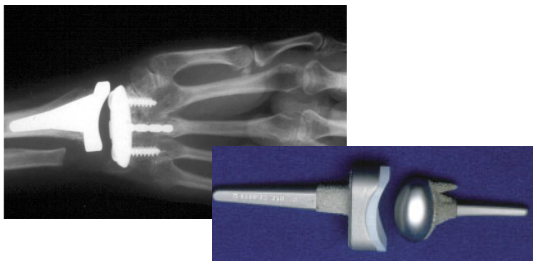
Developing and Testing Prosthetic Wrist Joint Designs

- Work by the Centre for Orthopaedic Biomechanics at the University of Bath, UK
- Prosthetic wrist joint development for more successful wrist replacement surgery
- A wrist simulator, controlled using dSPACE Prototyper, is used for testing designs

Successful replacement of the human wrist joint is a major challenge for modern orthopedic surgery. A multidisciplinary team of surgeons and engineers is working at the University of Bath to tackle some of the key issues in engineering a new wrist joint prosthesis. An important aspect of this work has been the development of a wrist simulator that can be used to test the functionality and performance of prosthetic wrist designs. The use of dSPACE Prototyper has enabled a control system for this wrist simulator to be created with minimum time and effort.

Wrist Simulator Design

The development of a machine that can be used to compare the performance of different prosthetic wrist designs under realistic loading conditions has been a challenging task. This simulator was required to reproduce typical motion and loading conditions of the human wrist while allowing measurement of the forces involved. Current wrist prosthesis designs are based on a refined ball-and-cup type joint. Dislocation of the joint under loading (for example produced by pushing oneself up out of a chair) can be a major problem following implantation and so one purpose of the simulator was to establish the factors that contribute to joint dislocation.



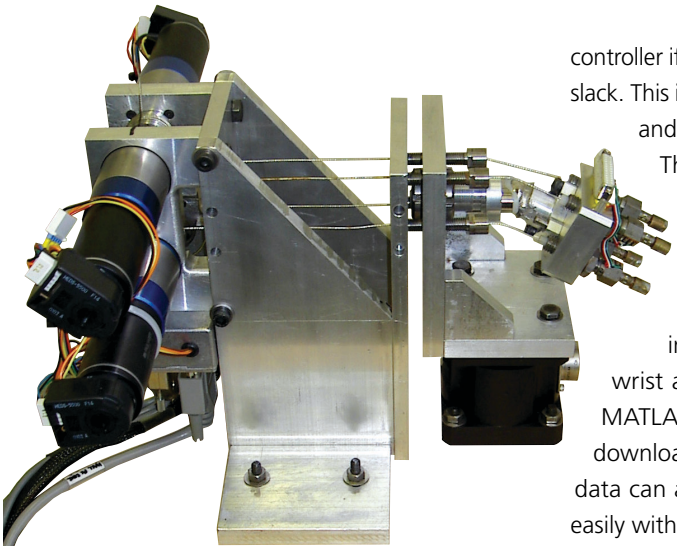
▲ *Wrist replacements that are currently in production.*

The Mark I version of the simulator has a modular construction with aluminum blocks used to represent the hand and forearm, in which the two halves of the prosthesis are fixed. Four cables, positioned to represent the main tendon groups within the wrist, are used to articulate the 'hand'. One end of each cable is wound on a shaft connected through a gearbox to a brushless servomotor, which is used to regulate cable motion and tension. The other end of each cable is attached to a load cell on the hand block so that cable tensions can be monitored and used for control feedback. Incremental encoders connected to the motor shafts provide the controller with motor position signals. The forearm block of the simulator is mounted on a six-axis force transducer, used to deduce instantaneous loading conditions.

All force and motor position signals are monitored by dSPACE Prototyper through the high-resolution A/D board and used by the control algorithm running on a dSPACE processor board. The output of this control system drives the motor power electronics and in effect determines the torque produced by the motors.

Control Algorithm Evolution

Due to the wider project objectives and timescales it was important to have the control system for the wrist simulator operational within weeks rather than months of the hardware being assembled. However, this meant that the control algorithm had to be developed without the luxury of a mathematical model of the system, which could have been used to synthesize algorithms and perform simulations.



▲ *The wrist prosthesis simulator allows testing and visualization of new prosthesis designs.*

Instead, the controller design process involved iterative development and testing on the hardware itself. Without the use of dSPACE Prototyper this would have been a very time-consuming and uncertain task.

The current system uses a closed-loop position controller based on an artificial neural network (ANN) algorithm. The external inputs to the algorithm are the time-varying position demand signals, in the form of wrist angular displacements. Additional control loops regulate the cable tensions by overriding the position controller if the tendon cables become too tight or too slack. This is achieved using standard PD (proportional and derivative) feedback with high gain.

The controller is initialized manually using ControlDesk. Prosthesis test routines that involve prespecified wrist motions can then be run automatically using MATLAB® script files that utilize the MLIB interface library. The motion paths for the wrist are uploaded to the controller from the MATLAB workspace, while measured data is downloaded following each test. In this way test data can also be recorded, viewed and processed easily within the MATLAB environment.

Outcomes and Outlook

The creation of the wrist simulator for functional testing and comparative assessment of wrist prostheses will allow significant progress to be made towards an optimum clinical design, without subjecting patients to unnecessary risks. Ongoing development of the wrist simulator itself is aimed towards more accurately replicating the behavior of muscles and soft tissues within the wrist and arm. Fast and efficient control system implementation and development, which are made possible through the use of dSPACE Prototyper, will be of key importance in achieving this goal.

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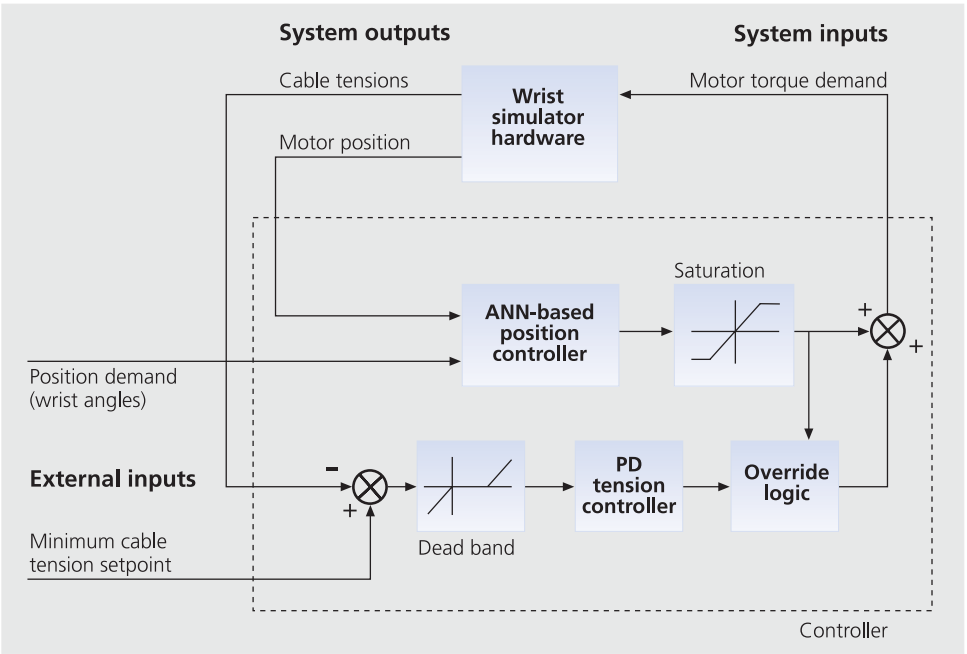

▲ *Block diagram of the closed-loop control system. The controller code runs on dSPACE control hardware.*