages developed by the customer.

Software - WebCommander

The WebCommander is a web page hosted by TIAGo. It can be accessed from any modern web browser that is able to connect to TIAGo. The WebCommander website contains visualizations of the state of TIAGo's hardware, applications, and installed libraries, as well as tools to configure elements of its behavior.

http://tiago-135c:8080
http://control:8080



Software - Manipulator's Motion planning/control

MoveIt

MoveIt is the most widely used software for robot manipulation. It is fully open source and free for industrial, commercial, and research use. By incorporating the latest advances in motion planning, manipulation, 3D perception, kinematics, control and navigation, MoveIt is state of the art software for mobile manipulation.

Whole-Body Control (WBC)

WBC is PAL's implementation of the Stack of Tasks. It includes a hierarchical quadratic solver, running at 100 Hz, able to accomplish different tasks with different priorities assigned to each. In order to accomplish the tasks, the WBC takes control of all TIAGo 's upper-body joints. WBC considers all joint limits as well as self-collision avoidance when planning motions for the robot.

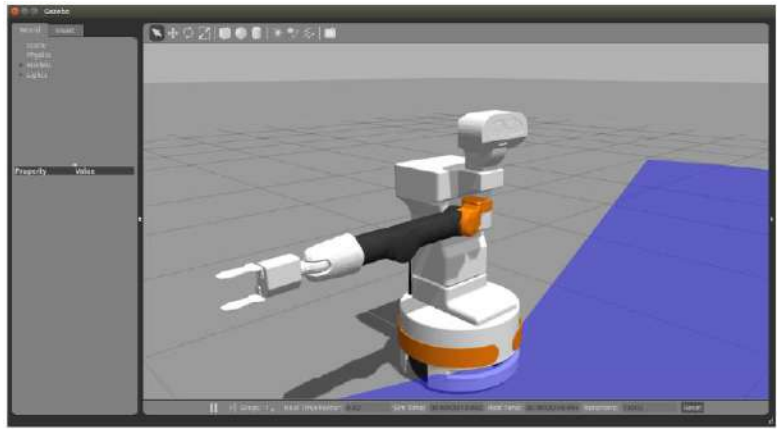
PlayMotion

TIAGo is provided with a motions engine to play back predefined motions involving joints of the upper body.
A default library with several motions is provided, and the user can add new motions that can be played at any time.

Software - Gazebo simulator

TIAGo has a ROS-based Gazebo simulator. When installing TIAGo's workspace on the development computer, we can run Gazebo simulations of TIAGo. Three different simulation worlds are provided with TIAGo.

Empty world



Office world

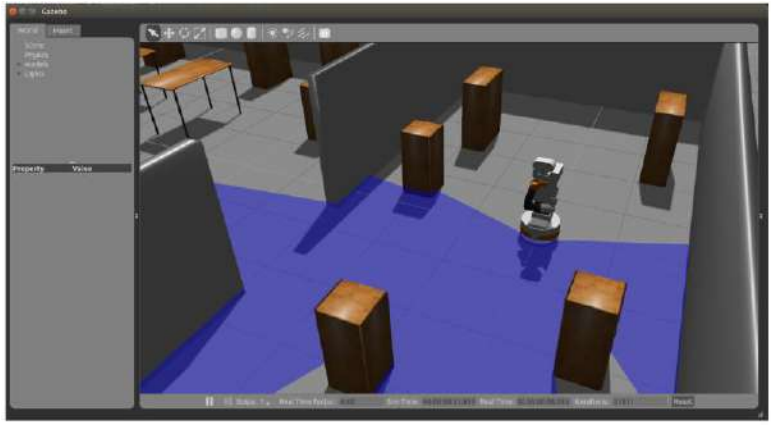
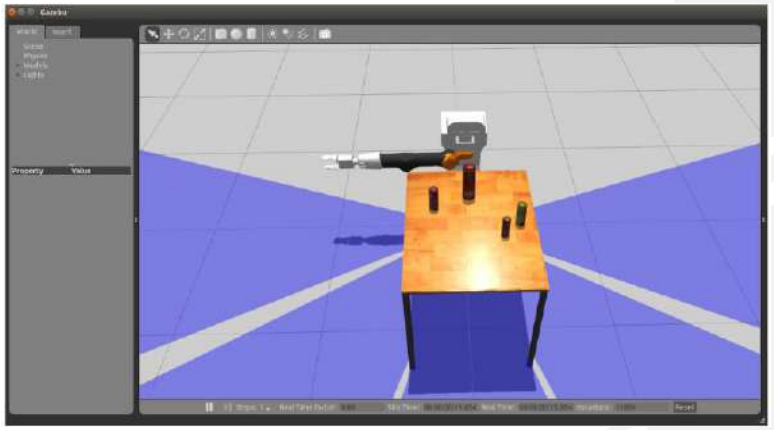


Table with objects world



How to learn TIAGo?

ROS

https://ros.org/
https://www.theconstructsim.com/

Gazebo

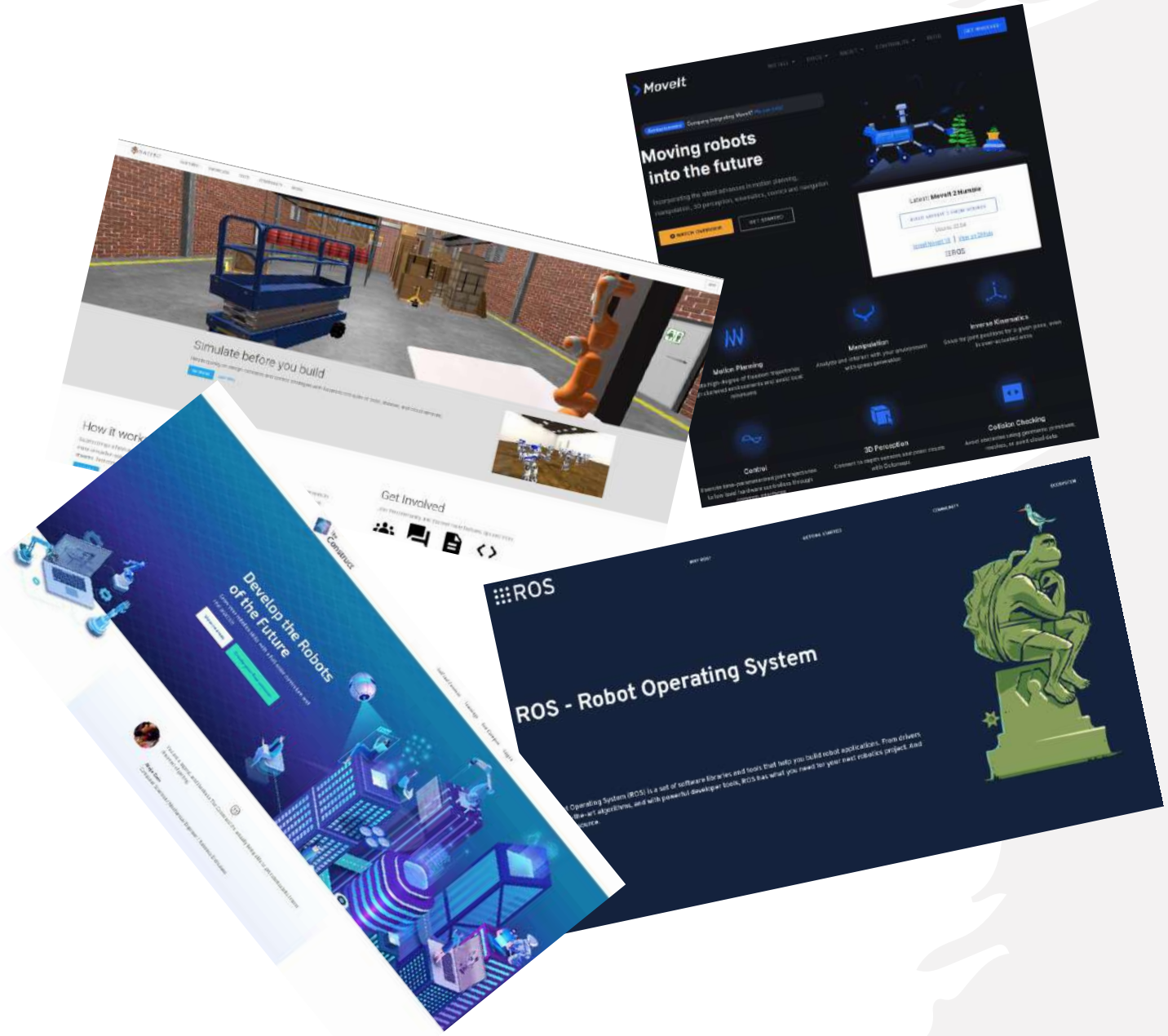
https://staging.gazebosim.org/home

MoveIt

https://moveit.ros.org/

TIAGo

http://wiki.ros.org/Robots/TIAGo/Tutorials
TIAGo Handbook



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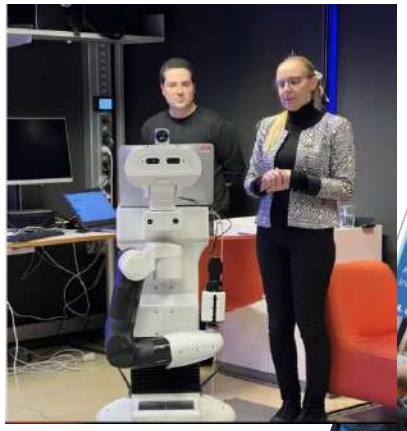
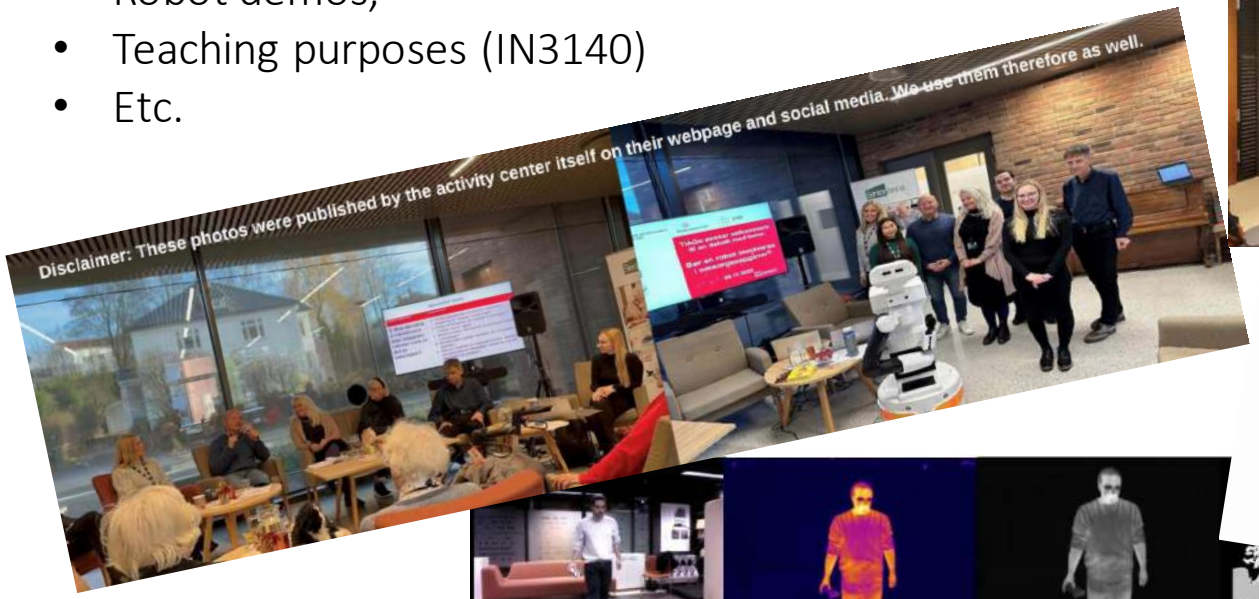
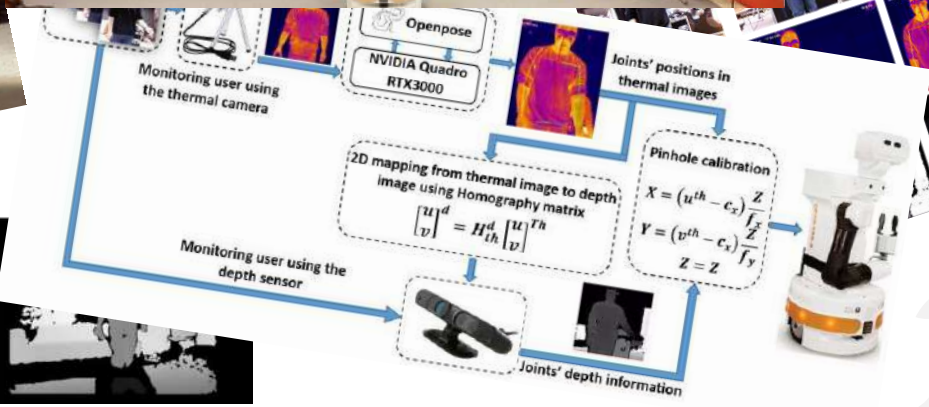
TIAGo for research

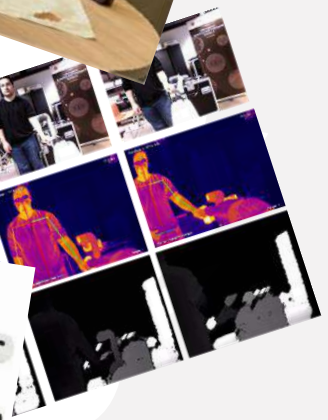
So far, TIAGo has been used in/for,

- 2/3 Ph.D. projects,
- Several Master projects,
- 2 (postdoc) researcher's work,
- Different user studies (making videos, data collection),
- Robot demos,
- Teaching purposes (IN3140)
- Etc.









Thank you!