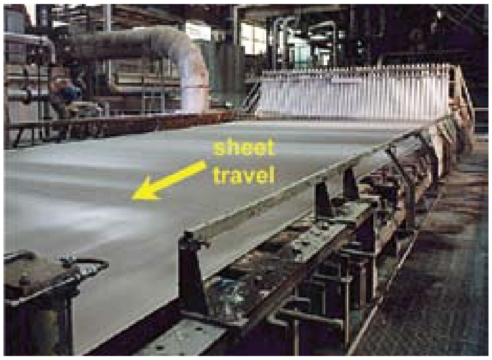
Cross-Direction Control of Paper Machines



Cross-Direction versus Machine Direction
Traditionally, paper machine control was limited to the "machine direction"—reducing the variation in the paper linearly along the direction of travel, without coordinating control "across" the sheet. Cross-direction (CD) control is a considerably more challenging problem—its solution revolutionized paper making!

A paper machine is a technological marvel! Think of it as a 100-meter-long, 10-meter-wide wire screen that can move at faster than 100 km/hour. At one end of the machine, pulp stock is extruded onto the wire screen; this stock is composed of about 99.5% water and 0.5% fibers. Over a 100-meter-long machine, the paper sheet travels a path that may cover more than 200 meters.

Ultimately paper is produced; the moisture content at the dry end is about 5-8% water and 92-95% wood fibers. With new "cross-direction" control technology, the paper can be produced to a thickness ("caliper") uniformity of within a few microns over entire production reels, each of which can contain a 40 km length of the paper sheet.

Scanning sensors measure sheet properties such as weight, moisture, and caliper in a zig-zag path on the moving paper sheet, and up to 300 individually controlled actuators in each of up to seven actuator beams are used for pulp stock metering, steam heat drying, water shower re-wetting, and induction heating.

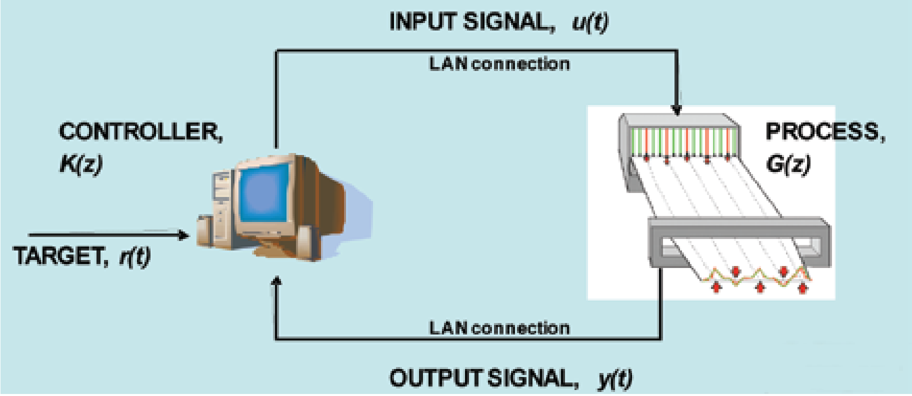
Problem Characteristics

The response of the paper to the cross-directional actuators has both a dynamic component and a spatially distributed component.

Analysis of the response in frequency domains reveals that the dynamic response is small at fast temporal frequencies and the spatial response is small at short spatial wavelengths (corresponding to the existence of small singular values).

A common closed-loop instability occurs at slow temporal frequencies and short spatial wavelengths—a result of combining aggressive control action (an integrator!) with low plant gain.

Honeywell's cross-direction paper machine control products, IntelliMap and PerformanceCD, are deployed on more than 300 paper machines. Benefits include up to 50% higher performance and about 80% reduction in control tuning time.



A long-standing industrial control problem solved by robust control design.

Contributor: Gregory Stewart, Honeywell, Canada

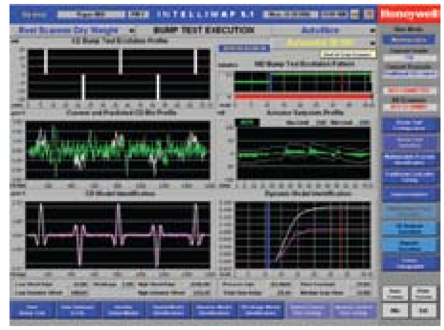
From: *The Impact of Control Technology*, T. Samad and A.M. Annaswamy (eds.), 2011. Available at www.ieeecss.org.

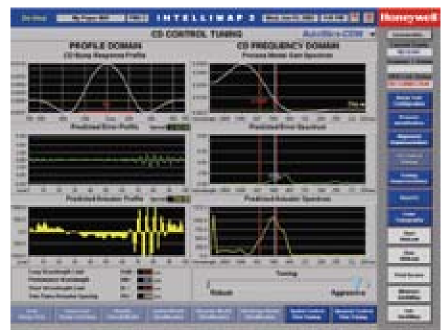
Operators and engineers in paper manufacturing plants are not experts in control theory. Providing tools that can be used by paper industry personnel has been instrumental to the success of this CD control innovation.

Design and Tuning Tools

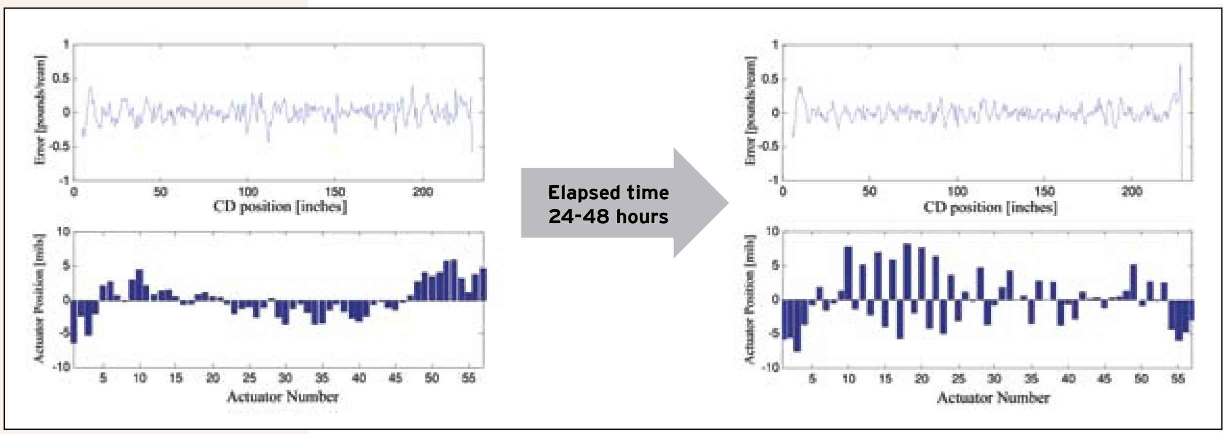
The tools provided for the success of this CD control innovation include:

- A test and identification tool that automatically makes changes to the actuators, collects the resulting sensor data, and analyzes the data to develop a large-scale, spatially distributed model.
- An automated controller tuning tool that takes the developed model and determines optimal tuning parameters for the cross-directional controller. The controller is designed using a technique called two-dimensional robust loop shaping.





The Previous State of the Art: *Prior to the introduction of advanced control, these systems would often develop a slow closed-loop instability, sometimes taking as long as 24 to 48 hours to appear after controller tuning.*



Awards

- IEEE Control Systems Technology Award from the IEEE Control Systems Society for "innovative application of modern identification and control methods to the papermaking process" awarded to D. Gorinevsky and G. Stewart in 2001.
- *IEEE Transactions on Control Systems Technology* Outstanding Paper Award given to G. Stewart, D. Gorinevsky and G. Dumont, "Feedback Controller Design for a Spatially Distributed System: The Paper Machine Problem," vol. 11, no. 5, September 2003.

For further information: Go to www.honeywell.com and search "paper quality control system"