Modelling and Control of a Biologically Inspired Trenchless Drilling Device

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***Abstract*— This work presents the methods used and initial findings of the control of the model for an autonomous trenchless drilling device, with bioinspired worm-like locomotion. The model is validated using Inverse Simulation. The initial control is detailed with data from the simulation and experimental device.**

Keywords—Mathematical Modelling, Simulation, Validation, Control, Robotics

I. Introduction

Several different services (water, communication, power) are running beneath the grounds of our cities. With increasing demands for these services and the replacement of outdated conduits there is a need to upgrade and lay new services. Normally to achieve this, large areas of land need to be excavated to allow the services to be laid. Trenchless drilling is a method that is used to avoid the excavation of large areas. The RoBot for Autonomous unDerGround trenchless opERations, mapping and navigation (BADGER) [1] project is developing an autonomous robot for trenchless drilling. The robot locomotion is worm-like. The modelling, simulation and control of the BADGER device is described in this work.

II. Basic Motion

The motion of BADGER is worm-like: areas of BADGER expand and contract as required. Elements of the system (clamps) provide anchoring to the sidewalls of the tunnel being drilled. When one section is anchored, another section extends, providing the required Weight-On-Bit (WOB) to the drill head. The section that lengthened then anchors, allowing the previously anchored section to contract towards the newly anchored section. Repeating this process allows the system to move along the tunnel being drilled.

III. Modelling and Control

There are several elements to control that are contributing to the worm-like motion: linear actuator, clamp, steering, Fig.1. The forward movement provides the forward drilling forces. For the modelling process and to replicate the motion, the Kinematic Investigation Testbed (KIT) is used, which is less than half the size of BADGER (100mm diameter vs 250mm).

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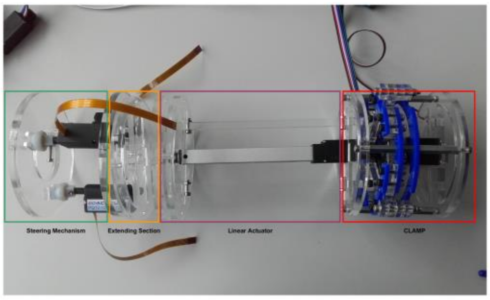

Figure 1: KIT with various parts highlighted

First, the mathematical model of the system with appropriate parameters (mass, friction, etc.) is derived. With KIT and the model available, validation is undertaken using Inverse Simulation [2,3]. With validation completed and the results from experimental runs on the model and KIT broadly matching, initial control experiments are undertaken for the forward motion (drilling direction) and the turning motion. Using Inverse Simulation as a high level controller and a PI controller for individual actuator control, the experiments are run on KIT. The validated model is used to optimise the control and the results are demonstrated on KIT.

IV. Conclusions

This work presents early results obtained from the process of modelling the BADGER and KIT devices. Use of Inverse Simulation has enabled the development of both a validated model and an initial controller. The simulation created will allow the further development of controllers and testing of different control strategies. The control of the BADGER system can then be fully realised for successful field trials.

References

[1] BADGER Project Website, http://www.badger-robotics.eu/, 15/07/2018

[2] Worrall, K., Thomson, D., and McGookin, E. "Application of Inverse Simulation to a Wheeled Mobile Robot," ICARA 2015, New Zealand, 2015.

[3] Thomson, D., and Bradley, R., "Inverse simulation as a tool for flight dynamics research - Principles and applications," Progress in Aerospace Sciences, vol. 42, no. 3, pp. 174-210, 2006.