EtherCAT: Optimum synchronization and precision of movement sequences

Bowling robot shows the way to the perfect game

Bowling is, of course, a popular sport in the U.S. It is estimated that 70 million people go bowling in the course of a year; more than two million regularly bowl as part of a club. As an umbrella organization, the "United States Bowling Congress" (USBC) coordinates and ensures the technical perfection of the sport by extensive material and quality tests. The association set a milestone in 2010 with the high-performance bowling robot E.A.R.L. (Enhanced Automated Robot Launcher), which was developed by ARM Automation. A PC- and EtherCAT-based platform from Beckhoff ensure precise control of the robot.

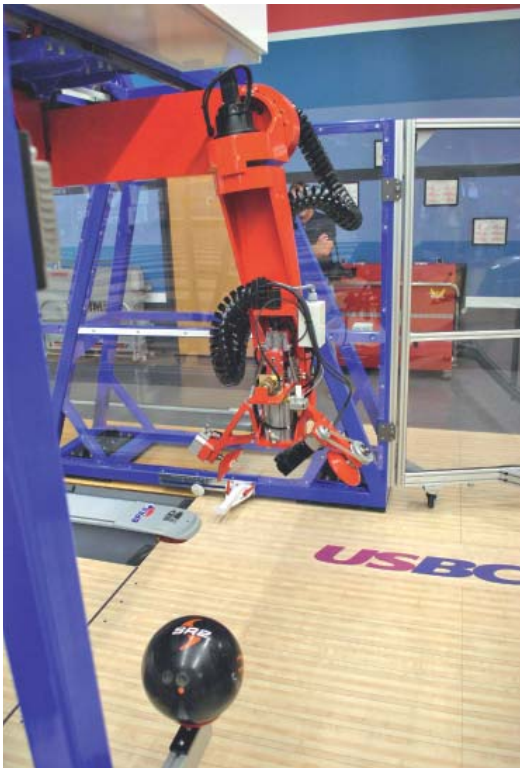
ARM Automation, based in Austin, Texas, develops custom automation solutions for challenging industrial applications. Founded in 1993, the main focus of the company is building robots for diverse areas and ranges of use: testing systems for orthopedic implants, robots for handling nuclear materials, underwater robotics for fountain shows, packaging and assembly lines for PC production, mobile robots for warehouse automation, laser micro-machining tools in semiconductor manufacturing, etc. The strength of ARM Automation is in the development of custom solutions which are precisely tailored to the application. "ARM Automation was the only company that was prepared to construct the robotic solution that we needed," explained Neil Stremmel, Managing Director of the USBC National Governing Body.

Bowling robots simulate player behavior

The development of the E.A.R.L. bowling robot was primarily aimed to conduct research and test the products and materials used in bowling. "The assessment of the robotic data allowed conclusion of the correlation of ball movement and scoring," Neil Stremmel explained. "E.A.R.L. has the ability to replicate virtually any bowler's style, which will aid coaching staff by showing how conditions change as individual bowlers compete and how to properly adjust to the ever-changing bowling environment." In order to eliminate the variation that a human bowler would introduce during the tests, the USBC used Harry, the bowling robot, in the past. "Harry didn't offer sufficient repeatability and was cumbersome when adjusting test conditions such as differences in position," is how Stephen Grupinski, President of ARM Automation described the initial situation.

Optimum synchronization and precision of movement sequences

The E.A.R.L. robot's motion system consists of a linear axis to position the ball across the width of the lane, a 5-axis positioning robot, a ball spinner and release mechanism installed on a gripper. With what may seem like a simple swing of the arm, when the robot grips the bowling ball and bowls it down the lane, there are actually many parameters which



The United States Bowling Congress has been at the forefront of bowling research and testing of new technology and materials for years.

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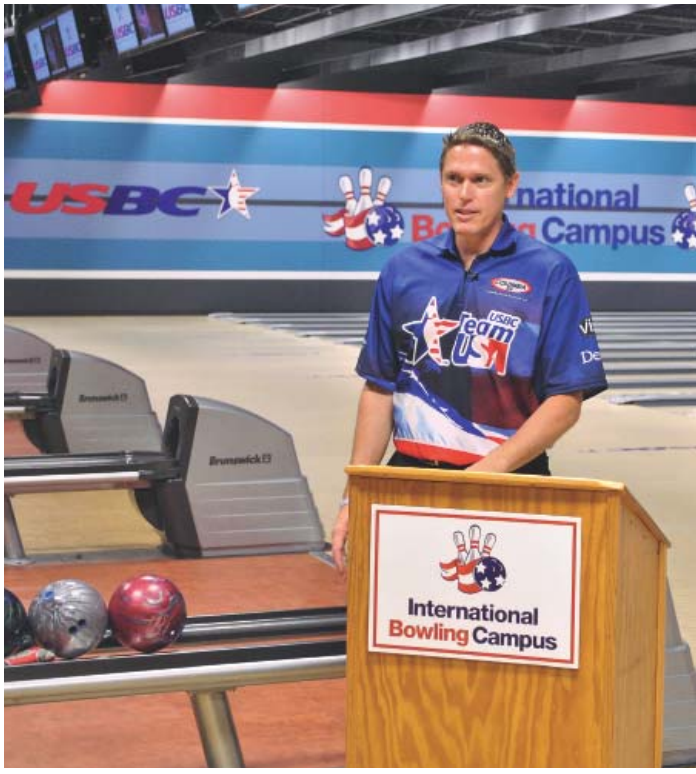

need to be captured for a single throw test. A typical E.A.R.L. test setting consists of the following:

- orientation of the robot gripper relative to the bowling ball's center of gravity
- release point of the ball relative to the bowling lane (height, position relative to foul line, position across the width of the lane, loft angle, ball trajectory)
- ball release speed and rotation speed.

"The biggest challenge overall for the mechanical and electrical control development was getting the timing of the bowling ball release," Greg Wiese, Project Engineer, ARM Automation said. USBC requires a speed of about 24 mph or 10.7 m/s for the ball release. If the system dithered 1 ms, it equates to roughly a degree in difference for ball loft and 12.7 mm difference relative to the foul line (if it goes over this line the bowl is void or out-of-bounds). Any additional dither and the ball could be thrown into the ceiling or slammed into the bowling lane.

"Thanks to the distributed clock function of EtherCAT, we have achieved optimum synchronization and precision," said Joe Geisinger, CTO of ARM Automation. "This provides the precision to coordinate the external I/O with the control and position of the drives in the sub-millisecond range: the position of the E.A.R.L. robot's end effector is communicated to the EtherCAT drives to determine the exact time at which the ball needs to be released. That position measurement is exceptionally precise, within 1 ms, and successfully creates the correct loft of the ball each time.

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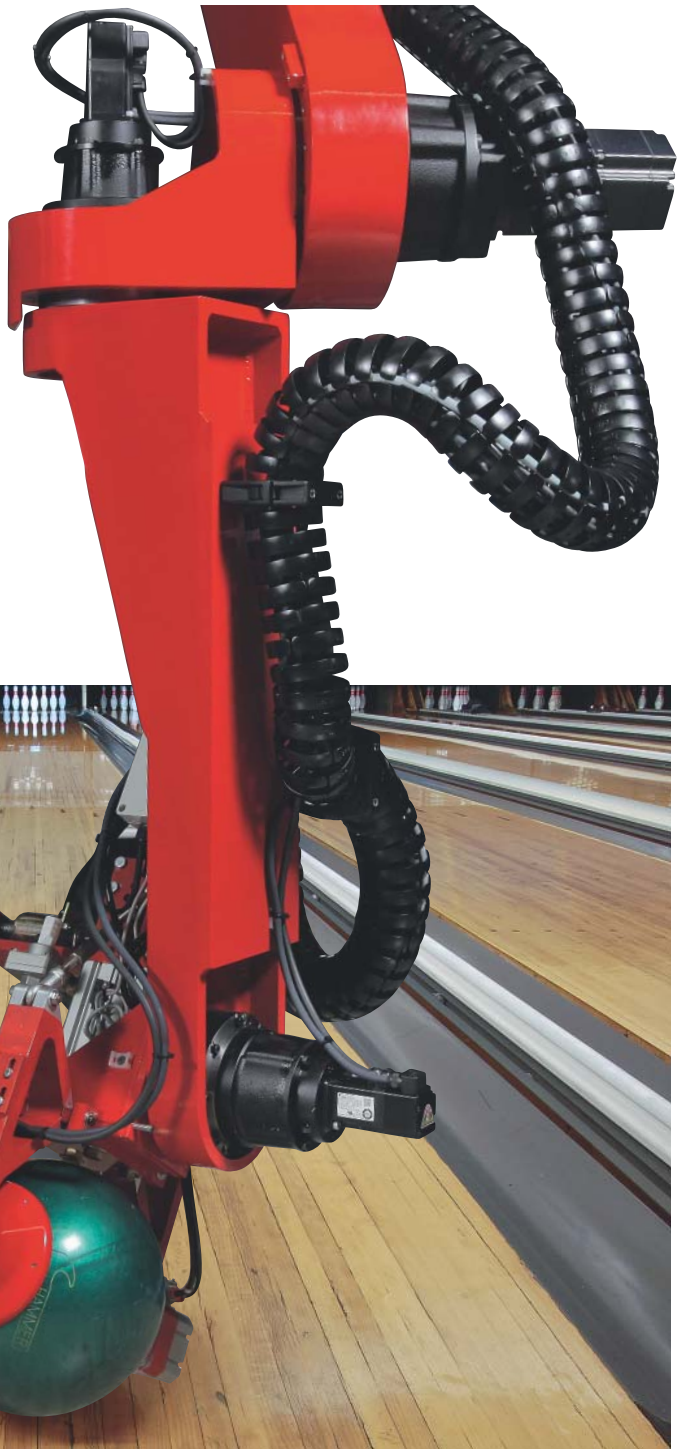

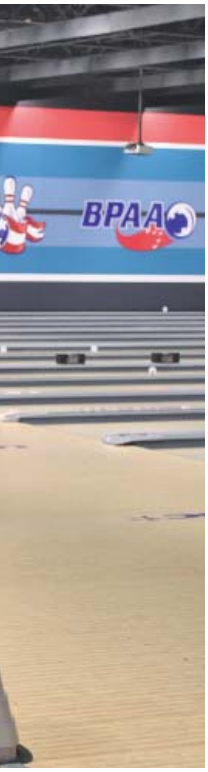

E.A.R.L. is able to release a bowling ball under test within 250 µs of a scan of the position."

Adjustment of the parameters within seconds

In order to tackle the tight precision requirements of this unique robot application, ARM Automation selected the EtherCAT- and PC-based control system from Beckhoff. The USBC personnel can easily input their test settings via a Control Panel. There are 11 variables for configuring different throws via the Control Panel to adjust speed and pick-up orientation. The robot can be reconfigured for completely different parameters in less than 10 seconds.

The control system includes a Beckhoff C6920 Industrial PC running TwinCAT NC PTP software and Windows CE operating system. EtherCAT serves as the communication system for I/Os and drives. The operator interface in use is the Beckhoff CP6901 Control Panel with 12" touch screen.

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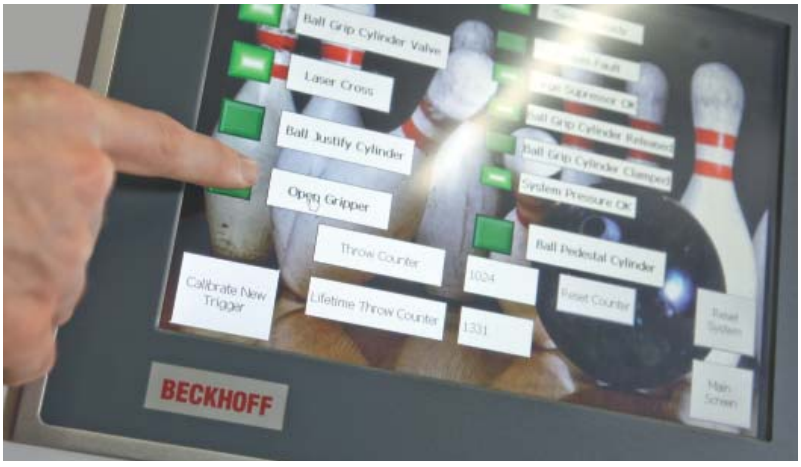

EtherCAT integrated Motion Control and I/Os

ARM Automation has been an active member of the EtherCAT Technology Group (ETG) for years and has developed EtherCAT slave devices. "We switched to EtherCAT years ago, as it offered us numerous advantages compared to traditional fieldbus systems," explained Stephen Grupinski. "The well-known Ethernet physics, general performance data, our customers' increasing interest in Ethernet-based networks as well as the ability to combine Motion Control and I/O in one and same network were important reasons for the change." "EtherCAT also allows us to diagnose the bus to detect broken links on the physical layer and easily determine exactly where the problem is located along the line," said Joe Geisinger. "Thanks to the open architecture of TwinCAT control software, it offers the flexibility of connecting to the configuration existing SERCOS devices via a mini SERCOS fieldbus card which is installed on the C6920 Industrial PC."

Development of Motion Control based on TwinCAT

E.A.R.L. required the ability to flexibly gather the inputs from a wide range of devices and communicate easily with the drives in a flexible environment. "TwinCAT System Manager and EtherCAT allow us to do just that – we can easily pull together different platforms," continued Joe Geisinger. The TwinCAT automation software coordinates the acquisition of I/O and position data from the drives, performs inverse kinematics, generates the next joint position commands and outputs the new position commands and data to the drives. ARM developed a kinematic transformation for E.A.R.L. which is implemented in TwinCAT and is fed into the NC via the external set value generation. "We used the Motion Control functions of TwinCAT for this," Joe Geisinger explained. "With NC PTP, we control the motion axes and constantly monitor the status of the EtherCAT drives."

The safety mechanism of the bowling robot was also reworked, in that TwinCAT monitors all the safety devices. If anything happens to go wrong during operation, the drives are immediately disabled and the robot goes into a safe state until the system is reset properly. E.A.R.L. is also enclosed in a protective cage with safety sensors, light curtains and safety relays installed all around to ensure optimum safety.

Optimized test situation, simpler handling

"We now have more options and better resolution for release height, trajectory, ball speed, RPMs, and loft," remarked USBC's Managing Director, Stremmel. "E.A.R.L is able to handle a larger range of ball diameters and RPMs. Moving E.A.R.L and changing its settings is much simpler and far more accurate than with our previous robot solution."

"ARM is constantly combing the automation industry for new tools and innovative processes to optimize and enhance its solutions," Stephen Grupinski explained and added: "our applications are inherently complex and are often highly custom in nature, requiring flexible control platforms that can be configured on-demand to suit our customers' needs. Beckhoff's open and modular control architecture provides us just the right toolbox to rapidly develop solid customized solutions."

United States Bowling Congress (USBC) **www.bowl.com**
ARM Automation Inc. **www.armautomation.com**
Beckhoff USA **www.beckhoffautomation.com**