The World´s Largest Industrial Robot

- **Queensland University of Technology uses dSPACE Prototyper**

- **Development of dragline control**

- **dSPACE DS1104 R&D Controller Board for optimizing the digging cycle**

Draglines costing up to $100 million each are used in Australian open cut coal mines. A dragline is like a huge crane which is used to clear and shift overburden, i.e., soil and rocks, with an excavation bucket suspended from its 100-meter boom. The bucket weighs 40 tons when empty and can reach 120 tons when fully loaded. Increasing the productivity of these machines by just a few percent could boost Australia's annual coal mining revenues by hundreds of millions of dollars. Current research by the Queensland University of Technology (QUT) uses dSPACE Prototyper to automate the machine's digging cycle.

The Digging Cycle

A typical dragline bucket scoops up about 100 tons of fragmented overburden in one go, swings it 90 degrees and unloads it to the spoil pile before returning to the dig face. This cycle is repeated once per minute, 24 hours a day, every day of the year. The digging cycle can be optimized by the following improvements:

- Maximizing the payload of the bucket by minimizing material spillage. Spillage is especially caused by the oscillations ("nodding") of the filled bucket when it is lifted off the slope.
- Improving the hoisting time. This can be achieved by controlling the bucket's motion, so that it moves along the ideal, minimum-time trajectory within its workspace.
- Reducing maintenance down time; achievable by reducing dynamic loads during the digging cycle.

Automation of the lift, swing, dump and return phases, which comprise 80% of the overall digging cycle time, will allow optimal bucket trajectories to be performed repeatedly and let the operators concentrate on the more challenging part of the cycle, which is filling the bucket. The result would be a significant productivity increase.

The Bucket – A Complex Pendulum

Automation of the bucket movement requires the coordinated control of the individual motor drives for the hoist, drag and swing axes. Also, whilst the bucket is being carried, the aim is to avoid material spillage caused by bucket oscillations. Each phase of the digging cycle requires a different motor control strategy, and the automation system must provide seamless transitions between the control modes.
In this research we concentrated on the control of the bucket's motion in the plane of the boom. The bucket and the rigging behave as a complex pendulum with a variety of dynamic modes, which present a variety of troublesome features for the feedback control of

◄ *A typical dragline used in open cut coal mines. The experiments with dSPACE Prototyper aim to optimize the digging cycle to increase coal mining output.*

◄ *The bucket for scooping up overburden: Weight 40 tons when empty, 120 tons when full.*

the bucket carry angle. A frequency response analysis of the in-plane pendulum dynamics of the bucket and rigging shows a system with several sharply defined resonances. Other problems are the non-linear behavior of the bucket-rigging system and the changes in the dynamic characteristics as the bucket moves through its workspace.

A Model of the Real World

Theoretical modeling, simulation and analysis produced a suitably stable and robust carry angle controller, which was implemented in the laboratory, on a reduced scale (1:20) planar model. A bucket-mounted sensor package has been developed to transmit carry angle data from the bucket to the controller. This package – containing a gyroscope and inclinometer – is a low power consumption, battery-powered unit, hardened for use in a hostile mechanical environment. It is capable of monitoring bucket carry angle, roll angle, and associated angular velocities at a 20 Hz sample rate. This unit interfaces with dSPACE Prototyper and with shaft encoders

mounted on the DC motor drives. Postgraduate and undergraduate students were involved in the research work and therefore the control hardware needed to be user-friendly so that all students could partici-pate. Using dSPACE Prototyper with the DS1104 R&D Controller Board along with MATLAB®/Simulink® provided an impressive combination of software and hardware. This allowed us to concentrate on solving the complex control issues without the frustrations associated with the need to create low-level code.

From Experiment to Real World

After the successful experiments with the 1:20 planar model, the next stage of the project is to transfer the control technology to a larger scale (1:7) experimental dragline, capable of full three-dimensional motion. We will switch to a dSPACE AutoBox in order to expand the number of inputs needed for automated digging trials of a fully functional machine.
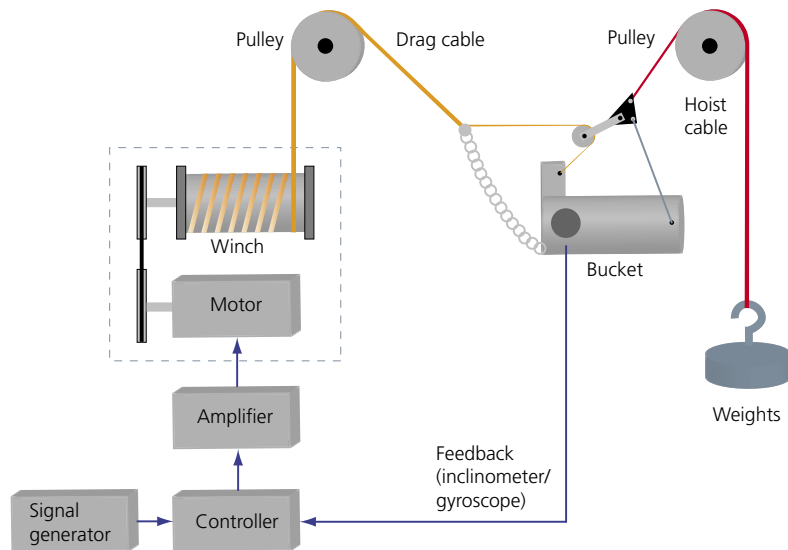
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◄ *The setup of the 1:20 planar model. The aim is to minimize material spillage by optimizing the bucket's motion control. A bucket-mounted gyroscope and inclinometer provide feedback control of the bucket motion.*