Development of Robotic methods for accessing marine piles

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Abstract

Currently jetty piles can only be accessed through either rope access or divers or often both. These methods require significant safety apparatus and are slow, manpower intensive activities. As well as this, they make Precise work difficult due to the low stability of the work environment. KAEFER Integrated Services in collaboration with UWA is developing a robotic platform to more efficiently access these areas and remotely conduct works. This will ensure the processes are conducted much more reliably and precisely whilst increasing speed and accuracy. This new approach will require new robotic technologies and methods to operate in these environments. Some examples of these new technologies included digital fabrication via 3d printing, low cost micro-controllers and more. As well as these operating advantages, the ability to remotely access equipment and monitor it is becoming more in demand as companies seek to further digitally integrate processes on work sites. A robotic solution will significantly improve work process in this traditionally difficult and hazardous role.

1. Introduction

1.1. Background

Piles are the structural element that support all marine structures. The marine environment creates significant challenges, mainly marine growth and surface corrosion (Arafati, Hossein, Mousavi, Rouzmehr, 2012). Both of these effects mean structures must be cleaned, inspected and then either wrapped or painted at regular intervals in their life span (Department of Defence United States of America, 2012). While these functions are fairly non-technical and straightforward to perform on land, many challenges are added in the marine environment. Accessing piles to perform these actions generally involves using a combination of rope access, boats or divers (EtherNDE, n.d.)(GeoVert, n.d.). These specialised methods make pile maintenance significantly more challenging than land based structural maintenance.

There have been significant advances in robotic technology in recent years. Consumer devices like smartphones and drones have resulted in a reduction in the cost of micro-computing technology and electromechanical components (Abhishek, Keshav, Gautham, Samuel, 2017). Manufacturing of custom mechanism has been advanced with the proliferation of digital fabrication methods such as 3D printing, laser cutting and CNC milling (M. Lau, J. Mitani and T. Igarashi, 2012)(Stansell, Tyler-Wood, 2016). Lastly, new computational methods such as convolutional neural networks have meant that lower cost cameras can be used to access a robots environment in ways that prevsioulsy required more expensive sensors (Krizhevsky, Sutskever, Hinton, 2017). All of these factors have resulted in a wave of robotic solutions for industry challenges.

1.2. Problem Statement

By their nature, rope access or using divers and boats are not effective solutions. Divers and Rope Access Technicians are highly skilled workers and thus are highly paid workers. Their labour costs can often be the largest cost in a project. In the environment they struggle to provide a stable platform for precise works. This results in precise work often being done slowly. The human nature of their work means that works may be performed inconsistently between piles. Thus the current methods of accessing marine structures can be described as inconsistent, slow and non-precise . Therefore low-cost faster technologies to access operate on these piles are needed.

1.3. Industry Benefit

It is the intention of this research to apply low-cost modern robotic methods to a traditional labour problem. Robots are able to conduct works much more precisely than human workers. This precision means that maintenance standards can be achieved more consistently. As well as consistency, the robotic solution operates faster than a comparable human solution and achieves significantly reduced labour costs for companies. These benefits have traditionally came at a high cost both in designing time and component cost, prohibiting their development. However, this research wishes to utilise new modern robotic methods while achieving a reduction in cost of parts and processes.

2. Process

2.1. Overall

The prepared robot, like most robots, is ultimately a combination of simple mechanisms and systems. The design of these systems has followed a simple cycle.

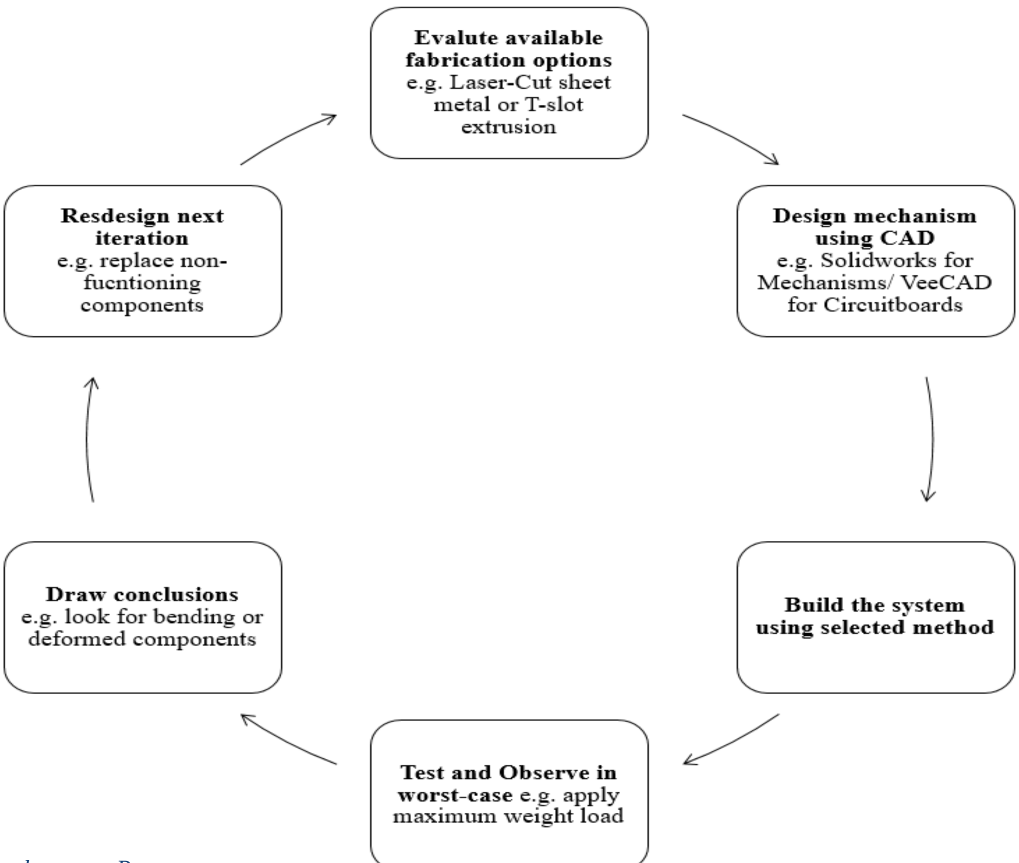

Figure 1 Simple system Prototype process

Ultimately, once all of these system have been prototyped to an acceptable standard, they are combined to first test if they function together and then tested to their limits to determine their performance.

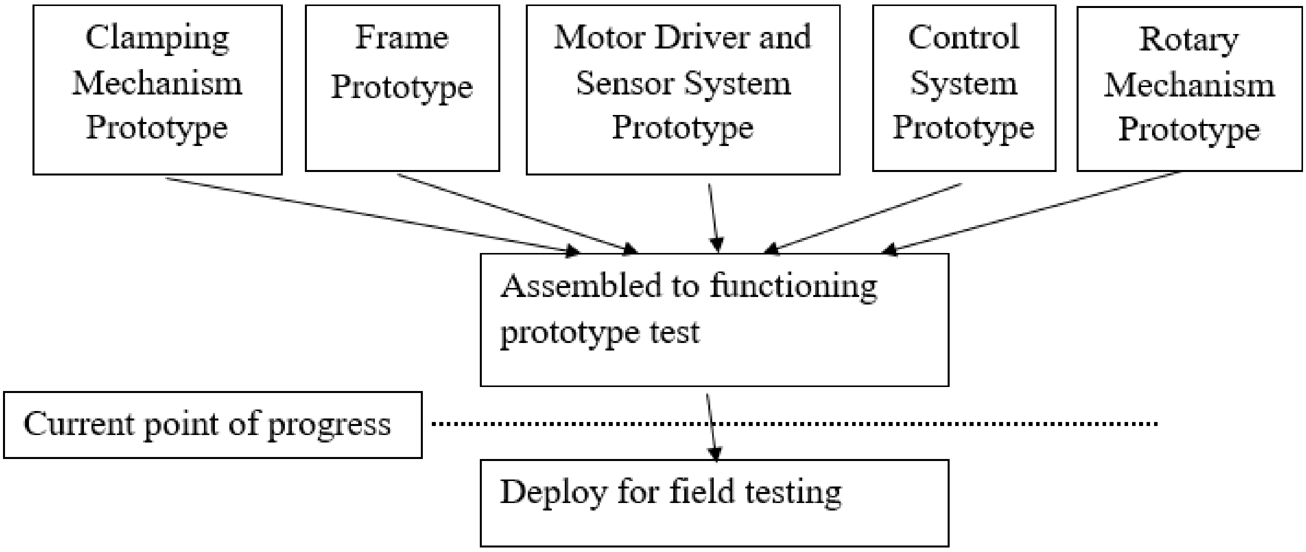

Figure 2 Overall Prototype Process

2.2. Tools, Equipment and Methods

Design Tools

- Solidworks for Component CAD (Solidworks Education, 2020)
- Solidworks for FEA Analysis
- VeeCAD for circuit board design (VeeCAD, n.d.)

Fabrication Tools

- 254cm 80T MitreSaw for aluminium cutting
- 1200W Laser Cutter for steel sheet cutting
- Metal Bender for sheet metal bending
- BenchTop 2kW Mill for small aluminium milling
- CNC 3-Axis Router for large section or custom-shape aluminium
- CO2 Laser Cutter for platic cutting
- Cordless drills for bolted component assembly
- Cordless angle grinder for metal deburring
- Soldering iron station for circuit board assembly

Software/Firmware Tools

- Arduino IDE for firmware coding and flashing (Arduino, n.d.)
- VisualStudio Code for C++ and Python programming
- Python 3.7 for High Level Software (Python Licensing, n.d.)

3. Results and Discussion

To date to results of the research have been demonstrated in tests in the form of prototypes and analysis.

Test	Date	Observation	Discussion
First Clamp Prototype	21st May 2020	• Inconsistent climbing speed • Clamping Actuator not holding	• Stronger Actuators needed • Stiffer Rails needed
Second Clamp Prototype	16th July 2020	• Despite >100kg direct loading in multiple directions, mechanism works fine • Some Hinges broke during assembly	• Hinges to be redesigned or procured
First assembled Test	23rd July 2020	• Signifigant flexing and deformation of the frame • Difficult to climb under manual control	• Larger frame using thicker aluminium extrusion and wider steel bracing • Control algorithm will have to synchronize all mechnaisms
Second Frame FEA Analysis	3rd August 2020	• ~90% less deformation under simple FEA analysis not including all bolt holes in analysis	• Second frame design will likely be effective

Table 1 Prototype and FEA Tests

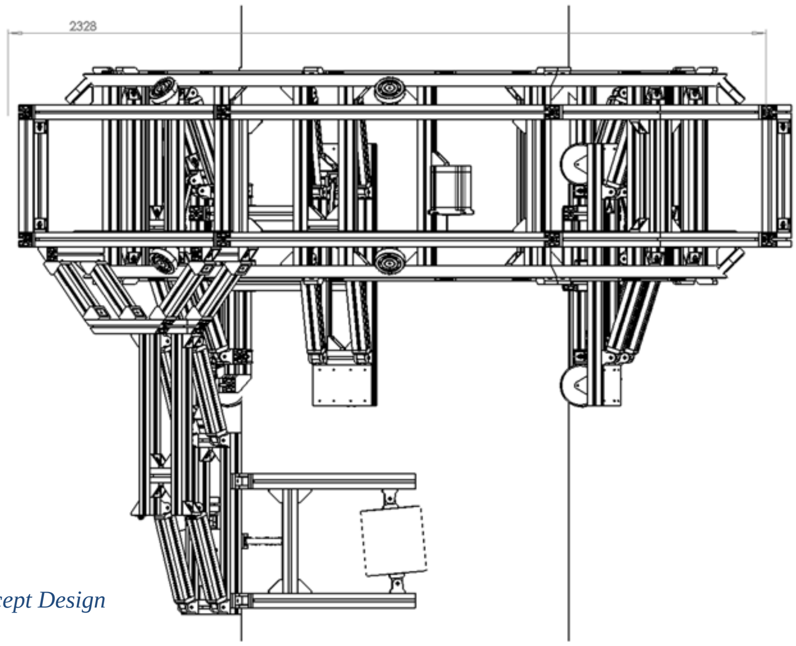

Figure 3 Early Concept Design

4. Conclusions and Future Works

4.1 Conclusions

Based on the above results, it can be observed that, despite some failing of some specific components during prototpye tests, overall the concepts used in the mechanisms designs and prototypes are sound. At this stage it is likely that the research will successfully yeild a robot with the desired outcomes.

4.2 Future Works

Modular Attatchements

Clearly, once the robot is completed it will need to be able prefom actual works. Thus, the modular attachments for it to be able to do so will be needed. These will most likely been a Airless paint gun for painting, pneaumatic bristler for blasting and surface finish and X-Ray Mount for inspection.

Automatated Components

Despite being less labour intensive than traditional methods, the robot still requires multiple skilled operator s in it current configuration. This is because some of the mechanisms, such as its locking mechanism require manual operation in set up. It is the goal that by automating these operations, the robot further reduce labour costs.

Preformance enhancements

The robot being developed by this project is intended to be fully functional, however as the robot operates in the field, it will become much clearer which components are very effective and which need to be further optimized or replaced. This will likely result in further versions which may be lighter or faster and more rugged due to replaced higher-quality or better designed components.

5. Acknowledgements

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UWA Makers

A special mention has been attributed to UWA Makers Club, which has not only provided excellent electronics and laser cutting facilities , but has also provided a rare facility for the basic training of small skills like soldering which are essential for any robotics project.

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