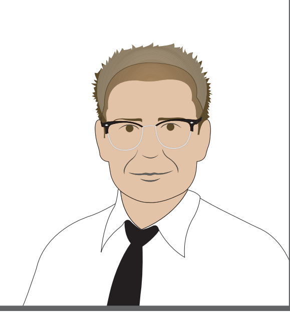

Remote Control

Mechatronic device extends author's reach over the Internet

In the spring of 2004, Margaret Atwood was in the middle of a grueling, multi-city, multi-country book tour. One night, with a 6 a.m. fight to catch, she wondered if there was a better way. She imagined signing books from afar, and she had the seed of an idea that would, years later, become the LongPen Freehand Script Robot.

Getting it all started

She teamed up with Matthew Gibson and created Unotchit Inc. (pronounced "you no touch it"), the firm under which they would produce the device. Senior systems engineer John Wiltshire, who has been with the project since Day 1, led the design team through multiple incarnations, starting with a simple X-Y plotter, then moving up to experimentations with a joint-articulated single appendage.

But when Jacob Apkarian, founder of Quanser Consulting Inc. in Markham, Ont., stumbled on the LongPen project in the newspaper, Unotchit had moved on was developing a prototype using linear actuators. Quanser is a leader in the development of real-time control systems, having developed haptic and simulator technologies, such as remote surgery, and Apkarian thought he could help. Gibson, in turn, had been looking to refine Unotchit's design and decided partner with Quanser in the summer of 2006.

"They were duly impressed with where we'd taken [our design up until that point]," Gibson said. "Now, they then took all that work and extrapolated and built it into, instead of linear control, a rotary control and made it smaller, faster."

Unotchit had a public event scheduled for September, so Quanser's control-system wizards were given an eight-week timeframe to go from concept to completion. To do so, Apkarian led a team of engineers that included Don Gardner and Ryan Leslie, both electro-mechanical design engineers, as well as roboticist and control specialist Paul Karam.

LongPen's launch took place at Toronto's Word on the Street festival Sept. 24, 2006, with a one-on-one book signing with Unotchit founder Margaret Atwood in Edinburgh, Scotland.

The process of design

Gibson says LongPen's design takes into consideration many factors of the human arm and how we write. "We [initially] underestimated the technical difficulty in replicating what nature has taken a great deal of time to perfect," he says.

The system is a pantograph-based device with an anti-backlash mechanism to correct for gearbox non-linearity. It also has four high-quality Faulhaber micro motors to maneuver the robotic arm. One is for vertical motion to make the robot approach the book, two are the pantograph so the pen writes on the X-Y plane, and the fourth lifts the pen toward and away from the paper.

The mechanical design was done in SolidWorks, but Apkarian and Karam needed to develop control strategies for the prototype. Gibson said the human hand oscillates at 30 Hz, pulls 6 to 9 Gs and uses 40 percent of the brain to accomplish the "simple" feat of handwriting. For the whole process to look effortless, there is a tremendous amount of work going on "behind the curtain." For instance, complex mathematical operations were used to solve what's called the "joint space and task space" movement.

"When you are moving your arm," Apkarian explains, "you are not only changing the angle of your joints, but also trying to control the fingertips of your hand. The relationship between the position in space, which humans perceive as X-Y-Z, versus the joint angles of the motors is highly non-linear."

The kinematical and dynamic equations for the robot were developed using Maplesoft Maple, software that helps formulate complex algebraic mathematics. Apkarian used Maple to solve the joint space and task space issue, while special algorithms were created to compensate for jerking.

Apkarian's team also used MathWorks' Simulink software—the controller design graphic language—to help with preliminary analysis, modelling and simulation of the device.

"First we do the mechanical design in the CAD program, but that is not enough to do the actual analysis of the motion and see if our kinematical (geometry) equations are correct," he says. "To test the geometry equations, we pass them through the simulator to see if it's actually doing the right thing."

Once that is finished, the control design blocks from Simulink and Maple are integrated and WinCon, Quanser's rapid control prototyping and hardware-in-the-loop testing system, converts the Simulink graphic control instructions into real-time code. The code then sends command and measurement signals to the robot via the data acquisition and control card (a Quanser Q4 or Q8), and the controller design block files and math guide the robot's movement. All of this runs on a real-time operating system called RTX, provided by Ardence. As the author-side writer writes, the signature is scrawled on the other end at the same time. RTX provides control of interrupt requests, I/O and memory to ensure tasks are executed with proper priority. (Users can also wait to send their message after it has been written in full.)

Scaling time and tricking the eyes

Making the robot respond the way the hand responds required a powerful motor and a huge device. At the same time, the systems needed to be small and portable.

"In order to compensate for the [smaller] motor's inabilities," Apkarian says, "we came up with advanced control schemes that would again not require so much performance … but still result in smooth and continuous, accurate motion." In essence, the team had to "scale time" or "stretch time" by breaking down the movements, essentially tricking the eyes into thinking the robot is writing fast.

When it was done (and on time, too), Unotchit and Quanser had created a robot that would replicate the author's signature from anywhere in the world over a TCP/IP Internet connection. The author with laptop is at one end and the robot with book at the other. From the author-end, data protocols are set up—start bit, stop bit, up-down and X-Y coordinates of the position they want to write—and the pen pressure is measured by a laptop tablet. The data streams to the robot, while algorithms smooth out all the missed points. The robot completes its task as the author lifts the pen from the page.

While some fans may miss the intimacy of an in-person signing, Atwood insists the machine doesn't alienate fans. It's designed to maintain the author-reader experience: streaming video allows the parties to converse, and users can even save their video exchange. "For many," Atwood writes on the company website, "it won't be a choice between the author-in-the-flesh and the remote signing. It'll be a choice between the remote signing and nothing." DE

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