

Robots for Autonomous Construction Site Monitoring

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Introduction

Regular scanning of construction sites with cameras and Light Detection and Ranging (LiDAR) sensors improves construction productivity by identifying problems early and allowing timely, lower cost fixes. The purpose of this project was to investigate the possibility of carrying out these scans fully autonomously using robots.

Requirements

There are certain requirements that must be met for this to be possible.

First, the robot must be capable of moving around the construction environment – navigating uneven terrain, travelling the full distance of a large construction site, carrying the payload for sensors, operating in construction conditions (primarily dust resistance), and safely operating around people.

Second, the robot must be capable of sensing to the required level of accuracy. This can be done with additional sensors, but robots are rated by their in-built sensor capacity as well. This included 360-degree cameras and LiDARs which could detect elements to a ~1cm accuracy from ~2m away.

Third, the robot must be capable of carrying out the task autonomously. This included following a pre-set path, self-scheduling its operation, dynamically rerouting around obstacles, self-charging once done, and detecting issues that require maintenance.

Fourth, the robot must be within a reasonable cost. Here, the hardware cost was expected to be less than \$8,000 USD. Also considered was the difficulty of repair and replacement, and whether it would require shipping to a servicer overseas. The possibility of managing the robots centrally was considered, as was any additional software costs, though the precise details of software were beyond the scope of this analysis.

Process

The main sources for information were the official websites and specifications, user manuals, and various third party sellers and reviewers.

Basic technical information is typically provided in the specifications on the main website or sales website. This includes step heights, operating times, load capacities, ingress protection ratings for those that have them, and basic sensor information.

Other information, including safety and use conditions, can be found in user manuals.

More detailed information about LiDAR can sometimes be found from third party sources, including sellers, or from dedicated pages on the manufacturer website.

Information about autonomy is typically reported on the main website and on third party sources, as well as in relation to provided software or sensors.

Sales prices for some are provided by the manufacturer, in other cases they will suggest contacting sales but third party sellers can provide a rough approximation. Details about replacement and maintenance are largely reported in manuals.

Comparison

Robots Chosen

All robots selected were legged, as wheeled or tracked robots were considered unsuitable for the intended sites and drones would be unsafe operating in close proximity to humans.

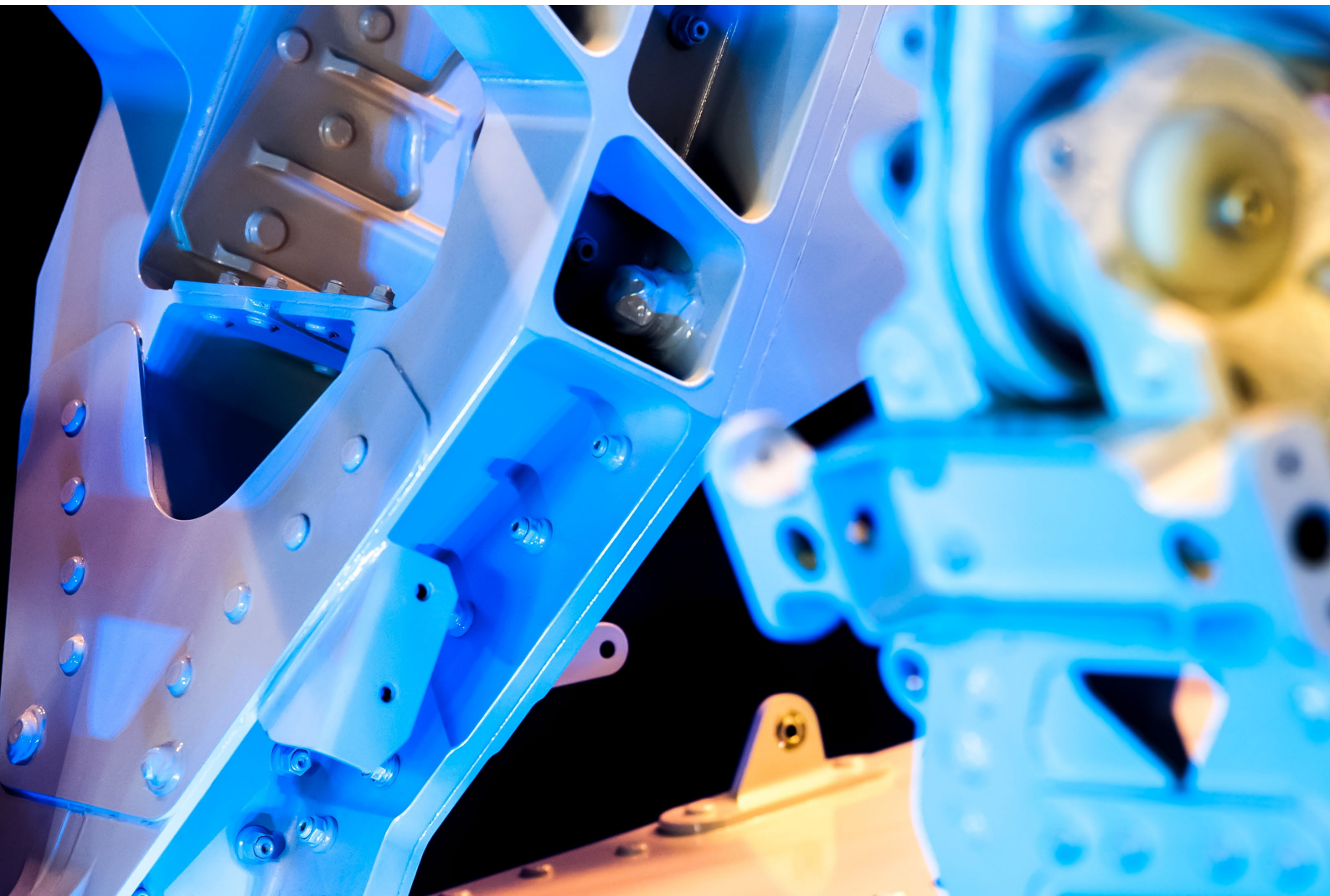
Legged robots are typically divided between quadrupeds (four legs) and bipeds (two legs), with quadrupeds being more popular for inspection due to their greater stability.

UniTree Go2 and DeepRobotics Lite3 are popular options for quadrupeds within the intended price range of <\$8000.

LynxM20 and UniTree B2 are more capable quadrupeds for inspection, with the B2 being comparable to the highest end of industrial inspection quadrupeds (including Boston Dynamics Atlas and DeepRobotics X30).

LimX Tron1 is an experimental bipedal robot.

Boston Dynamics Atlas is the most recent release of Boston Dynamics, and is intended to be a viable industrial humanoid robot.



Form Factor and Mobility Assessment

Robot	Terrain mobility	Run time/ distance	Payload capacity	Environment Endurance	Safety
UniTree Go2 (6/10)	30 (AIR) or 40 (other) degree climb angle, max drop 15-16 cm	1-2 hours	7 (AIR) to 8 (other) kg	Not dust or water resistant.	It can avoid humans, but sensor failure can cause problems. A 2 meter distance is recommended.
Deep Robotics Lite3 (LIDAR) (4/10)	18cm clearance, 40 degree slope angle	1.5-2 hours, 2.7km	2.5kg	Not dust or water resistant.	Advised to stay at least 1 meter away, and not share slopes or stairs with it. It is capable of obstacle avoidance.
Deep Robotics LynxM20 (9/10)	25cm continuous step height, 40 degree slope angle	2.5h/12km (loaded at 15kg), 3.5h/15km (unloaded)	15kg	IP66	Advised to stay more than 2m away, all present must have read the safety manual.
LimX Tron1 (7/10)	30 degree max angle, 20cm max step	2h	10kg	Not dust or water proof	Capable of obstacle avoidance with sensor kit.
Boston Dynamics Atlas (9/10)	Capable of moving on stairs and uneven terrain, numbers not officially reported	4h	30kg	IP67 resistance.	Yes, built for operation with humans.
UniTree B2 (9/10)	20~25cm continuous steps, 45 degree climbing angle.	5h/20km (unloaded), 4h/15km (loaded at 20kg)	40kg	IP67	1-2m safety distance. Software can enhance safety.

Red for payload capacity indicates that adding additional sensors would be outside of limits.

Ingress protection (IP) ratings are used to formalize comparisons of dust and water resistance. The first digit refers to dust protection, where 6 is the standard in industry, and the second to liquid protection, where 5 means it can get wet and 6 or higher means it can be temporarily submerged.

Sensing and Capture Quality Assessment

Robot	Capture formats	Suitable depth of view
UniTree Go2 (Does not meet requirements)	4D LiDAR L2. Wide angle front facing camera.	Yes
DeepRobotics Lite3 (Does not meet requirements)	Contains 16-line LIDAR. Wide angle front facing camera.	No
DeepRobotics LYNX M20 (Meets requirements)	96-line LIDAR and multiple wide angle cameras	Yes
LimX Tron1 (Does not meet requirements)	IMU sensor. LIDAR and 360 camera available with sensor expansion kit.	No
Boston Dynamics ATLAS (Does not meet requirements)	360 degree camera, no LiDAR.	No
UniTree B2 (Meets requirements)	LIDAR (Automotive grade, 32 wire) and multiple cameras.	Yes

In order to meet requirements, there must be a LiDAR and 360 cameras, and the LiDAR must be capable of precise measurement (within ~1cm) at a distance of 2m. This was determined by comparing to standard recommendations for LiDARs by their characteristics.

Autonomy and Intelligence Assessment

Robot	Consistent path navigation	Autonomous scheduling	Dynamic rerouting	Self-charging	Issue detection
UniTree Go2 (6/8)	Yes	No	Yes (ISS2.0)	Yes, with a special attachment	No
DeepRobotics Lite3 (5/8)	Yes (Perception Development Manual)	No	Yes	No	Can detect performance issues, including retaining motion logs.
DeepRobotics LYNX M20 (6/8)	Yes (Pro)	No	Yes	Yes (optional capability)	No
LimX Tron 1 (4/8)	Yes, with sensor kit and additional software	No	Yes, with sensor kit and additional software	No	No
Boston Dynamics Atlas (7/8)	Yes	No	Yes	Yes	Orbit can detect issues with performance, but not specific parts
UniTree B2 (7/8)	Yes	No	Yes	Yes	Can detect issues with performance, but not specific parts.

Autonomous scheduling is not counted in the card as a robot turning itself on was found to not be advisable for safety reasons.

Commercials and TCO

Robot	Cost per Hardware Unit (USD)	Maintenance Requirements	Replacement requirements	Fleet management	Software cost
UniTree Go2 (9/12)	\$1600 for Air, \$2800 for Pro, \$4500 for X	CR Kennedy might offer service if you buy through them	Replacement is possible, will affect warranty. Parts can be difficult to acquire.	Yes, with special software	Free software available, more detailed/specialized control increases cost
DeepRobotics Lite3 (9/12)	\$2890 for basic, higher models specified at sales	Need to ship overseas	Replacement is possible, will affect warranty. Parts can be difficult to acquire.	Yes, with special software	Free ROS/ROS2 software as well as paid specialized
DeepRobotics LYNX M20 (3/12)	\$49000	Need to ship overseas	Replacement is possible, will effect warranty.	Yes, with special software	Free ROS/ROS2 software as well as paid specialized
LimX Tron 1 (3/12)	\$15000 (only pre-order)	Must ship overseas for major repairs	Modular, easy to replace parts	Yes, with special software (SDKs for development are only available through the EDU version)	Free as well as paid SDKs available. Out of the box Python software system.
Boston Dynamics Atlas (3/12)	\$150,000	Regular maintenance process. There is a servicing company in Australia, and Boston Dynamics is in the process of creating an enterprise education process for maintenance without shipping elsewhere.	Modular replacement possible, will affect warranty.	Yes (Orbit)	Using Orbit has additional unspecified costs.
UniTree B2 (3/12)	\$100,000	CR Kennedy may provide servicing, otherwise must ship overseas	Replacement is possible, will affect warranty.	Yes	Free software available, more detailed/specialized control increases cost

General maintenance is generally consistent across robots (cleaning sensors, regular checks, major servicing must go through qualified servicer for warranty). Precise details can be found in manuals.

Software costs were excluded from the rating, because detailed analysis of software was beyond the scope of the project.

The hardware cost is rated as 3x more important than the other factors.

Conclusions

The higher end quadrupeds meet most of the practical requirements, but at far too high a price. The bipeds all have higher prices for the same level of operation.

All robots are constrained by the costs of maintenance, as there do not appear to be any licensed servicers in New Zealand so shipping costs would be excessively high. The UniTree robots may have available service from local sellers, but confirming that would require further questioning.

Overall the direction is encouraging and robots are developing rapidly, albeit with a few key gaps. The current market leading robots are not yet ready to become common on construction sites. It is only a matter of time before they close these gaps and become part of standard procedures.

Robot		Form Factor and Mobility	Sensing and Capture Quality*	Autonomy and Intelligence	Commercials
UniTree Go2		6/10 	Does not meet requirements 	6/8 	9/12 
DeepRobotics Lite3		5/10 	Does not meet requirements 	4/8 	9/12 
DeepRobotics LYNX M20		9/10 	Meets requirements 	6/8 	3/12 
UniTreeB2		9/10 	Meets requirements 	7/8 	3/12 
LimX Tron1		7/10 	Does not meet requirements 	4/8 	4/12 
Boston Dynamics Atlas		9/10 	Does not meet requirements 	7/8 	3/12 

*Even if provided sensors do not meet the requirements, different ones can be attached if the payload requirement is met. None of the robots meet the standard for use at present. The robots within the price range do not meet requirements for form factor or full autonomy, and especially their lack of protection against dust makes use in a construction environment non-viable.

-  Meets requirements
-  Does not meet requirements
-  Does not meet requirements

