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Improving the Picture of Food Production

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If you are what you eat, then it might be good for food to get the right – and therefore light – touch. Photonics-driven improvements in food inspection and handling could result in fewer illnesses, less waste, cheaper prices and better quality.

There is clearly a need for better inspection. According to the Centers for Disease Control and Prevention, food-borne illnesses hospitalize more than 300,000 people and cause 5000 deaths each year in the US. Thus, an improved ability to detect contaminants and problems could save lives.

Take the case of chickens and turkeys. According to the US Department of Agriculture (USDA), the US poultry industry produces 43 billion pounds of these birds a year. Screening them during processing is labor-intensive.

“Currently, poultry is inspected by human inspectors,” said Moon S. Kim, a research physicist with the USDA’s Agricultural Research Service in Beltsville, Md.

To improve the situation, Kim and colleague Kuanglin Chao, an agricultural engineer, have turned to hyper- and multispectral imaging, an approach that combines the materials identification of spectroscopy with the location capabilities of machine vision.

USDA agricultural engineer Kuanglin Chao examines the output from a hyperspectral poultry inspection system. Courtesy of Moon S. Kim and Kuanglin Chao, USDA.

To do this, they collect spectral data on a pixel-by-pixel basis, creating a hyperspectral data cube through full spectrum capture. The result is a multispectral volume if the collected data is restricted to fewer bands. Based upon the results from good and bad samples, the researchers can determine if a given bird is OK to process or should be shunted aside.

USDA scientists have been working on the inspection problem for years, researching the technique for use on poultry, fruits and vegetables. During that time, Kim has seen significant technology advances.

In particular, he points to improvements in sensors, such as the advent of electron-multiplying CCDs originally developed for astronomy and microscopy. These have undergone a significant increase in speed over the past decade, he said. “Now it’s much faster, and that enables us to use the technology for in-line applications. It’s almost two orders of magnitude faster.”

This also has allowed the researchers to build line-scan systems that can handle 2.5 chickens a second. That’s fast enough for commercial use, and Kim noted that one system currently is in field tests with a poultry processor. If all goes as planned, the system could enter service by next year.

Aside from potentially removing the variability of human inspection, the technique offers other advantages. One system can do multiple inspection tasks. It also can be reprogrammed to handle another inspection chore by simply changing software. That’s why the same setup can be used to examine chickens for contaminants or to check fruits and vegetables for bruises or defects.

The performance of an inspection system is not just a function of the sensor alone, according to Xing-Fei He, a senior product manager with Dalsa Corp. in Waterloo, Ontario, Canada. He noted that food and agricultural product processing often is done in harsh environments. The sensors must work across a wide range of temperatures and humidity, withstand vibration and shock, and contend with water, blood and guts.

A hyper- or multispectral system also confronts another challenge: light. The USDA poultry inspection research, for example, has shown that imaging from 520 to 600 nm is critical for success. But what’s best for looking at birds may not be best for looking at vegetables, which absorb strongly in that range and throughout the visible in general.

The spectral intensity, uniformity and stability of the light are important inspection ingredients. But that presents a problem, He said. “You cannot find a light that’s uniform across the spectrum because there’s no such light source.”

The machine vision standard, a halogen lamp, tends to tail off toward the blue. White LEDs, which are increasingly used, begin to falter toward the red. Deploying multiple sources might be the answer, but that adds cost and complexity.

In addition, the data generated can be enormous. Capturing hundreds of spectral points for every pixel is the same as generating that many monochrome images. Fortunately, this problem is lessened if only some spectral points have to be evaluated and acted upon in real time.

For his part, He believes that the data processing and lighting problems will be solved. He sees the trend progressing from monochrome to color processing and then, eventually, to multi- and hyperspectral imaging.

Expanding the spectral information collected can lead to systems that do more than spot problems once processing has started. They also could be used to improve quality before processing begins.

A case in point comes from field work being done by Constellation Wines U.S. Jim Orvis is the director of research and development for the company, a wine- and beverage-producing division of Constellation Brands Inc. of Victor, N.Y.

Orvis, who is based in Madera, Calif., noted that the quality of a wine ultimately depends upon the quality of the grapes. Producers would like to pick these at the right time, but because an entire vineyard will not mature in lockstep, they have been seeking ways to nondestructively sample grapes on the vine. Harvesting could then be done selectively, yielding what could be a more uniform and, perhaps, higher quality product.

In the case of Constellation Wines, research has involved the use of near-infrared spectroscopy as a way to identify where red grapes are in their maturation process and as a gauge of quality. This has proved fairly successful in the lab but much more problematic in the field.

Orvis would like to see an inexpensive and rugged instrument with built-in geolocation capability. The latter is particularly important if it is to be used to map a vineyard for selective harvesting.

He added, however, that determining grape quality is a challenge. The solution is likely to involve some hand labor to correctly position the sensor – at least at first. “It’s a difficult problem to solve because you’re looking through the canopy. You’ve got to be able to get through the canopy at the grapes.”

Another example of using more spectral information comes from the Battelle Memorial Institute. The Columbus, Ohio-based nonprofit manages or co-manages national labs for the US departments of Energy and Homeland Security. Its latest food and agricultural inspection technology came out of bioterrorism and homeland security applications.

The company’s rapid enumerated biological identification system makes use of Raman spectroscopy to identify biological materials at the species level, said senior scientist Andrew Bartko. It works by comparing the measurement of individual cells to a library, looking for a match.

Based on techniques developed to combat bioterrorism, this unit rapidly identifies biological samples, allowing food to be tested for contaminants. Courtesy of Battelle Memorial Institute.

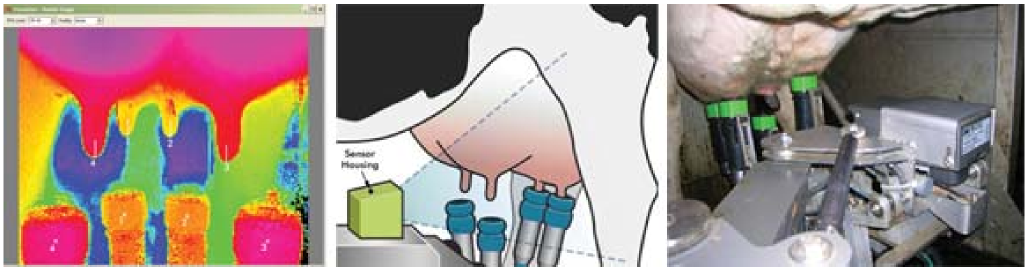
Bartko envisions the system working in several modes. One would be by examining the biological materials in rinse water. Optics, imaging and image analysis would determine which particles to analyze and which to ignore. Another mode would look at airborne particulates, using imaging and analysis techniques to spot and identify the species of such things as mold spores.

Bartko said the self-contained system is about the size of a microwave. He also indicated that determining the mold contamination within coffee beans could be done while a shipment was sitting on a dock.

“From the time you hit ‘go’ to a decision, it’s about 15 to 20 minutes, depending upon the level of contamination. Low contamination might take a little longer. If it’s grossly contaminated, you’ll know immediately,” he said.

Besides the spectral dimension, there is another one to exploit. Imaging has largely been a two-dimensional affair, but that is changing, thanks to technological advances.

LMI Technologies Inc. of Delta, British Columbia, Canada, specializes in 3-D sensors, according to Barry Dashner, vice president of marketing. For food processing applications, getting a complete 3-D picture can be critical to success.



Look, Ma, no hands! Using 3-D imaging generated by a properly placed time-of-flight sensor (schematic, above, and photo, left), an automated system can reliably attach milking cups to a cow, cutting labor costs and increasing milk production. Color mapping helps show distance (upper left image). Courtesy of LMI Technologies Inc.

Products from LMI, for instance, are found in automatic milking machines, robotic devices that attach themselves to cows without human intervention. The cows simply enter the stall, and the machine does the rest.

For that to work, more than 2-D imaging is needed because attaching a suction device to the wrong spot will not produce milk. Also, a wayward attachment might be enough to scare a cow off automated milking forever.

LMI uses a variety of methods to get 3-D information. Traditionally, the company's products have used structured light, in which a series of dots or lines are projected onto a surface. The surface profile is then determined by the distortions in this known geometry.

For cow milking, however, LMI makes use of time-of-flight sensors that send out pulses of infrared light. The time it takes to travel to and from an object determines surface distance. One advantage of this approach is that it yields 3-D information and a gray-scale image.

Automated milking enables smaller-scale operations to cut labor expenses. It also could boost output because it allows farmers to follow the right timetable for maximum productivity.

In explaining this, Dashner said, "The cows go on their own schedule. They come down. They walk into the milking machine. They're happy, and they give 10 percent more milk."

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