Applications Of Robot Dogs In Condition Monitoring

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Introduction

The issue at hand is that in a building over time, no matter how it would be damaged, either by natural damage by erosion or by accidental damage, that damage would be built up over time if not addressed. Although seeing visible damage might be permissible under certain conditions, in a professional or business environment, waiting for the damage to be realized is not helpful in keeping a respectful or safe working condition. The Unitree Go2 is a robot dog with 12 DOF employed for educational use to play around with LiDAR as an innovation and its usage on an everyday basis [1]. It is designed for high-level mobility, autonomy, and flexibility in many applications including research, industrial inspection, and human-robot interaction. The Go2 from Unitree Robotics features high-performance actuators and AI obstacle avoidance. Dynamic motion capabilities allow it to travel over rough terrain, climb stairs, and recover from a fall. It is controlled through an app, remote controller, or programmed instructions, and it has applications such as security patrolling, payload transportation, and robot research. It also offers customizability since developers are free to implement additional sensors, AI models, and features depending on specific needs. Moving to the design of the applications of robots dog with LiDAR technology, mention is made of applying it in real-life situations like navigating through construction zones or toxic environments. LiDAR is a technology used in autonomous vehicles today to detect traffic and pedestrians [2]. In this research, it will plot the process of a current scenario of the situation with forming barriers in a 3D map by using laser pulses to form measurements of distance to an object such as furniture, doorways, and people. There also is an experimentation of climbing the stairs, plotting a 3D map of the library, outside campus, and a hallway. The robot dog also has an external camera in which can be used to process images of information regarding the situation at hand in relation to the environment. In this research, there will be tests on feasibility of having a robot traverse a location to potentially be used in gas leaks in a building, hurricane, fire, and burning buildings to assess damages and situation at hand that would be dangerous for humans to pass through. While undergoing the experiment process, the robot dog moves from point A to point B where it moves in the same path numerous times with different obstacles and lighting conditions which may exist in the way which may impact the effectiveness of getting to the goal destination. When superimposing statistical data on a graph to graph an observation of the experiment, there is the implication that the path from A to B will take longer based on the number of the total size of obstructions present in the location, or the effects of lighting in the area. When using the model experiments and statistical information, there is a consideration that there is some lag to reach the destination if there is an object in the way or various surfaces, but there is hardly any variation when there is no light in the environment since LiDAR is not affected because the technology employs light beam sensors to measure the depth and height of the environment in a 3D simulation map.

Figure 1: Unitree Go2 (Robot Dog)

Mapping Process

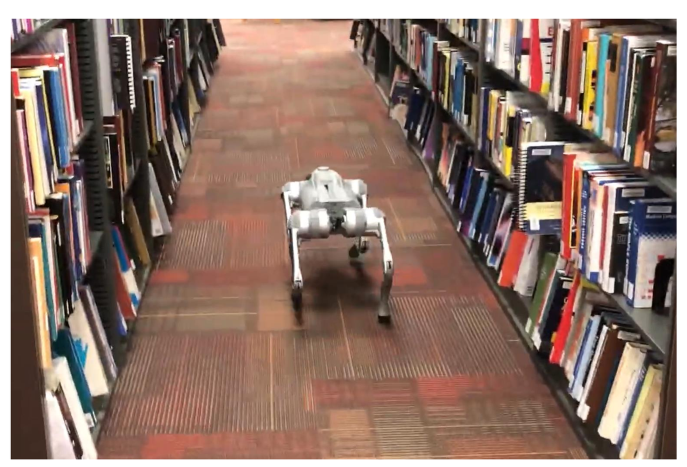

Figure 2: Robot Dog Walking in Library

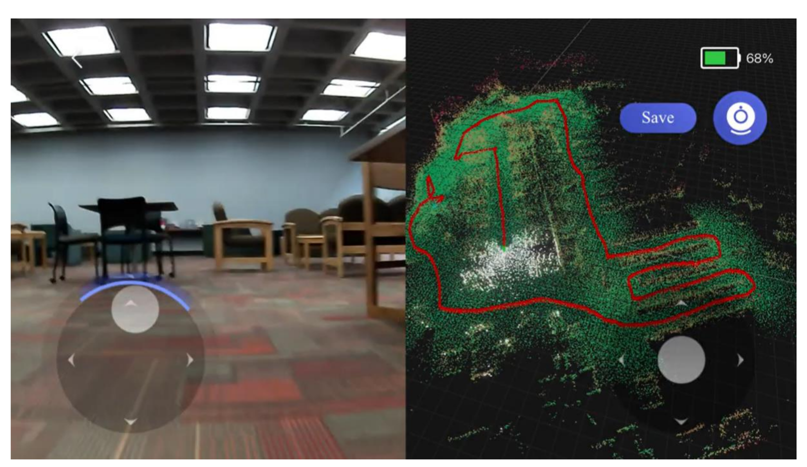

Figure 3: Robot Dog Walking in Library LiDAR Map

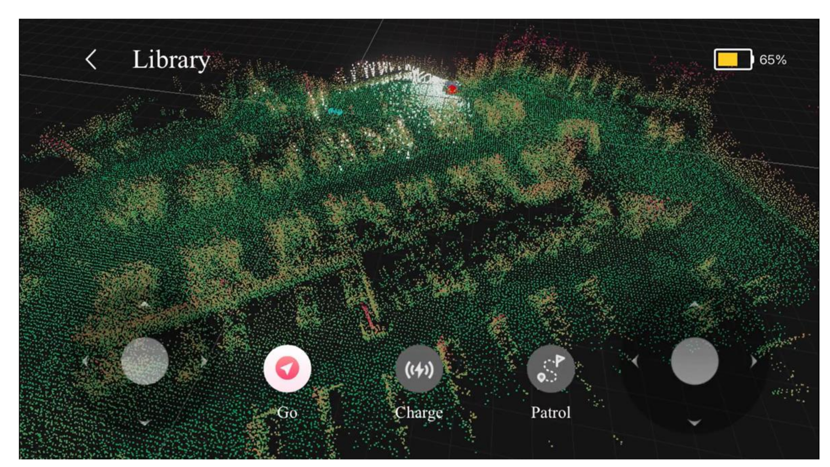

Figure 4: Map of the LTU library generated from data collected by the LiDAR sensor of the Unitree Dog

To begin to map with the Unitree Go2, the first thing to do is power on the robot. This involves ensuring the robot is charged to full or connected to a power source, and then pressing the power button down until the system has booting up. Cues such as LED lights and motor movement confirm that the robot is in a ready-to-use state. Upon powering it on, the second thing is to link the robot to a smartphone or tablet using the Unitree Robotics app. The Go2 typically emits its own Wifi signal, which one taps into through a smartphone or tablet. Once successfully connected, the app screen will display real-time system status information such as battery, motor temperature, and signal strength. Once the connection is established, users navigate through the app to locate the "Mapping". On selecting "Start Mapping", it activates the LiDAR sensors and onboard computational hardware, and the robot begins scanning and processing the world in real-time. After doing this, the user can either command the robot through one of three methods: the touchscreen joystick within the app, a remote control, or programmed movement instructions through pre-defined waypoints. As the robot moves, it emits laser pulses through its LiDAR sensor, which bounce off surrounding objects and surfaces. These bounces are used to calculate distances and create a detailed 3D map of the world. While the robot is scanning, users can watch the map creation process in the app. A graphical display in real time shows either a 2D floor plan or a rotating 3D point cloud model made up of walls, obstacles, paths traveled, and the robot's current location. The interface typically supports zooming, panning, and rotating the map to better view the environment while it is being constructed. Once the area has been fully mapped, the user may stop the process by clicking "Stop Mapping." The map is saved automatically to the robot's internal storage or exported to the user device. Once it has been saved, the user may view the map from the app's "Saved Maps" page. These maps can be saved for later use in navigation tasks, enabling the robot to remember explored worlds and move around more effectively. Users can also enrich the map with virtual obstacles or border regions through the app to restrict the path the robot can travel. Waypoints can be included along the stored path as well to define custom patrol routes or inspection paths. In general, the Unitree Go2 offers a super-smooth and extremely utilitarian mapping experience.

Data Gathering

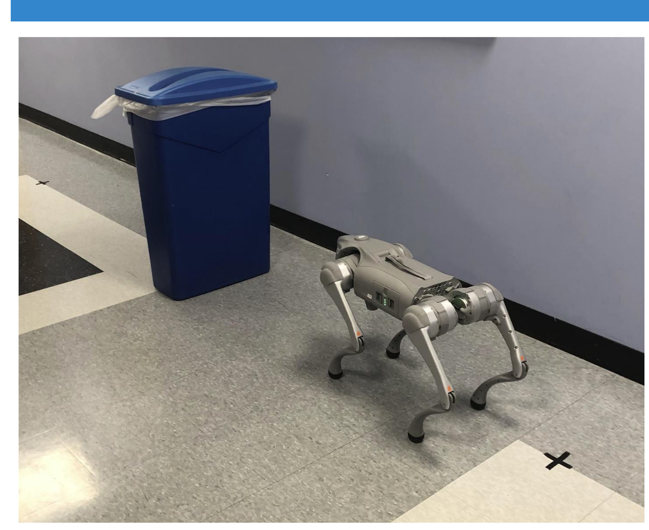

Figure 5: The path used has an obstacle blocking the middle which therefore, would maneuver around it to its destination

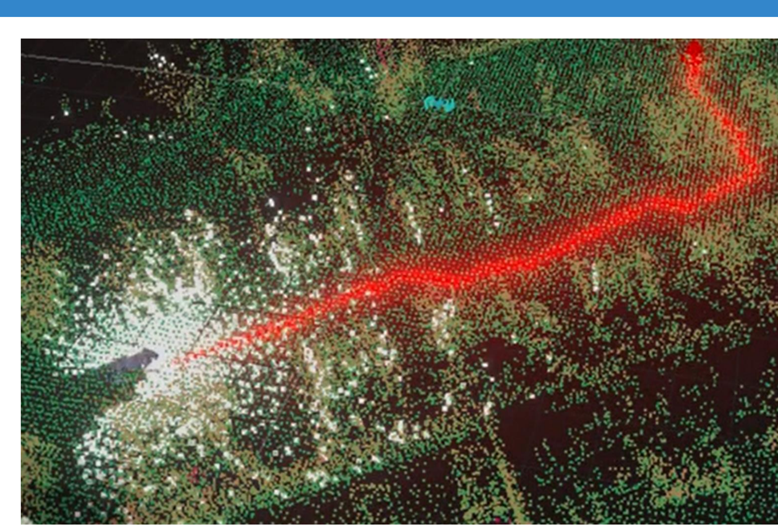

Figure 6: Robot Dog following predetermined pathway

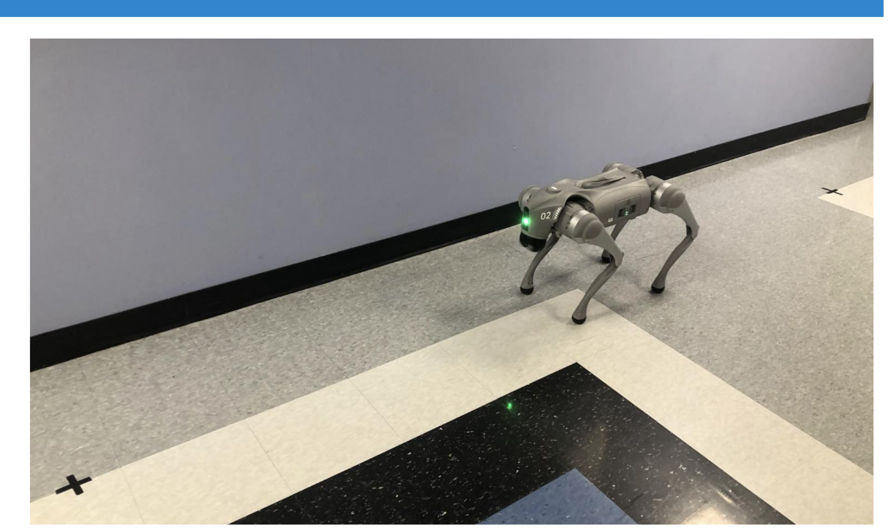

Figure 7: A 10 ft path marked by black tape with no obstructions

The data gathering began with a measured distance of 10 ft, placing markers at both ends of the distance. The robot was placed at one of the points, facing the other point. After powering on the robot, the area around the distance was mapped. Once mapped, a patrol route was created, with the start and end points of the patrol route being the end markers of the distance. Markers in the patrol route have orientation, with the ones in this test set to point at the opposite point. The patrol was set to last a duration of 3 minutes and the times were measured using a mobile stopwatch app. The robot would begin by moving from the starting point to the end point and change it's orientation to the orientation of the point. After reaching a point, the robot pauses, then begins moving towards the next point, in this test it would be the starting point. The times were separated into 4 different intervals, a forward movement time that measures how long the robot was in a moving state until a pause at the end point, a forward pause time representing the pause after the forward movement until the next movement, then two similar time periods to represent the same motion in the opposite direction regarding the starting points. Two tests were conducted using this method, the first test being a comparison between the time taken to travel without obstruction against a minor obstruction to show a delay when traveling along the path. This involved a trash can with dimensions of 30 x 9.5 in with a height that forces the robot to traverse around the object. The obstruction was placed 5 ft directly in the way of the end point. The second test involved another 10 ft distance taken in a different location but on the same smooth tiled surface. To create a control, the time taken for the robot to complete each phase of the movement was measured the same way as the first test. The second portion of this test involved turning off the lights to see if lighting had any effect on the robot pathing. The only light sources for this experiment was the glowing light on the robot and the light emitted from the tablet. The time taken for the robot was again measured to be compared to the prior test.

Statistical Data & Model Analysis

Using MATLAB, the results from the data collection are shown in Figures 9 and 10 and Tables 1 and 2. Table 1 shows the results for the first control test, which yielded similar results to the second control test. The data collected is relatively consistent besides the overshoot in trial 6, but Figure 9 demonstrates the time delay due to an obstruction in the way of the path compared to the same with no obstructions. It is visible to see that the obstruction causes a delay of about 0.787 seconds, which would make sense from a physical standpoint, having to travel around an object should take longer. Figure 10 displays that there is a difference in the time taken to complete the path while the lights are off. This should not have a major effect on the LiDAR, which leads to human error being a factor as to why the path in the dark takes longer to travel, even though they are the same distance. This can be seen in the larger standard deviation in almost all the trials shown in Table 2, which may be due to the difficulty of discerning whether the robot has stopped or not increases when the lights are off. Overall, the data suggests that the robot completes a path quicker with no obstructions, and even when there are obstructions the time taken it minimal. When removing the outlier seen in trial 5, the modified average drops to a similar amount to the control average in Table 1, which further suggests that the lighting in the room has no effect on it's performance.

The appropriateness of employing the Unitree Go2 robot dog for on-time monitoring is highly appropriate, facilitated by its autonomous mobility and navigation. Because buildings are gradually damaged naturally or through accidents over time, their rectification in such cases at once is crucial, especially in commercial or risky scenarios. Go2, equipped with LiDAR and AI-enabled obstacle avoidance, offers a robust and programmable path of patrol between points, such as point A to point B, and is thus optimal for regular inspection. In simulations under realistic scenarios, the robot dog was successful in navigating most places, such as corridors, outdoors, and libraries, confirming applicability for real-time surveillance and data collection in dynamic real environments. The time it took for the robot to travel from two fixed points was recorded and plotted for observation of how it moves. From the data collected, an equation can be constructed to represent the time the robot takes to travel a distance:

$$t(x, L) = 1.23x + \sum_{i=0}^{n} 0.082 l_i \qquad (1)$$

where x is equal to the total distance the robot must travel, L is the collection of all obstructions in the direct path of the robot, n is the total number of obstructions of L, and l_i is the length of the obstruction along the path to travel. For example, in a 200-meter perimeter building per floor and assuming an average patrol speed of 1.2 meters per second, the robot would complete one patrol loop in approximately 2.8 minutes. This allows planners to predict how long the robot would take to scan through a whole building, which is useful for scheduling and upkeep. However, real environments typically pose obstacles and varying surface types that affect travel time. In testing, the robot had to navigate around carpet and gravel surfaces, as well as periodic objects in its path. The changes in surface had minimal effect on the speed, but objects to traverse around had an impact on the travel time. For instance, a 10% longer detour caused a 1-second delay when traversing a 10-meter path. While small, these delays accumulate when repeated patrols or large-scale deployments are being made, affecting the overall operational efficiency. The robot's LiDAR system plays a key role in overcoming such hurdles. Unlike cameras, LiDAR uses laser pulses to measure distance and build real-time 3D maps of the surroundings, making it precise even in unknown or dynamic environments. Such capability is essential in applications like natural disaster relief, hazardous area inspection, or structural damage inspection. The Unitree Go2 uses real-time SLAM technology to continuously adapt to its surroundings, allowing it to sense obstacles, uneven ground, and structural elements like walls or staircases with high accuracy [1]. Perhaps most significant among the experiment findings was the minimal effect that lighting levels had on LiDAR performance. Testing under fully dark conditions showed only minimal differences in traveling time compared to well-lit conditions. This minor variation, typically less than 1%, is due to an operator mistake during the initiation or termination of timers and not any navigation error of the robot. The robot maintained a consistent course under dark conditions, demonstrating that LiDAR's use of light beam sensors is independent of ambient light. This makes it applicable in instances of power outages or nighttime surveillance when human navigation would be impaired. Overall, the model analysis demonstrates that the Unitree Go2's robust LiDAR technology and dynamic movement capabilities make it feasible solution for secure and effective monitoring across various conditions. Its ability to adapt to obstacles, maintain accurate maps in darkness, and capture time-based information makes it a highly useful piece of equipment for both routine inspections and potential response in hazardous situations.

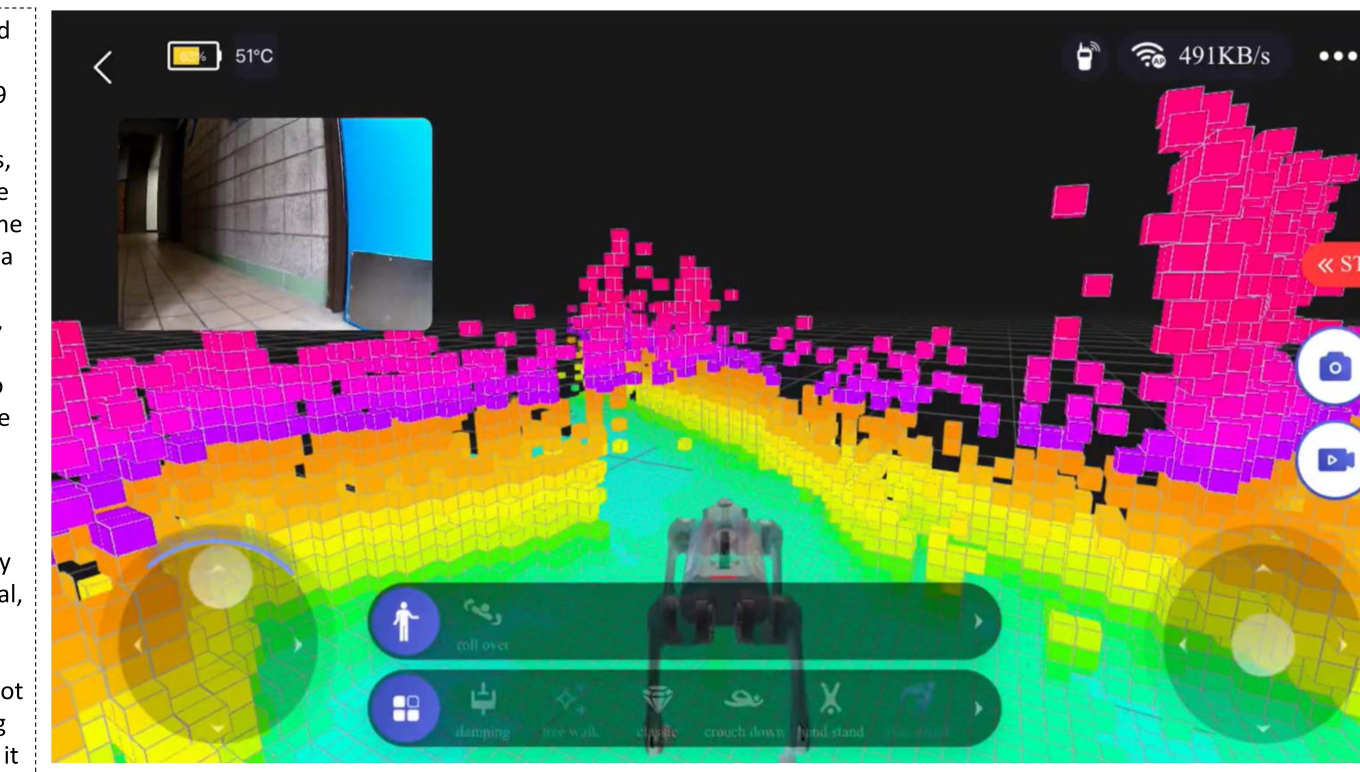

Figure 8: 3D Map of an Open Doorway

Lap	Forward Move Time (s)	Forward Pause (s)	Return Move Time (s)	Return Pause Time (s)
1	12.42	1.66	11.67	1.84
2	11.92	1.7	12.16	1.37
3	12.06	1.65	11.8	1.79
4	11.8	2.03	12.07	1.45
5	13.18	1.92	11.87	1.62
6	13.36	1.81	12.36	1.43
Average (s)	12.276	1.792	11.98833333	1.583333333
StdDev (s)	0.6659028958	0.1725398505	0.1995745475	0.2080064102
Max (s)	13.36	2.03	12.36	1.84
Min (s)	11.8	1.65	11.67	1.37

Table 1: The results from the first portion of the first test involving no obstruction

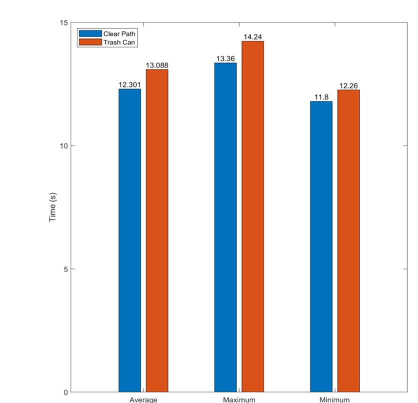

Figure 9: Shows the time taken by the robot when completing the empty path (blue) against the obstructed path (red).

Lap	Forward Move Time (s)	Forward Pause (s)	Return Move Time (s)	Return Pause Time (s)
1	13.99	1.91	11.76	1.78
2	11.96	1.48	12.35	1.6
3	12.94	1.46	12.05	1.53
4	12.48	1.62	12.44	1.33
5	13.89	1.66	12.8	2.27
Average (s)	13.052	1.626	12.28	1.702
StdDev (s)	0.8823661372	0.1807761046	0.3950316443	0.3560477496
Max (s)	13.99	1.91	12.8	2.27
Min (s)	11.96	1.46	11.76	1.33
Modified Average (s)	12.46	1.626	12.28	1.702

Table 2: The results from the second portion of the first test involving the lights off

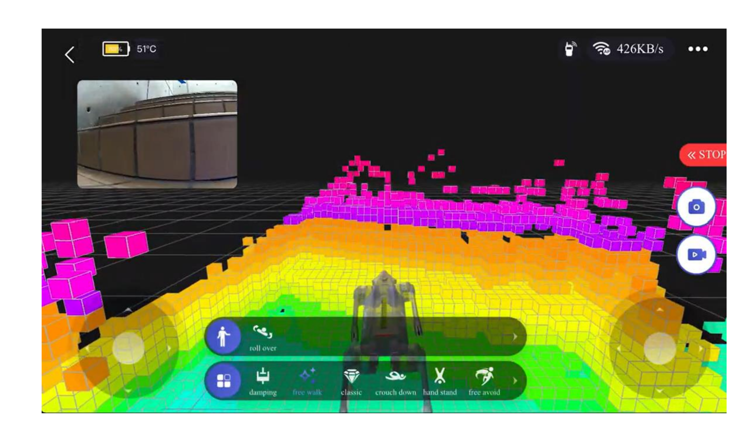

Figure 11: 3D Map of Stairs

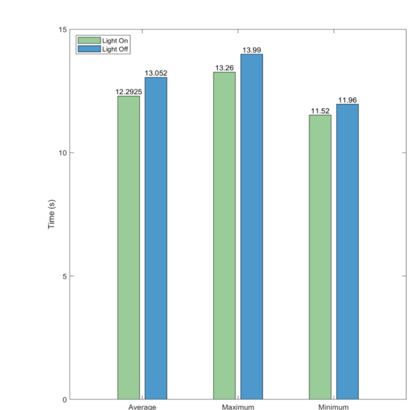

Figure 10: Shows the time taken by the robot when completing the path with the light on (green) against the lights off (blue).

Conclusion

To conclude, the research indicates the effectiveness of the LiDAR robot dog in mapping and navigating environments of all types, even hazardous sites where human life can be endangered. Through experimentation, it was achieved that the type of surface, light conditions, and the presence of obstacles differently affect the efficiency of the robot in navigation. While lighting did not play a significant role since LiDAR operates with light beam sensors, the surface structure and objects obstructing the path were essential factors in determining how long it would take to reach the target. Upcoming research must focus on the manner in which various surface types impact the robot's stability, velocity, and accuracy of travel. For instance, observing how the robot moves on slippery floors, uneven terrain, gravel, sand, and wet surfaces can provide useful insights into how to maximize its movement algorithms. Testing on different inclines and rough terrain can also maximize its mobility for practical applications, such as search-and-rescue missions or industrial site surveys. Conducting trials in extreme climatic conditions—i.e., heavy rain, snow, or storms—can assist in assessing the robustness of the robot under uncertain weather conditions. From these research studies, quadruped robots can be improved and enhanced to perform missions in different uncertain situations.

References

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[2] Warren, Mial E. "Automotive LIDAR Technology." IEEE Xplore, 1 June 2019, ieeexplore.ieee.org/abstract/document/8777993.

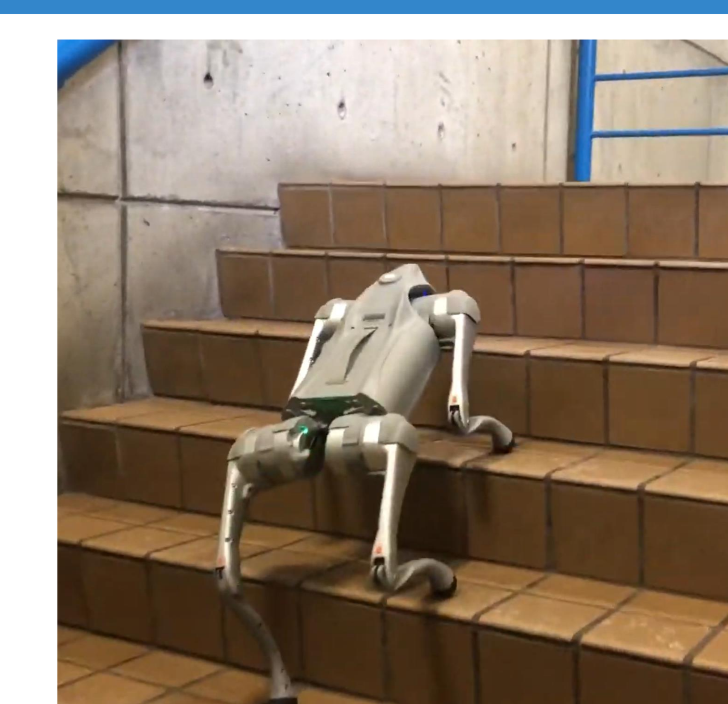

Figure 12: Robot Dog Walking Up Stairs