AuE 8230: Autonomy Science and Systems

ASSIGNMENT 1 B : TURTLEBOT- TEARDOWN

CONTENTS

TurtleBot 3: Burger

Attributes	Specifications
Max. Translational Velocity	0.22m/s
Max. Rotational Velocity	2.84 rad/s (162.72 deg/s)
Max. Payload	16 Kg
Perception	LIDAR - 360 LDS-01
Actuator	XL430-W250
MCU	32-bit ARM Cortex®-M7 with FPU (216 MHz)
SBC	Raspberry Pi 3B
IMU	Gyroscope 3 Axis Accelerometer 3 Axis

Source: https://www.roscomponents.com/en/mobile-robots/214-turtlebot3-burger.html#/courses-no/turtlebot_3_burger_model-burger_intl_

TASK 1 : HARDWARE COMPONENTS OF TURTLEBOT3

TURTLEBOT3 BURGER IS A TWO-WHEELED DIFFERENTIAL DRIVE TYPE PLATFORM HAVING FOLLOWING COMPONENTS :

Core Components :

- Chassis
- Motors
- Wheels
- OpenCR
- Single Board computer
- Sensors
- Battery
- Memory Card

- Detailed Part lists :

	Part Name	No of components
Chassis Parts	Waffle Plate	8
.	Plate Support M3x35mm	4
.	Plate Support M3x45mm	10
.	PCB Support	12
.	Wheel	2
.	Tire	2
.	Ball Caster	1
Motors	DYNAMIXEL (XL430-W250-T)	2
Boards	OpenCR1.0	1
.	*Raspberry Pi	1
.	USB2LDS	1
Sensors	LDS-01 (HLS-LFCD2)	1
.	Raspberry Pi Camera v2.1	0

	Part Name	No of components
Memorys	MicroSD Card	1
Cables	Raspberry Pi Power Cable	1
.	Li-Po Battery Extension Cable	1
.	DYNAMIXEL to OpenCR Cable	2
.	USB Cable	2
Miscellaneous	Assembly components	154
Powers	SMPS 12V5A	1
.	A/C Cord	1
.	LIPO Battery 11.1V 1,800mAh	1
.	LIPO Battery Charger	1
Tools	Screw- driver	1
.	Rivet tool	1

Source: https://emanual.robotis.com/docs/en/platform/turtlebot3/features/#specifications

TASK 1 : HARDWARE COMPONENTS OF TURTLEBOT3

DETAILED BREAKDOWN OF COMPONENTS

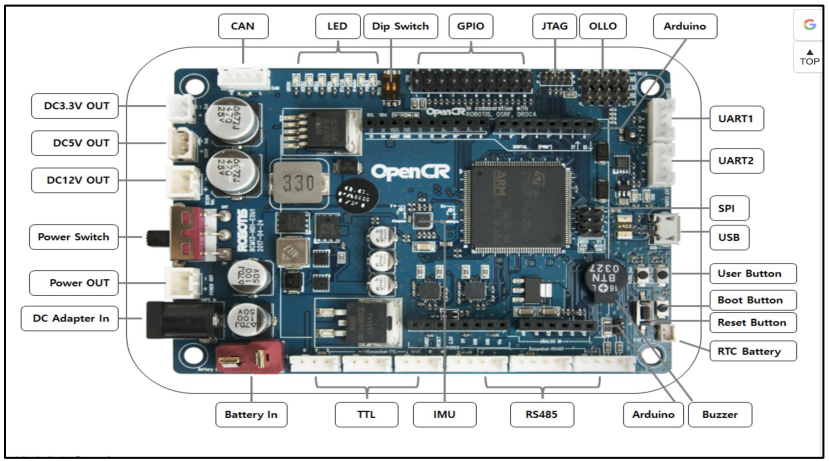
360 degrees LiDAR LDS -01 Performance specifications

- 2D laser scanner capable of sensing 360 degrees
- Hardware connection compatibility - USB interface with PC, UART interface for embedded board
- Detection distance (Range) 120 mm ~3500 mm
- Scan rate – 300 +/- 10 rpm
- Angular rate – 360, Angular Range
- Distance accuracy ranges from +/- 15 mm for small ranges and +/-5% for higher.
- Distance Precision ranges from +/-10 mm for small ranges and +/-3.5 % for higher

Datasheet of LDS -01= Datasheet

OpenCR Controller Board

- ARM Cortex-M7 based STM32F7 chip with floating point unit
- Software platforms :Arduino IDE and traditional Firmware Development
- Communication interfaces: USB for connecting to PC, UART, SPI, I2C, CAN for other embedded devices
- Optimum performance with Single board computer providing hot swap power inputs



TASK 1 : HARDWARE COMPONENTS OF TURTLEBOT3 - Burger

DETAILED BREAKDOWN OF COMPONENTS

Raspberry Pi 3B

- Processor: 64-bit quad-core ARM Cortex-A53
- Clock frequency: 1200 MHz
- RAM: 1024 MB
- Wi-Fi : Yes
- Bluetooth : Yes, 4.1
- Power supply : 5v 2.5A

Source: https://www.generationrobots.com/en/402366-raspberry-pi-3-model-b.html

Dynamixel XL430-W250-T Servo Motor

- Torque: 14 kg-cm/ 1.4N-m
- Speed: 61rpm
- Input Voltage: 12V
- Reduction Ratio: 258:1
- Operating Range: 0-360 degrees
- Feedback: Position, Temperature, Load, Input voltage

Source:https://www.generationrobots.com/en/402823-dynamixel-xl430-w250-t-servomotor.html

TASK II : Benchmarking of TurtleBot 3 - Burger

Attribute	TurtleBot2	Specification	Cost	TurtleBot 3	Specification	Cost
LIDAR	-	-	-	360° LDS-01 LIDAR	Scan Rate:300 RPM Fs: 1.8kHz	$196
Camera	Asus X Tion	640 * 480 pixels	$183	30 IntelSense HD	1920 * 1080	$290
Memory	4GB DDR3	DDR3 1333 (PC3 10600)	$22	4GB DDR4	DDR4 2666 (PC4 21300)	$23
Battery	Ni - Ion	Upto 2400mAh	$10	Li - Polymer	1800mAh	$22
SBC	Dragon Barrel 410-e	1GB RAM - 533 MHz	$75	Raspberry Pi 3	1GB RAM - 450MHz	$149

TASK III : MODULARIZATION OF TURTLEBOT3

Components 1. LiDAR	Key difference in Performance characteristics	Approx. Cost	Application uses cases
LDS -01- sold by Robotis existing	Range of **0.120 ~3.5 m** Accuracy : +/- 15 mm for small ranges +/-5% for higher ranges of distance	196.10$	Simultaneous localization and mapping (SLAM), navigation for path planning, Advanced Driver Assistance System (ADAS) application
Velodyne's HDL 32E source:https://velodynelidar.com/products/hdl-32e/	Range of **100 m** Accuracy : +/- 15 mm for small ranges +/-5% for higher ranges of distance 3D Lidar	8000$	real-world industrial applications, including autonomous vehicle control and operation, mobile terrestrial mapping, aerial 3D mapping, and security surveillance
Intel Realsense Lidar Depth source:https://www.intelrealsense.com/lidar-camera-l515/	Range of **0.25 – 9.00 m** ± 2 cm Accuracy 3D sensor with RGB-D(depth) Cameras	349$	gesture recognition, object recognition and scene recognition based on 3D depth output of LiDAR
RP Lidar 360 scanner source:https://www.slamtec.com/en/Lidar/A1	Range of **25 m** Accuracy :1% of the range(≤3 m) 2% of the range(3-5 m) 2.5% of the range(5-25m)	99$	Extreme performance Ideal for indoor environments with maximum ranging distance and sampling frequency.

TASK III : MODULARIZATION OF TURTLEBOT3

Components 2. SBC	Key difference in Performance characteristics	Approx. Cost	Application uses cases
Raspberry Pi 3 B+ (Currently used) Src:https://www.sparkfun.com/products/14643?src=raspberrypi	Cortex A-53 1.4GHz 64-bit quad core processor 1 GB LPDDR2 SDRAM Gigabit ethernet over USB 2.0	$ 35	Lesser memory
Raspberry 4 B source:https://www.sparkfun.com/products/15446?src=raspberrypi	Cortex A-72 1.5 GHz 64 bit quad core processor 2GB LPDDR4 SDRAM True Gigabit ethernet	$45	Faster Processing, more memory
Pine A-64 source:https://pine64.com/product/pine-a64-lts/	Cortex A-53 1.1GHz 64-bit quad core processor 2 GB LPDDR3 RAM 128 MB Flash, 128GB expandable storage Gigabit ethernet, 2.4 GHz Wifi, Bluetooth 4.0	$ 32	More memory, Bluetooth and Wifi capabilities

TASK III : MODULARIZATION OF TURTLEBOT3

Components 3. Cameras	Key difference in Performance characteristics	Approx. Cost	Application uses cases
Kinect 2 Source:https://www.researchgate.net/publication/321048476_A_Post-Rectification_Approach_of_Depth_Images_of_Kinect_v2_for_3D_Reconstruction_of_Indoor_Scenes	FOV: 70 x 60 degrees Range: 0.5-4.5m Depth resolution: 512 x 424, 30 fps RGB: 1920 x 1080, 30 fps	$ 160	Object detection, Skeleton tracking
Orbbec Astra Pro Source: https://shop.orbbec3d.com/Astra-Pro	Range: 0.6-8m FOV: 60 x 49.5 (horizontal x vertical) Depth: 640 x 480, 30 fps RGB: 1280 x 720, 30 fps Accuracy: 1-3mm at 1m.	$ 150	Object detection, Face Recognition, Gesture recognition, Environment Perception, 3D Map Reconstruction
Intel RealSense D 415 Source:https://store.intelrealsense.com/buy-intel-realsense-depth-camera-d415.html?_ga=2.136741301.446428654.1643894918-731221196.1643894918	Range: 0.5-3m Depth Accuracy: <2% at 2m. FOV: 65 x 40 degrees Depth resolution: 1280 x 720, 90 fps RGB: 1280 x 1080, 90 fps	$ 259	Object Detection, Environment Perception, Visual Odometry, Face Recognition

Decision Matrix

Single Board Computer	Price	Pros and Cons
Raspberry Pi 4 Model B	$35 ~ 55	Better IO performance with multiple storage options Great for Robotics and Computer Vision application Faster wireless connectivity with 2.4/5GHz Wi-Fi and Bluetooth 5.0
Raspberry Pi 3 Model B	$35	Easy to setup, customizable. Heating issues under high computing loads. Ethernet port can't reach theoretical maximum speed of 1Gbps
Rock Pi S	$23.99	Strong processor that would run better than a Raspi Zero But, Lack of community as compared to Raspi
RockPro64	$32	Excellent performance in retro gaming and video streaming Lacks wireless and bluetooth

Decision Matrix

Lidar	Price	Pros and Cons
RP Lidar 360 Scanner:	$99	Pros: 1. Sample rate up to 8000 times, highest in the current economical LIDAR industry. 2. Integrated the wireless power and optical communication technology to self-design the OPTMAG technology, which breakouts the life limitation of traditional LIDAR system. 3. Lowest cost Lidar available Cons: Not suitable for short range and operations where accuracy is needed
Intel Realsense Lidar Depth	$349	Pros: Inbuilt RGB Camera that will not require sensor fusion algorithms with LIDAR functionality Can scan outdoors, even in full sunlight. Good build quality and very sturdy, can withstand bumps and shocks with no major degradation of performance Cons: Overall noise level (and hence reconstruction quality) is relatively high, especially for the D435 and D435i. Sometimes has difficulty picking up small geometric details.
Velodyne's HDL 32E	$8,000	Pros: industry-leading range and resolution, detects vehicles and people with high precision even under challenging environmental condition Cons: High cost
LDS -01- sold by Robotis existing	$196.10	Pros: high positioning accuracy, even in the dark environment Robust Hardware security devices high level of physical security where space is often limited. Cons: In case of low memory, Data can be unreadable

Educative Platform	Programming Language	Supported Robots	Physical Robots	Simulator	Open Source	ROS	Evaluators
Mobile Robot Interactive Tool	SysQuake (~MATLAB)	Three	No	No	~Yes	No	No
Robots Formation Control Platform	~parameters	Moway	Yes	RFC SIM	No	No	No
Guyot et al.	C	e-puck	No	Webots	~Yes	No	No
SyRoTek	C/C++	S1R	Remote	Stage	No	Yes	No
Farias et al.	C/C++	KepheraIV	Remote	V-Rep	No	No	No
TRS	Python/ MATLAB	Several	No	V-Rep	Yes	No	No
Tekkotsu	C++	Several	Yes	Mirage	Yes	No	No
Robot Ignite Academy	Python	Several	No	Gazebo	No	Yes	No
robotbenchmark	Python	ThymioII, Nao	No	Webots	Yes	No	No
Robot Programming Network	Python/ Blockly	Several	Remote	Stage Webots	No	Yes	No
Robotics-Academy	Python	Several	Yes	Gazebo	Yes	Yes	Yes

CONCLUSION

To conclude the Teardown of the TurtleBot 3 - Burger, we have chosen the appropriate Hardware to build a new version of the TurtleBot.

Hardware	Selected Model
Camera	30 IntelSense HD 415
Single Board Computer	Raspberry Pi 4
LIDAR	Velodyne HDL 32E
IMU	3 Axis, Gyroscope, Accelerometer
Memory	4Gb DDR4 2666 (PC4 21300)