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A robot and sensor platform for consistent measurements of beef shortloin cross-sections with a variety of optical sensors. (#571)

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Notes

Introduction

We present a proof of concept robotic platform that autonomously acquires measurements with a variety of different non-contacting, all-optical sensors. Often optical sensors have strict requirements to collect quality data, including sample offset distance, lighting and even translation of the sample during scanning. All these requirements can be addressed in real time using a suitable robotic arm and sensor platform, whilst simultaneously reducing the amount of sample handling. Robotics and light-based sensors are increasingly used in food processing to improve speed, precision and hygiene (Meshram BD, 2018). Our robotic and sensor platform allows for fast and repeatable multi-sensor scanning of in-tact meat samples. Contour mapping of the sample surface adaptive scanning, which is particularly important for sensors that are highly sensitive to sample offset distance, such as Raman spectrometers and hyperspectral cameras. In addition, a GUI allows for user selection of regions of interest to be assessed in greater detail. In a research setting, the consistency of data collection between sensors allows for objective comparisons of the performance of each sensor to predict the food quality attributes.

Methods

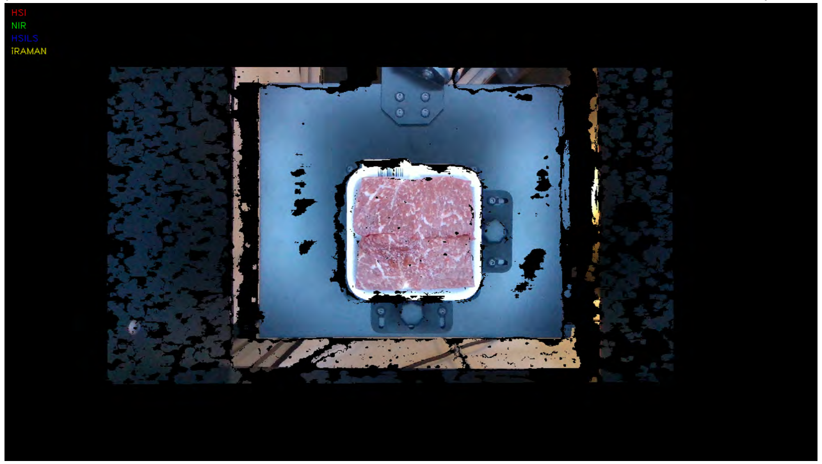
Our robotic platform includes a range of point and wide area optical sensors and a robotic arm used to move the sample between the sensors. Figure 1 shows a block diagram of the robot and sensor platform, and Figure 2 shows schematic of the final setup. The entire platform is encased in blackout curtains to reduce interference from eternal light sources. We used the platform to collect a series of measurements on 364, 100mm X 100mm cross section cuts of beef shortloin. The samples ranged in IMF from 0.6-19.36%, pH from 5.2-6.95 and adjacent steaks were used to measure the tenderness at 7, 14 and 21 days ageing analysed according to MIRINZ tenderometer protocol. Samples are first placed by hand onto a polystyrene tray, then onto the robotic arm. The robotic arm moves the samples to a three dimension mapping camera (C. K. Wong, 2011). The surface contours of the sample are measured, and the GUI allows the user to select the co-ordinates of the sample to be measured by each sensor. These co-ordinates are passed to the robot arm and adapted to each of the individual sensors co-ordinate system. Autonomous scanning of the sample is then initiated. The robot arm moves the sample to each sensor and indicates to start data collection via an Arduino micro-controller. Simultaneously, pneumatic shutters and LED lights are activated to control the lighting for each sensor if required. Our proof of concept system includes 3 HSI cameras, an NIR spectrophotometer (Labspec4, ASD Inc.) and Raman spectroscopy point sensor. A Xenics XEVA 1.7-320 hyperspectral camera, denoted HSI Linscan in Figure 1, and the Raman point sensor require translation of the sample during scanning. The required distance between sensor and sample ranged from 5mm for the Raman sensor and 370mm for the HSI linescan sensor.

Results

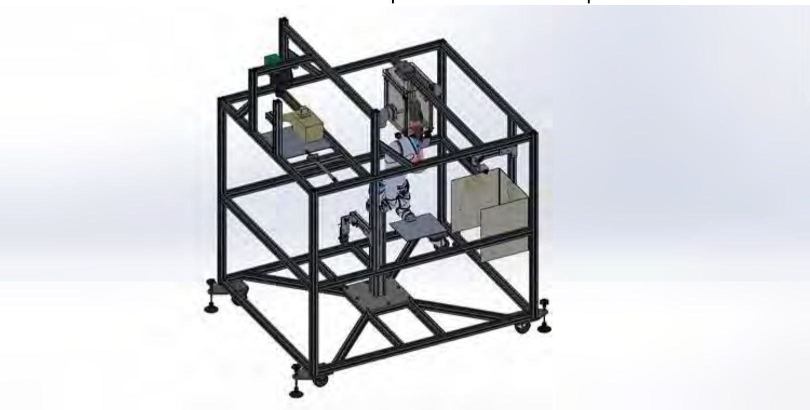
While scanning with the HSI linescan sensor the robot arm translated the sample at a rate of 11 mm/s in order to cover a sample length in less than 10 seconds. Similarly, the sample was translated in a spiral pattern at a linear velocity of 110mm/s for the Raman point sensor to collect data over most of the sample surface in this time frame. Samples were moved between sensors at a rate of 250mm/s, and the total time for loading of the sample and data collection with the 5 optical sensors was estimated to be ~90 seconds. As this an improvement over previous protocols where a person is required to position the sample for each sensor. The accuracy of the sample surface mapping and robot arm positioning was validated to be +-1mm. Figure 3 shows an example of the 3D mapping of a cross section beef shortloin cut. Black areas indicate where the distance from the camera could not be determined. Because of the consistency of measurements across the sensors, combinations of the available spectroscopic data have been used to build models to predict meat quality parameters using multiblock partial least squares regression (MB-PLSR). Two thirds of the samples are used to generate the predictive models (calibration data set) and the remainder are used to check the performance of the model (validation data set). Intramuscular fat percentage (IMF%) and pH predictive models were produced, with r^2 validation of 0.87 for IMF% and 0.91 for pH, with a mean square error of 1.416, and 0.021 respectively.

Conclusion

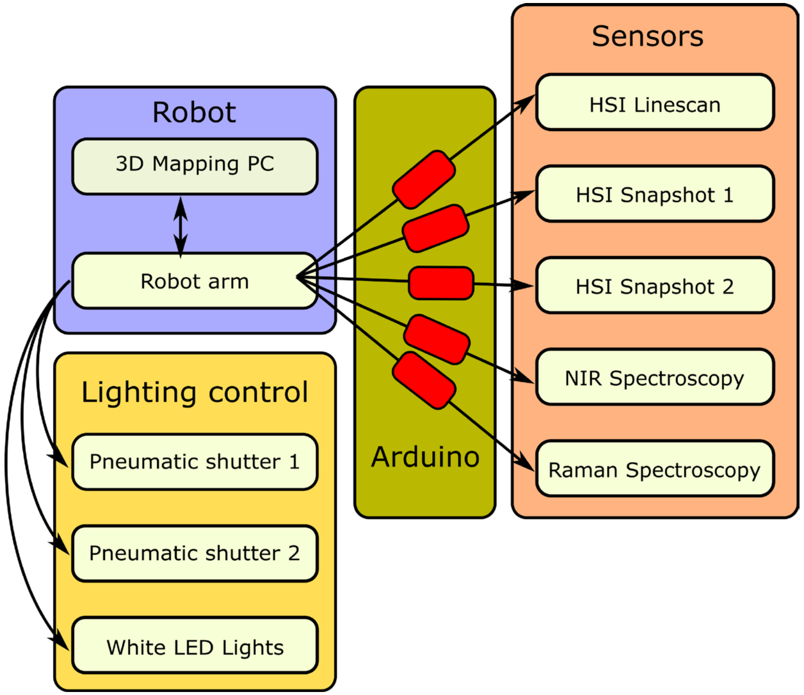
We present a robot and sensor platform to collect consistent measurements across samples with a variety of optical sensors. This proof of concept system was applied to measurements of many beef shortloin samples. Because of the consistency between sensor data, robust models were created using multi-block PLSR for both IMF% and pH with r^2 for the validation data set of 0.87 for IMF% and 0.91 for pH.



Example of 3D mapping of a beef short loin cross section.
Figure 3. Example of 3D mapping of a beef short loin cross section. Black areas indicate where the distance from the camera is not measured. The GUI allows the user to select points on the sample to be scanned.



Schematic of the robot and sensor platform.
Figure 2. Schematic of the robot and sensor platform. The robot is placed in the centre of an aluminium frame, to which the sensors are attached. The frame is covered in black out curtains before scanning begins.



Robot and sensor block diagram
Figure 1: Robot and sensor block diagram. The robot arm communicates with each sensor unit via an arduino micro-controller. Lighting of the sensors is also controlled by opening/closing shutters and activating LED lights. A 3D mapping camera measures the contours of the sample and computes the co-ordinates to be measured. These co-ordinates are passed to the robotic arm and autonomous sensing begins.

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