Abstract
Real-time detection of feces on poultry carcasses by a line-scan hyperspectral image camera

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Introduction

Currently, USDA inspectors visually examine chicken carcasses for finding surface fecal contaminants, among many others related to food safety. USDA researchers have been studying the use of imaging spectroscopy for fecal detection and have found that three key wavelengths, at 517 nm, 565 nm and 802 nm, could maximise the detectability of surface fecal matter on poultry carcasses. Developing a real-time multispectral imaging system poses a challenge to both researchers and real-time system designers because the hyperspectral imaging system platform used for research is usually not appropriate for high-speed real-time applications. In this study, a line-scan hyperspectral imaging system that can be used for both research and real-time imaging purposes was built, and evaluated for its potential to detect fecal matter on poultry carcasses during commercial poultry processing.

Materials and methods

The line-scan hyperspectral imaging system consisted of a spectrograph (Headwall Photonics, Fitchburg, MA, USA), an EMCCD camera (Andor Technology, Belfast, UK), tungsten-halogen line lights, a computer, and custom software. The hyperspectral imaging system measured a line scan of 1004 pixels with 1002 wavelengths in the nominal spectral range between 300 nm and 1100 nm. The real-time multispectral imaging with the developed system was possible due to (1) the unique feature of the EMCCD sensor (a random track mode), that was capable of getting access to user-defined areas on the CCD sensor and (2) the design of a real-time data processing algorithm. By using the random track mode, only three wavelengths at 517 nm, 565 nm and 802 nm were selected and transferred from the camera buffer to the computer system memory. Real-time image processing was possible by adopting a circular buffer technique. A circular memory buffer designed for real-time multitasking allowed the

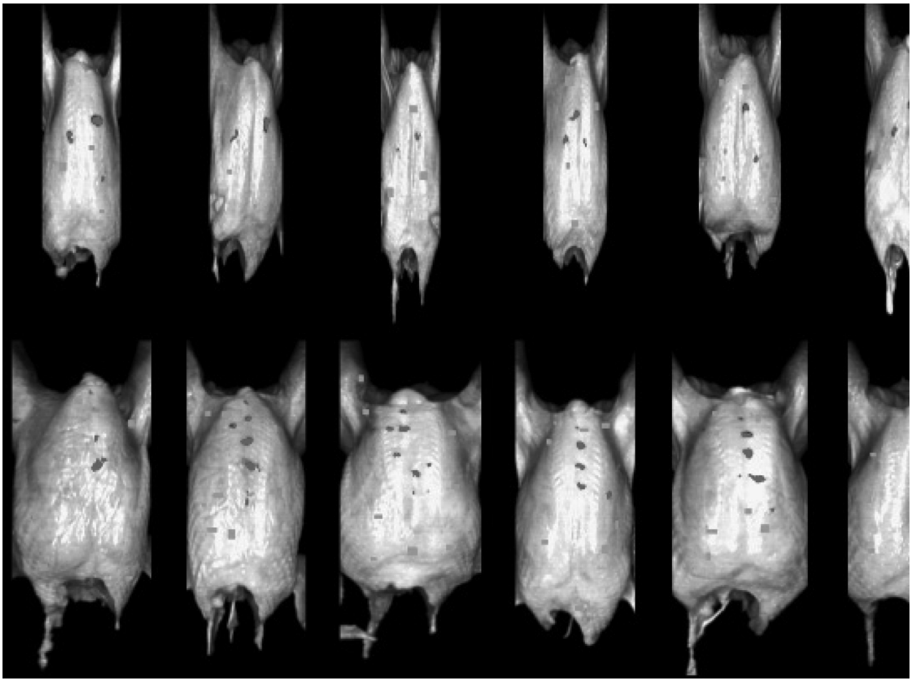

Figure 1. Mosaic of sample birds with fecal matter. Red colour pixels were feces detected by the system. Green pixels were normal skin selected by user for a scatter plot analysis shown in Figure 2.

acquisition of line images and the simultaneous grabbing of line images managed by a ping-pong memory technique. The multithreading features provided by Microsoft Windows were utilised to implement the multitasking in C++. An image-based trigger algorithm was developed to determine the start and end positions of birds and then to specify the locations of the captured data on the circular buffer. The fecal detection algorithm was based on dual band ratios of 565 nm/517 nm and 802 nm/517 nm, followed by thresholding. At each pixel, a reflectance calibration was performed with a 99% Spectralon target and a dark current. Twelve chickens were used for testing the imaging system at two different speeds (140 and 180 birds per minute) in a pilot-scale processing line. Four types of fecal materials (duodenum, caeca, colon and ingesta) were applied on the carcasses for evaluation of the detection algorithm.

Results and discussion

A real-time multispectral imaging system configured from the line-scan hyperspectral camera processed three-band line-scan images at up to 180 birds per minute. The actual width of each bird was varied depending on the processing line speed. The performance of fecal detection was comparable to what the previous research had achieved. The efficacy of the dual-band ratios was also confirmed. The study suggested that this type of real-time multispectral imaging using a hyperspectral image camera could be feasible in other applications.

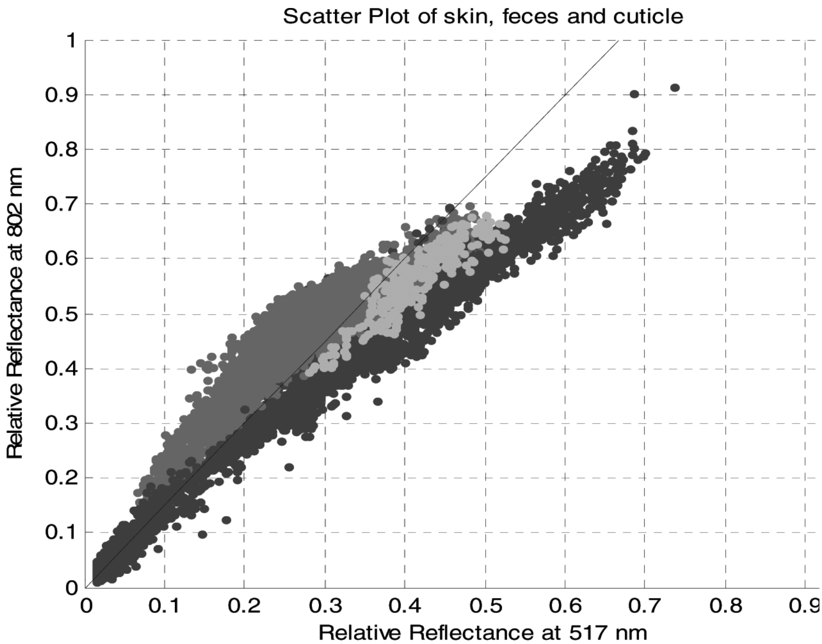

Figure 2. 2D scatter plot of reflectance data at 517 nm and 802 nm overlaid by the decision boundary. Red, blue and cyan refer to feces, normal skin and cuticles (false positives in 565 nm/517 nm ratios).