CEO Patric Lüthi (in the foreground) and Robert Urech, Area Sales Manager, Beckhoff Switzerland, delighted with a new work of art.

PC-based NC and drive technology for a painting robot

Ten high-precision servo axes open up a new world in fine-art painting

IT specialist, Patric Lüthi has developed a unique, robot-controlled painting technology for producing fine works of art. Using acrylic paints, his OilPainter robot can emulate existing pictures as well as create stunning originals. To accomplish this, Beckhoff TwinCAT NC I software controls five main and five auxiliary axes which run via servomotors and servo drives, also from Beckhoff.

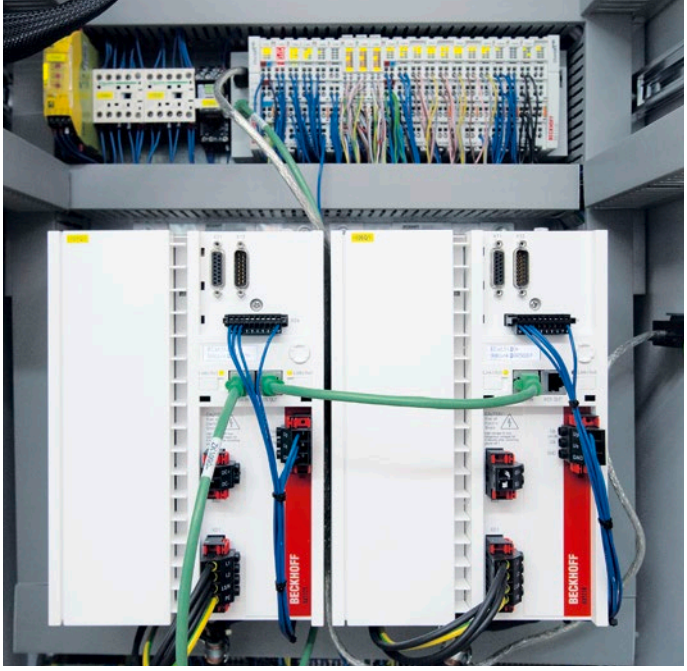
The OilPainter is a fully automated picture painting machine that produces images with acrylic paints in a post-impressionist style. It can paint a Mona Lisa in the style of van Gogh or a picture of Audrey Hepburn that looks like it was created by Andy Warhol. The first production-ready model of the painting robot is currently located in a former print shop in Zollikerberg near Zurich in Switzerland, but will soon produce one-of-a-kind paintings for a large furniture retailer, among other clients.

"To create these unique works of art, the data for the motif to be painted must be provided to the controller in a vectorized, pre-programmed form. That way, the machine knows each brushstroke before it even begins painting," explains Patric Lüthi, the CEO of OilPainter Ltd. in Zurich. "When the robot paints, it follows the program stroke-by-stroke with 11 different brush widths, which in turn can be positioned at any angle. By dividing the image into X/Y axes and the R-axis as the rotational brush angle, any stroke can be executed with any brush width. However, unlike a human painter, the OilPainter can rotate the R-axis continuously, for example, to paint a complete spiral without having to lift the brush or to generate a calligraphic work of art."

Numerically controlled servo technology for high-precision movements

When the machine paints, the five main axes provide the motion and the five auxiliary axes mix the colors. The three main axes (X, Y and R) must be perfectly synchronized at all times. The Z-axis is governed by the height profile of the canvas and the support table. The fifth main axis controls the brush position, which can be synchronized or non-synchronized with the R-axis.

The OilPainter is controlled via TwinCAT NC I software, as Patric Lüthi explains: "TwinCAT NC I controls the three path axes and the five auxiliary axes. In addition, the jet axis is linked via a master-slave axis, while the Z-axis is safety-



Control cabinet with two servo amplifiers from the AX51xx series and three EL7201 servo terminals in the I/O level located above

The OilPainter machine in its total length

controlled with a separate process. The paint is applied with high-precision, medical-grade pumps, whose auxiliary axes move simultaneously with the three main axes. The pumps, in turn, are driven via three EL7342 2-channel DC motor output stages. The system generates any color in a mixing chamber just ahead of the brush, proportionally with the pumps and in perfect synchronization with the motion speed – even during acceleration or deceleration."

The X- and Y-axes are driven by Beckhoff AM80xx servomotors. The motor for the X-axis is flange-mounted to the axis, utilizing an angular gear with shaft feedthrough and driving two belts. "This way, we can use a standard motor that is mounted perpendicularly to the axis," Patric Lüthi adds. "These servomotors are controlled via AX5125 and AX5118 1-channel Servo Drives, respectively, and we leverage this control technology to support fast and highly-dynamic positioning tasks." The Z- and R-axes are controlled via AM3112 servomotors, featuring maximum torque yield, high dynamics and high positioning accuracy. They are designed for use with compact EL7201 servo terminal. In fact, the OilPainter uses the high-speed EtherCAT industrial Ethernet protocol for all communication tasks. With a cycle time of 1 millisecond, the controller checks whether all axes are operating synchronously 1,000 times per second.

Applying colors correctly takes practice – even for a robot

According to Patric Lüthi, the technical challenges are huge when it comes to the correct application of acrylic paints: "The color flow must be perfectly coordinated with each brushstroke. In addition, the right color tone must be available instantly without any premixing. That's why we place the high-viscosity paint under pressure so that it can be pushed to the pumps through hoses. The pumps, in turn, operate with low pressure so that the color can flow smoothly from the brushes without splattering."

The palette of the OilPainter consists of five basic colors: cyan, magenta, yellow, black (K) and white. "This is a basic difference when compared with color handling by inkjet printers, which rasterize the image in CMYK. We don't rasterize, which is why we also have white as a basic color and for mixing pastels and greys. Normally, you can produce black with CMY, but it's actually more of a dark-brownish black. That's why the software adds black. We create greys from black and white, with the mixing ratios determined by the color's coverage as well as the quantity and size of the pigments," summarizes Patric Lüthi about the application requirements placed on the machine's control technology.

High flexibility through library of functions

The degree of digitization in the final OilPainter artwork depends on the picture's complexity and the desired results. "The user must determine which brush width and color you want to use. After all, we don't merely want to copy the original painter's style – which is why we have developed our own logic," explains Patric Lüthi. "If you want to paint the reflection of sunlight on a face, for example, the system must know which brush should apply the white color at which point. The result is impressionist. If you permit only straight brushstrokes, the picture looks like it was painted with a putty knife. Alternately, if you permit only points, the finished art is close to pointillism. The time it takes to produce a painting depends on the number of brushstrokes. For example, if you have 10,000 strokes with each taking one second, a picture can take several hours."

All brushstrokes are stored in a Visual Basic interface. With its numerous library functions, TwinCAT uses this information to generate the various painting options. "The controller translates the data into CNC commands. The GUI generates the G-code and transfers each complete brushstroke to TwinCAT for execution. A complete picture requires thousands of brushstrokes, and if you were to convert all brushstrokes into their waypoints in a single step, you would wind up with a huge G-file, which would overtax the computer's RAM and make interruptions impossible," explains Patric Lüthi. "However, we must be able to clean the system between color changes or wait until parts of the picture have dried to continue painting."

Although a painting robot seems quite exotic at first glance, the solutions can be transferred to other industries, which is why OilPainter Ltd. has already received inquiries to develop solutions for other compounding challenges, again featuring Beckhoff control solutions.

Further information:
www.oilpainter.com
www.beckhoff.ch