A better approach to decentralized control

A motion ring with distributed hardware and centralized software offers the best of both worlds.

Today's motion-control designers face an increasingly difficult dilemma. Traditional machines with highly centralized controllers are getting more complex, and requiring more wiring. This adds cost, multiplies possible failure modes, and can even decrease performance because thicker wiring bundles do not flex as easily.

That's why many designers look to distributed-control systems. The allure of these systems is undeniable Ñ place the intelligence for a particular task close to sensors and actuators. Wires connecting local controllers to sensors and actuators are short, and any information sent to or from the central controller can be combined using a high-level protocol and transmitted over a single cable.

The Geo Macro drive communicates with a controller through a 125 Mbits/sec fiber-optic ring. The drive sends PWM, torque, velocity, or position commands and accepts a wide range of motor-position feedback. The one and two-axis servodrive amplifiers support a wide variety of motors, power ranges, and user interfaces.

Distributed drawbacks
However, most distributed-control hardware and software have been developed for the process-control industry and are not optimized for motion control. Process control has neither the high frequency nor strict determinism required in many motion-control applications.

As a case in point, look at fieldbuses such as CANbus and Profibus. They are widely used for discrete I/O control, and do a wonderful job of simplifying wiring to I/O points while maintaining typical PLC scan rates. But remember, PLC scan rates are usually slower and less regular than those needed for motion-control feedback.

A common answer to this problem has been to distribute all servorate tasks Ñ interpolation, loop closure, and possibly motor-phase commutation Ñ into a node that performs quickly and deterministically. Higher-level communication to and from the node often permits lower frequency and determinism.

Many designers make a motion axis "just another node" on the I/O fieldbus. This works well in some applications, particularly if motion is not coordinated. However, the approach has limitations. For an axis drive to handle servorate tasks, it must have dozens of set-up parameters, including set-points, speeds, accelerations, numerous gain terms, and safety limits.

These values are typically shoehorned into a fieldbus data structure that was never intended for this purpose. Even if most parameters remain constant for an application, setting those that do not (such as end points and speeds) is typically far more cumbersome than using a centralized controller. Many users find they have simply traded hardware-wiring complexity for software and communications complexity.

In applications that demand tight coordination between axes, most I/O fieldbuses lack the required synchronization mechanisms to ensure coordination. And multiaxis motion that is simultaneous but not tightly coordinated still poses problems. If one axis faults out, this information may not transfer to the central controller and onto the other axes in time to prevent problems. This is not a hypothetical issue. In Silicon Valley recently, a cassette carrying over $1 million worth of silicon wafers was smashed in just such an incident.

Even with purely sequential moves, the distributed approach can be cumbersome. The need to confirm that move n has properly completed before move n + 1 begins can take a great deal of time on distributed systems over typical I/O fieldbuses. On many systems, the delays account for as much as 30% of overall cycle time.

Communications breakthrough
Fortunately, it is now possible to get the hardware benefits of distributed systems while maintaining the software benefits and performance of centralized systems. The solution is to distribute interface electronics while keeping the control software as centralized as possible, performing most tasks in a single processor where interactions are fast,

deterministic, and easy to code. This requires a central processor that executes high-frequency, real-time tasks such as servorate tasks which, in turn, requires a high-bandwidth and deterministic communications link.

Until recently, the technology to support such a link was unavailable at a reasonable price. But during the 1990s, tremendous investment in networking technologies drove capabilities up and costs down. One key technology was 100-megabits-per-second (Mbps) Ethernet, developed for high-end office systems. While office networks use nondeterministic software protocols, the underlying hardware can be used in deterministic systems.

A second key technology that entered the mainstream was high-bandwidth fiber-optic transmission. Fiber-optic communication eliminates electrical transmission waveform problems and all electromagnetic-interference issues. It also provides isolation between nodes, eliminating possible ground-loop problems.

Leveraging these developments, Delta Tau Data Systems has addressed the needs of industrial machine builders with its Macro (Motion And Control Ring Optical) communications system. Macro builds on Ethernet and fiber-optic hardware technologies with a uniform packet structure, real-time updates, and a simple, deterministic master/slave protocol to create a communications link that permits highly distributed hardware and centralized software.

Ring operation
The Macro fiber-optic ring transmits data at a raw rate of 125 Mbps, with 2 of every 10 bits redundant for low-level error checking, resulting in a true data rate of 100 Mbps. Packets contain 72 bits of transmissible data, with 24 bits of supporting data (a header byte, ring-address byte, and a check-sum byte for second-level error checking) for a total of 96 bits, permitting packet transmission in a microsecond. One packet contains all the data needed for closed-loop axis control.

The system transmits up to 256 packets per ring cycle. Even with a conservative assumption of 0.5 msec between packets, a fully loaded ring updates at 2.5 kHz. In more-typical applications, a 16-packet ring updates at up to 40 kHz; a 32-packet ring at up to 20 kHz. The master-controller-clock signal drives its own repetitive calculations as well as ring transmission timing, keeping hardware and software fully synchronized. In other words, the ring is fully self-synchronized and devices on the ring are tied to the master clock.

A single ring can hold multiple master controllers that communicate through each other to their own slave devices. All are tied to the ring master clock. Packets of command data simply pass through masters and slaves until they reach the correct address. There, the slave receives command data and substitutes feedback data into the data packet on the fly. The packet then returns to the master over the remainder of the ring.

Ring protocols

Macro operates in several control modes:

Position mode: Position commands, position feedback (for reporting only).

Velocity mode: Velocity commands, position feedback.

Torque mode: Torque commands, position feedback.

Sine-wave mode: Phase-current commands, position feedback.

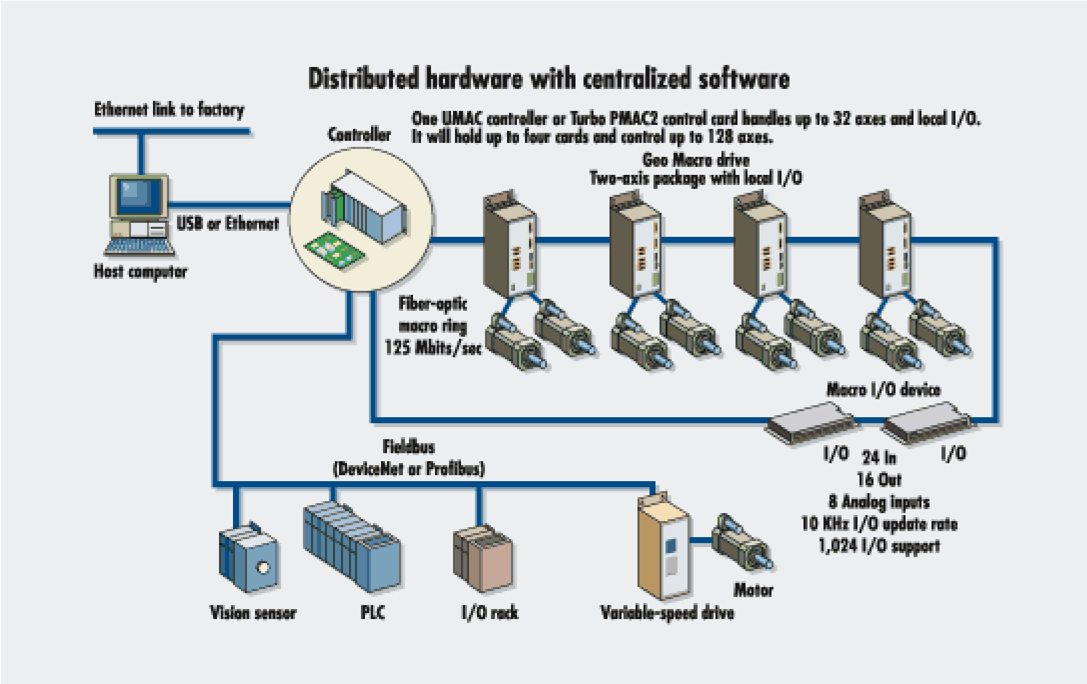
Direct PWM mode: Phase-voltage commands, position and phase-current feedback.

In all modes, both command and feedback data update and transfer at ring cycle rates. The controller's servo and commutation routines can operate as if in a self-contained controller, reading feedback from the ring just as they would read local feedback (for example, directly from an encoder counter), and writing command outputs to the ring in the same manner as they would to a local device (such as a d/a converter). From this point, the Macro-ring hardware takes over automatically. Note that the last two modes are unique to this system.

Protocols are simple, so software and hardware at the slave nodes can be implemented quickly, reliably, and cost effectively. Other strategies require every remote slave node to have powerful and complex capabilities.

In addition, nonservo I/O can be directly mapped and transferred over the ring at the ring update rate, making it as easy for the controller to use I/O over the ring as it is to use I/O on the controller.

These features combine the best of centralized and distributed-control strategies. The system can greatly reduce wiring cost and complexity as in other distributed schemes. But the control strategy can be kept centralized, as in a "unitary" controller, minimizing software cost and complexity. n



The Macro fiber-optic communications system offers the benefits of distributed systems, such as local control of electric motors and hydraulic servovalves, along with the speed and simplified programming of centralized software.