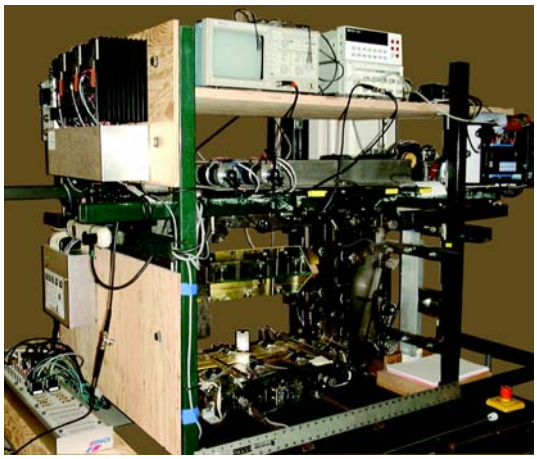
Perfecting Paper Paths

- Inter-sheet spacing control for large volume printers and copiers
- Experimental paper path controlled with dSPACE Prototyper
- University of California at Berkeley and Xerox Corporation in a joint project

Increasing demands on printers and copiers, like increasing velocities and throughputs, called for an increase in reliability and operation accuracy, especially of the paper path. A joint research project between the University of California, Berkeley, and Xerox Corporation has developed an innovative control process that detects and corrects slight timing inaccuracies by utilizing feedback control along the full paper path, thus avoiding so-called "soft jams". With dSPACE Prototyper the whole control development process was sped up, resulting in a first-cut closed-loop control implementation of certain control loops in only one day instead of weeks.

Fatal Soft Jams

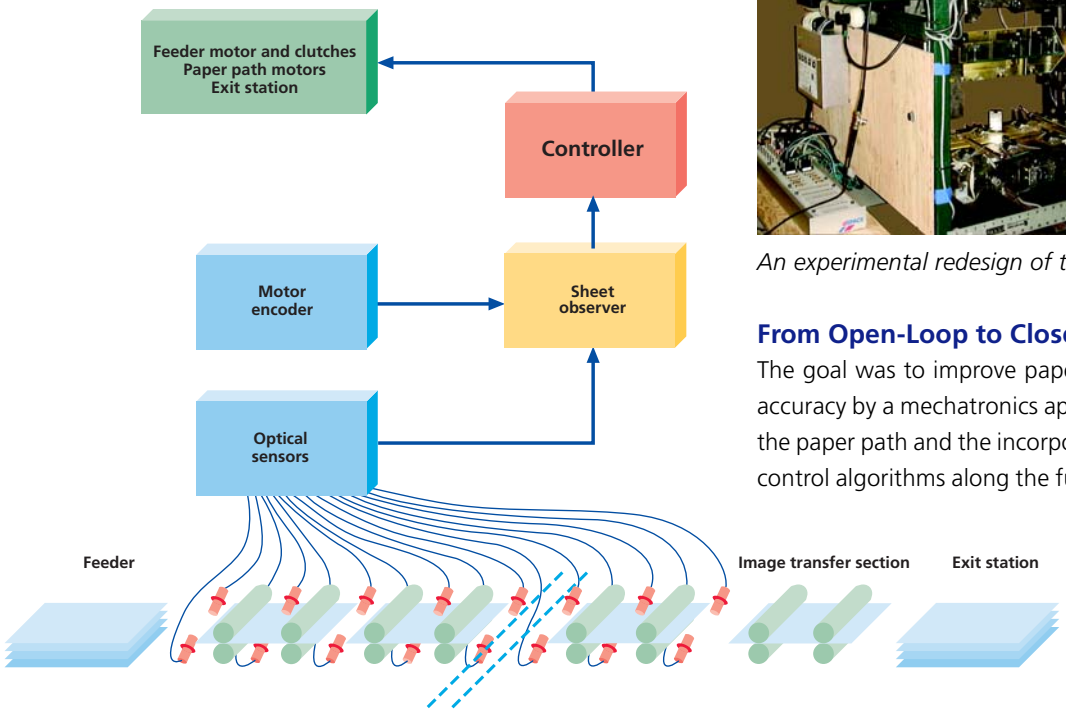
As sheets of paper are transported through a printer paper path, the exact path they take through bends depends on a variety of factors, for example, sheet stiffness, thickness, weight, velocity, and bend radius and angle. For longer paper paths, the actual path length that various types of papers are subjected to can vary on the order of centimeters, which results in variations in paper path timings. This means sheets arrive at certain locations earlier or later than intended. If these variations get excessive, the paper path controller shuts down the machine, which can easily happen if the user prints on media with nontypical properties. Such shutdowns are referred to as "soft jams", and represent more than half of all shutdowns. These jams correspond to papers being slightly too early or too late and can be attributed to the traditional open-loop operation of the paper path. A better mode of operation would be if the controller could detect slight timing inaccuracies and correct them before they get too large for the system to handle.



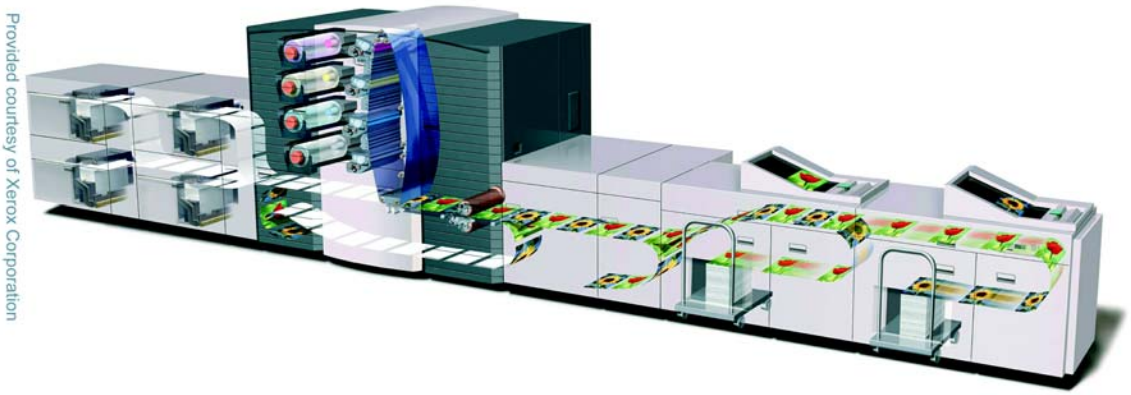
An experimental redesign of the paper path.

From Open-Loop to Closed-Loop Control

The goal was to improve paper path reliability and accuracy by a mechatronics approach, a redesign of the paper path and the incorporation of closed-loop control algorithms along the full paper path to con-



Basic overview of the paper path and other printer subsystems.



Internal overview of the Xerox DocuColor iGen3 Digital Production Press.

trol the sheet positions. Optical sensors along the paper path measure sheet positions, and motor encoders provide indirect measurements of sheet velocities. These measurements are processed by a sheet observer, which generates position and velocity estimates for all sheets in the paper path. These estimates are used by the controller to control the sheet positions along the paper path by sending currents and voltages to feeder motors and clutches, paper path motors and a solenoid activated exit station. The exit station enables sheets to exit from the paper path.

Easy Function Development

An experimental paper path was built and controlled using dSPACE Prototyper: The control algorithm is coded in Simulink® and Stateflow®, with a small portion of custom C code implementing the paper position and velocity observer. A MATLAB® script defines all system parameters: paper path dimensions, sensor locations, print job parameters, control parameters, etc. The application is then built and downloaded to a DS1103 PPC Controller Board, which was chosen as the electronic control unit prototype. The experiment is started from dSPACE's experiment software, ControlDesk, and all the data, which includes estimated sheet velocities and positions, section velocities, sensor signals and control errors, is collected by MATLAB scripts utilizing MLIB/MTRACE. The sheet positions in the process direction are controlled using an inter-sheet spacing control algorithm that removes position errors and rejects disturbances due to varying paper path geometries and media type throughout the whole paper path.

Speedier Development Process

One key advantage in using dSPACE Prototyper and MATLAB/Simulink/Stateflow control design environment from The MathWorks is the speed at which control algorithms can be designed, implemented, tested and executed on the real hardware. We experienced this first hand since initially, the control hardware consisted of a PC with interface boards programmed in C++. With the new rapid control prototyping tools, the whole control development process was sped up by an order of magnitude and the implementation of certain closed control loops was possible within one day instead of weeks. During the whole development process we really appreciated the support of dSPACE support engineers, who were always very helpful.

A Controller for any Printer and Copier

With the architecture redesign and the use of feedback control algorithms, soft jams are now avoided. When operating near the system performance limits, the system is able to correct for errors using the new concept of closed-loop control of the full paper path. As an example: In a print job with 10 sheets of papers of varying weight, stiffness and other properties, the sheets follow the same trajectories using the new control as if all 10 sheets had been the same type of paper. We developed a controller that is ready to be successfully introduced in future products with long paper paths.

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