Motion Control of Hexapod using Model-Based Design

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Abstract

Six-legged robots, also referred to as hexapods, can have very complex locomotion patterns and provide the means of moving on terrain where wheeled robots might fail. This thesis demonstrates the approach of using Model-Based Design to create control of such a hexapod. The project comprises the whole range from choosing of hardware, creating CAD models, development in MATLAB/Simulink and code generation. By having a computer model of the robot, development of locomotion patterns can be done in a virtual environment before tested on the hardware. Leg movement is implemented as algorithms to determine leg movement order, swing trajectories, body height alteration and balancing. Feedback from the environment is implemented as a internal measurement unit that measures body angles using sensor fusion. The thesis has resulted in successful creation of a hexapod platform for locomotion development through Model-Based Design. Both a virtual hexapod in SimMechanics and a hardware hexapod is created and code generation to the hardware from the development environment is fully supported. Results include successful implementation of hexapod movement and the walking algorithm has the ability to walk on a flat surface, rotate and alter the body height. Implementation also contains a successful balancing mode for the hexapod whereas it is able to keep the main body level while the floor angle is altered.

I. INTRODUCTION

Model-Based Design is today a common method for developing control systems. An interesting way of testing the limitations of Model-Based Design is to use it in different projects. By using it to develop movement patterns for a hexapod it will be possible to evaluate the benefits of such an approach in robotics. This article summarises the work done in master thesis project with the same title [1].

Part of the thesis involves choosing a hexapod platform. A hexapod platform consists of the six legged chassis, a micro-controller, a wireless hand-held remote and an open source control program. Model-Based Design and automatic code-generation is to be used in order to replace the supplied control algorithm and thus be representative of modern control implementation. The main goal of the thesis is to generate fully working code that can be downloaded to the hexapod robot and make the hexapod walk in a controlled manner. As a challenge the locomotion of the hexapod has been developed towards the goal of walking in uneven terrain while keeping the main body level.

Figure 1: *The PhantomX Hexapod Mark II is the platform used in this project.*

II. METHOD

I. Development method

Traditionally system development consists of several steps [2]. A team of system engineers define system specifications that are handed as documents to software engineers that interprets them and implement software code. The next step is to test on hardware and usually errors are first realized here, but it has to be corrected all the way back to phase one. Not until testing has been successful can the system go into production.

Model-Based Design (MBD) is a modern way of improving upon this approach. In order to cut down on both developing costs and time, software like Simulink and Embedded Coder provide means of creating virtual models and automatically generated code. The variant of MBD used in this project is called the V-model [3], see Figure 2. As a first step in the V-model, a requirement analysis is done and then a high level design of the system is defined in Simulink. Next, a CAD model of the hexapod is constructed and integrated into Simulink for continued development. If controller performance is satisfactory in software, it is tested on the hexapod platform. During development, code is tested from a bottom up approach, each component is tested and when results are satisfactory the component is integrated with the system.
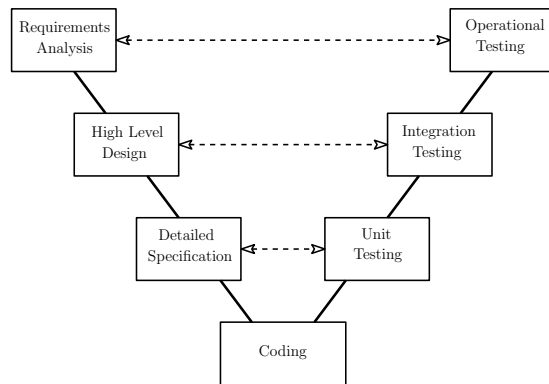

Figure 2: *Structure of the V-model.*

II. Locomotion

Motion patterns for robots are often created as hard coded static patterns. But in order to achieve ter-rain handling the motion develop in this project is focused on more dynamical movement. An inverse kinematics algorithm for each leg was developed and used to translate leg positions into servo angles. By combining algorithms for creating leg trajectories, determining legs to lift, altering height and balancing, a more dynamic motion patterns could be achieved. Later in the project constraints for legs were calculated in order to develop more reliable movement.

III. RESULTS

As a result of the MBD approach a fully operational development platform was created. The original hexapod kit was modified to have more computational power and additional sensors for balancing. Locomotion was developed in a Simulink environment, viewed on a virtual model and the by the press of a button, C code is generated and downloaded to the hardware in a successful way.

The locomotion developed during the project has resulted in a hexapod able to walk in arbitrary directions, rotate, alter height and balance while standing still. All this is controlled by a remote much like a video-game controller. To view the resulting locomotion: https://www.youtube.com/watch?v=vGBNpEx8doc, or the balancing: https://www.youtube.com/watch?v=dCN-lKQaNCw.

IV. DISCUSSION

This thesis highlights the major stages in the development process of a control system using Model-Based Design. Because of the wide spectrum of the project, knowledge in use of CAD-tools, electrical engineering, control, mathematics, physics and programming were required. Unfortunately a fully stable terrain walking hexapod was never achieved due to lack of time. The reason for this was the vast amount of work put into set-up of the development environment. Using the virtual model in creation of locomotion proved to be very valuable and if this project is continued the environment should prove to be a useful tool.

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