ECE 4600 – Project Summary: G08 – ServoSentry

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Project Summary

ServoSentry is an autonomous security robot that integrates dual locomotion modes with advanced computer vision to provide real-time situational awareness. The robot's design centers on a modular carrier board, which enables quick switching between a wheeled system; optimized for rapid movement on flat surfaces and a quadrupedal system; engineered to navigate uneven terrain. The system is powered by an NVIDIA Jetson Nano that runs deep learning models for object and masked-person detection, operating at approximately 14.8 FPS, while a Raspberry Pi handles sensor data and locomotion control through reliable UART and Ethernet communication.

The wheeled configuration demonstrates strong performance by achieving speeds up to 0.52 m/s and reliably supporting loads beyond 1.75 kg. In parallel, the quadrupedal setup, though slower, has proven capable of steady load-bearing and stable movement. An ultrasonic sensor, exceeding expectations with a range of up to 500 cm, enhances the robot's obstacle avoidance capabilities. Although continuous operation tests indicate a battery life of 35–40 minutes, discrete movement during intruder detection extends runtime to nearly two hours, highlighting the system's efficiency when used in practical, on-demand scenarios.

Extensive testing shows that ServoSentry can effectively track intruders by keeping targets centered in its field of view and dynamically adjusting its trajectory in real time. The integration of precise computer vision with adaptive locomotion not only ensures smooth navigation and obstacle avoidance but also lays the groundwork for further enhancements in battery endurance and overall movement speed. This versatile design and robust performance make ServoSentry a promising platform for scalable, real-world robot applications.

Table of Performance Metrics

Module	Task	Minimum Requirements	Measurement Unit	Metrics	Outcomes (pass/fail)
Computer Vision	Object Detection Speed	Detection of one frame within 0.25s (4 FPS)	Time (s)	Frames Per Second (FPS)	0.067 seconds per frame at 14.8 FPS
	Detection Accuracy	≥ 70% detection rate for intruders	Percentage (%)	Accuracy rate	70% for intruders, 70% for other people and 55% for other objects (Pass)
Software	Object Recognition Classes	Detect at least 11 object classes across two datasets	Number of classes	≥ 11 classes	10 classes using the COCO dataset and 2 classes using the masked-model dataset (total = 12 classes) (Pass)
	Data transmission between vision and control system	Correctly send bounding box coordinates and object class data over UART	Data format integrity (e.g., object label and (X, Y, h, w) coordinates)	All data being transmitted is received by raspberry pi.	The raspberry pi receives all data being sent -> Object class detected & (X, Y, h, w) coordinates (Pass)
Sensor	Ultrasonic Range	The ultrasonic sensor should reliably measure distances of at least 100 cm	Distance (cm)	≥ 100cm	Sensor successfully measures up to 500 cm (Pass)
Communication	Wi-Fi Connectivity for Remote access	Maintain reliable communication over a distance of at least 1 m	Distance (m)	≥ 1m	Wi-Fi module installed, and remote communication established within 1m. (Pass)
Power Supply	Battery Endurance	The battery should power the robot for at least 2 hours	Time (hours)	≥ 2 hours	Quadrupedal system: 35 minutes when in motion. (Fail) 40 minutes when stationery. (Fail) Wheeled System: 40 minutes when in continuous motion. (Fail)
Locomotion	Quadrupedal and wheeled load capacity	Must support the mass of robots' locomotion.	Support robot's total mass (excluding motors)	>1.75kg	Quadrupedal and wheeled system more than 1.75kg successfully supported (pass)
	Quadrupedal and wheeled movement.	Robots can move and turn without falling over.	Speed (m/s)	>0.25 m/s	Quadrupedal system: 1.63 cm/s (Fail) Wheeled system: 0.52 m/s (Pass)
Integration	Swap carrier board between leg and wheels system	The carrier board must be swappable within 15 seconds	Time (s)	<15 s	24.63s (Fail)
	Autonomous Navigation and System Integration	System reliably executes autonomous navigation, obstacle avoidance, and intruder tracking with minimal response delays.	Response delay	<1s	Quadrupedal system: reliable autonomous navigation, obstacle avoidance, and intruder tracking. <1s delay (Pass) Wheeled system: reliable autonomous navigation, obstacle avoidance, and intruder tracking. <1s delay (Pass)

Budget

Proposed budget		**Actual purchases**		**Link**
Item	**Total cost**	**Item**	**Total cost**	
Tilt/pan kit	$49.39	-	-	-
Wheels	$21.27	-	-	-
DC motors for wheels	$25.22	-	-	-
Motor drivers for wheels	$19.03	Motor drivers for wheels	$19.03	Amazon
Servos for hip knee joint (x2)	$163.50	Servos for hip and knee joint (x3)	$247.44	Amazon
Servos for leg rotation	$39.55	Servos for leg rotation - Donation	$0	-
Motor driver for legs	$22.93	Motor driver for legs (x3)	$54.21	Amazon
IMU (accelerometer)	$15.68	-	-	-
Battery pack	$87.71	Battery pack	$61.02	Amazon
DCDC converter	$16.74	DCDC converter (x2)	$38.40	Amazon
XT60 connector	$60.48	XT60 connector	$11.29	Amazon
DC Power pigtail	$19.03	-	-	-
Battery charger	$11.19	Battery charger	$16.94	Amazon
Nvidia Jetson Nano	$307.00	Nvidia Jetson Nano	$307.00	Amazon
-	-	Wheel and motor kit	$111.75	Amazon
-	-	ACDC power supply	$17.91	Amazon
-	-	Ball bearings 30pcs	$15.81	Amazon
-	-	Metric screw kit (x2)	$61.00	Amazon
-	-	Magnets 100pcs	$15.81	Amazon
-	-	3D printer filament (x3)	$94.89	Amazon
-	-	Web Camera	$0	-
		Ultrasonic Sensors	$0	-
-	-	Jetson Nano cooling fan	$13.84	Amazon
-	-	WAGO connectors	$13.16	Amazon
-	-	Micro USB connectors	$14.68	Amazon
-	-	Twippo connectors	$17.11	Amazon
-	-	USB connector – L shaped	$14.97	Amazon
-	-	HDMI connector – L shaped	$8.12	Amazon
-	-	Raspberry Pi Model 3B+ - Donation	$0	-
Proposed total cost	**$888.95**	**Actual cost**	**$1154.36**	
Proposed remaining funds	**$311.05**	**Actual remaining funds**	**$45.64**	

The ECE department provided us with $600, and our advisors contributed an additional $600 for a total budget of $1200. Entries with "-" indicate an item listed on the proposed budget that we did not end up purchasing. Some listed items are shown with a total cost shows as $0, which means that the item was either borrowed from the ECE Tech Shop or from another team member, thus the link is provided as "-". Unless otherwise noted, a single unit of each item was purchased or proposed for purchase. Total cost reflects the price of all units ordered of the item, including tax and shipping.