RISE
of the ROBOTS

Poultry deboning has proven too difficult for an automated solution to match the performance of humans. Until now.

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Some of the most promising developments in robotics are occurring in the areas of cut-up within the poultry industry — and although automated deboning equipment has existed for years, widespread use of robotics hasn't cleared one of its highest hurdles: yield issues.

The Georgia Tech Research Institute (GTRI) has a long history of developing technology for the food processing and agricultural industries. One of its key projects in recent years has been the development of a robotic shoulder deboning system for poultry, known as the Intelligent Cutting/Deboning Robot.

Though the GTRI researchers have poked around in more mature robotics-rich industries for inspiration — automation and electronics among them — they had to necessarily innovate, due to the uniqueness of the product. Where lack of variability in cars and microchips has helped those industries integrate automation more broadly and smoothly, fast and efficient processing of the broiler carcass has become the food production industry's holy grail.

So the GTRI researchers may be forgiven if it's taken them almost a decade to develop an "intelligent cutting" system that's close to commercialization. They've married a variety of technologies such as high-speed force

Several factors combine to make deboning difficult to automate. Data on external features is gathered easily through an imaging system, but the information essential in determining where to cut is all on the inside.

control and vision systems to think like humans — making snap decisions and working on each product differently — only faster and better.

"This is a really difficult problem. A lot of companies may not even think it's possible [to automate with robotics], but they're thinking just a few years out," says Doug Britton, manager of GTRI's Agricultural Technology Research Program. "We should be tackling those problems that are 10 years

"It's really easy for humans to do this but really hard to teach a robot how to do it."

out that are really big challenges, not the little incremental things."

OPTIMIZING YIELD

Humans learn quickly on where to make the cuts based on the external features of the bird. It's not a conscious model but rather an intuitive feel that is acquired through repetition. Gary McMurray, chief of GTRI's Food Processing Technology Division, notes that mastering the cut (as measured by consistent yields at high speeds) is the biggest hurdle for both human and robot. "It's one thing for a small operation that's losing a couple grams here and there, but a couple grams adds up in a plant that processes 1.5 million birds a week. These cuts directly impact the yield of the breast meat."

Subsequent processes that follow the clavicle-shoulder-scapula deboning cuts include separating the breast from the wing and harvesting the tenders — none of which is more difficult than the process for which the robot was designed. "You're trying to estimate interior features from the outside," McMurray says.

In addition, the worker has the unique ability to react to forces during the cutting process. "The need to adjust the path

of the blade in real time comes from a variety of reasons: the model for predicting the internal structure of the bird is not perfect, natural variations in the bird, or the bird structure has been changed during processing (missing wing or broken clavicle)," McMurray says.

"The focus of the poultry industry has been corn and yield. They're running a business. They're focused on making money. They're doing that by maximizing their corn use and optimizing yield," Britton says. "If you can do those two things, you can remain competitive and stay in business. If you can't, you're done."

ROBOTICS 201

The GTRI robotics team has spent the past year working toward dual goals: transitioning the cutting system to a new flexible prototype system and optimizing the cutting trajectory.

The new system is built using a "six-degrees-of-freedom" (DOF) robotic arm, giving researchers the flexibility to perform the cuts with a variety of blade orientations while maintaining a precise trajectory of the tip of the blade. Degrees of freedom range from one to six and reference the number of X-Y-Z coordinates on a given plane. For

example, a straight line cut requires one DOF; to cut the surface of a table requires two DOF (on the X and Y coordinates). For more complicated processes, it takes six DOF, or six parameters to define the position and orientation of a point in space.

"Originally we thought that as the line moved it would naturally define the Z position, but we could only cut in a single plane," McMurray explains. "We needed another degree of freedom. We knew that workers change the orientation of the blade, but we didn't know how important that was to the yield."

For the force control, the device is a stand-alone force control system that mounts at the end of the robot's arm with a blade attached at the opposite end. It can be preprogrammed to maintain a constant force, and it will adjust the position of the tip of the blade to achieve that force. "With this system, we have been able to successfully perform the cut through the shoulder joint — and at no time did the blade cut through a bone," McMurray says. "If the blade ever made contact with the bone, the control system quickly and efficiently guided the blade around the bone and then continued cutting the meat."

To optimize cutting trajectory, researchers eyed two main problems. First, they performed additional modeling to improve the accuracy in predicting the bird's internal structure. That required extensive data collection of the internal structure of a bird — specifically, a multitude of internal points on each bone, tendon and ligament was identified, and their 3-D positions were collected. That allowed the researchers to develop more robust models of the bird's internal structure.

Next, they collected real-time data on the orientation of the blade and the tip position during a series of manual cuts, necessary for the team to direct the orientation of the blade and determine

"POULTRY is even more variable than pork and beef."

its impact on yield.

"We're now taking data from the workers to optimize trajectories," McMurray says. "Up to now we've been concerned about where the tip of the blade was located, assuming it was a 15-degree orientation, but if we can optimize the orientation of the robotic blade we can get more yield."

In other words, since no carcass is the same, humans must modify the orientation of the blade to accommodate each carcass. "The processing speed in poultry is so fast, and percentage change from bird to bird is so significant," Britton says.

McMurray monitored workers performing manual shoulder cuts to merge that new data with the existing model to optimize the blade orientation.

As the team is moving into the final research phase of the project, the ability of the system to perform automated cuts has been proven. There are no reasons to believe that the automated system will not be able to match the performance of the average worker, McMurray adds. "We have a system that's in the range of a plant worker's abilities. The key is collecting this last bit of data."

He and his team are now exploring options for commercialization, with final cuts expected by August and full-scale tests wrapped up by January.

ERGONOMIC INJURIES PERSIST

"This isn't taking away a job that people want," McMurray says. Processors rotate workers on the deboning line as often as every break. "This is a job people can only do for short periods."

Although the poultry processing industry has cut occupational injuries and illnesses by 75 percent over the last two decades, one-third of all days away from work remain work-related musculoskeletal disorders (MSDs).

Against that backdrop, turnover on deboning lines typically tops 100 percent and can reach 150 percent, he adds. ◎