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An integrated sensor platform for food reassurance

Malcolm J W Povey, **Ian Blakemore**, **Raied Al-Lashi**, **Christian Tiede**, **Xiaobo Zou**, **Xiaowei Huang**, **Jiyong Shi** and **Peter Yuen** describe a collaboration between Jiangsu and Leeds Universities, which aims to bring together leading edge technologies in supply chain management and monitoring from farm to fork to develop an economical, robust and versatile integrated sensor platform for food reassurance.

Introduction

Given the increasing pressures on the global food system to produce more from the planet's diminishing resources, the need to produce food that is safe to consume and reflects the information declared on pack is becoming ever more difficult to achieve as shown by the recent 'horsemeat' scandal. The salutary lesson that emerged from this latest food scandal was the vulnerability of the highly complex food supply networks that we rely on. For example, the wafers in the popular KitKat are 'glued' together with plaster-of-Paris which is sourced from India.

These convoluted food networks increase the potential for product contamination through either physical, chemical or microbial means, with potentially life threatening consequences. Recent issues include the 2005 Sudan Red dye scandal, in which food products were contaminated with the potentially carcinogenic dye, and the 2013 worldwide recall of dairy products manufactured by Fonterra, because whey products suspected of being contaminated with botulism-causing bacteria were found during safety tests. It is important to remain vigilant in identifying and solving emerging challenges in global food networks to ensure a high level of consumer trust in the supply chain and food sold for consumption.

The challenge

A raft of technologies have been developed, which have the potential to ensure that existing and future supply chain management systems are working properly to exclude unwanted and harmful material by '100% detection' of foreign bodies in food (e.g. plastic, metal, bone, stone, nut and nut shell, micro-organisms, virus and prions). This provides reassurance that systems and control measures in place are fit for purpose and working. The challenge is to engineer these leading edge technologies to work together, from the farm scale to the production line and packing station, in an economical, robust and versatile commercial platform.

Sensor integration

Existing acoustical, optical and microwave technologies have the potential to be integrated into a single platform, which can be affordably mass produced, to introduce resilience, versatility and practicality in the sensing of unwanted and harmful material

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in food. Sensor readings can be combined through data fusion and data analytics; in the future they may be integrated with existing food safety and assurance schemes (such as the UK Red Tractor and Food Standards Agency) to enhance existing regulatory and supply chain management and provide process 'reassurance'.

A joint China-UK workshop entitled '100% Inspection – Reality or Fantasy' was held in Leeds in November 2015 and attended by a Jiangsu delegation of five, together with manufacturers, supermarkets, technology providers and food industry organisations. The technologies planned for fusion in the integrated sensor concept were successfully demonstrated at the workshop, including detection of plastic in ready meals, passive detection of small mammal activity and a demonstration of Unmanned Aerial Vehicle (UAV) technology. The workshop attendees recommended rapid at line microbiological analysis and the detection of plastic in food as two priorities for development.

There are many factors that influence the quality of farm produce, such as agro-processing, time, handling procedure and environmental conditions. At each production step, the quality of product needs to be monitored and controlled. Remote and non-invasive sensors can monitor these steps and aid in the 'traceability' of food throughout the global supply chain. Sensors may be deployed on ▶

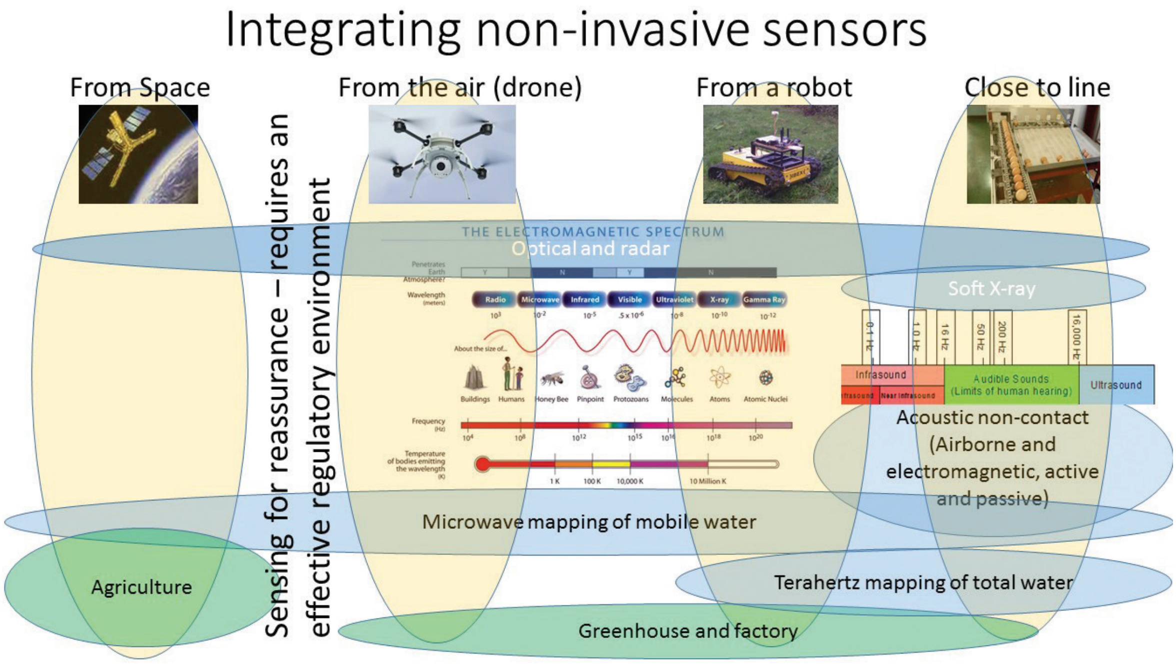

Figure 1 Remote and non-invasive sensing from the planetary scale to near process line

satellites, UAVs and drones, robots or towers close to the production line as shown in Figure 1.

From space, satellite remote sensing, such as hyperspectral imaging and microwave imaging, can provide key information in near-real time over large areas, such as monitoring climate change impacts on agriculture, monitoring global crop and natural vegetation conditions and guiding the pesticide and irrigation on crops [1,2] .

From the air, drone aircrafts equipped with spectrometers, airborne sound and microwave sensors etc. can be used in precision farming in land or greenhouse to adapt the application of input factors (e.g. nitrogen or pesticides) to current demand and inform management strategies based on the given growing conditions (for example seeding based on soil moisture) [3,4].

Non-invasive sensors are effectively the 'eyes' for robots operating in a greenhouse, factory or at line and together with data integration techniques they permit 'new ways of seeing', including guiding the actions of robots and sensor deployment. A range of technologies offer real potential in the development of integrated sensor platforms.

Passive and active acoustics

Air borne ultrasound techniques were developed at Leeds University for non-invasive detection of plastic in packaged food, initially in conjunction with Nestle [5], and are now a near to market application using off the shelf technology. The method is very versatile and can operate both passively (e.g. small mammal detection) and actively (e.g. plastic in food). It is also currently in use for the inspection of eggs.

> **This [optical sensor] technology has the potential to detect prions and allergens at very low levels.**

Optical sensors

Optical sensor technology, such as hyperspectral imaging (Figure 2) and multiple imaging technologies, including sensor fusion technology from Jiangsu and Cranfield, are generic and depend on the development of sensors which react to the presence of specific proteins. These sensors react to specific and narrowly defined wavelengths of light, indicating the presence of the target protein [6]. This technology has the potential to detect prions and allergens at very low levels.

An example is Adhiron Quantum

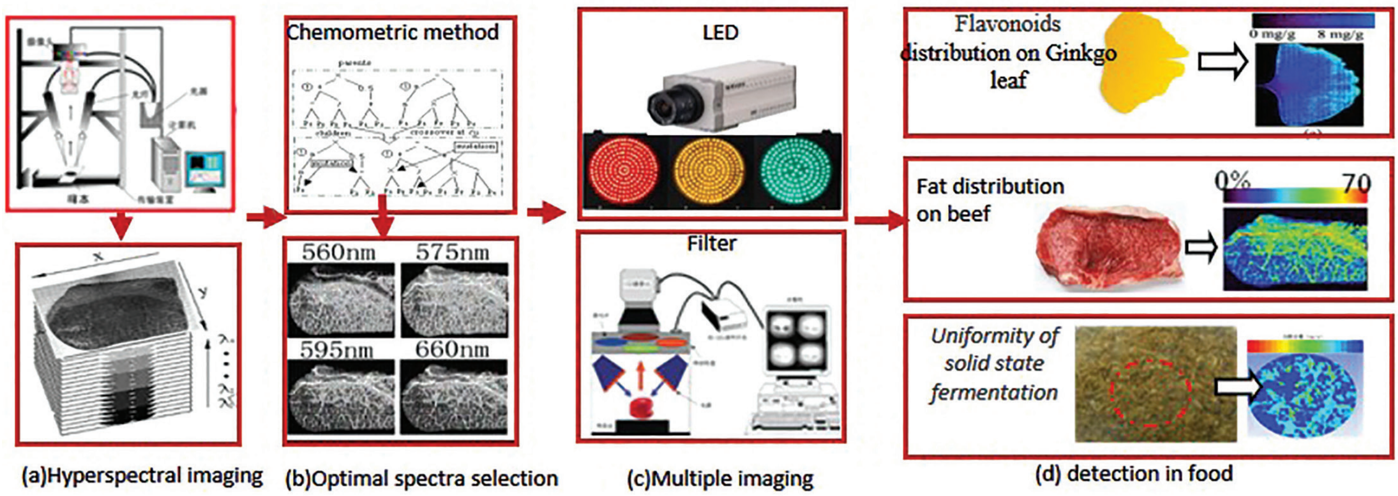

Figure 2 Hyperspectral imaging and Multiple imaging

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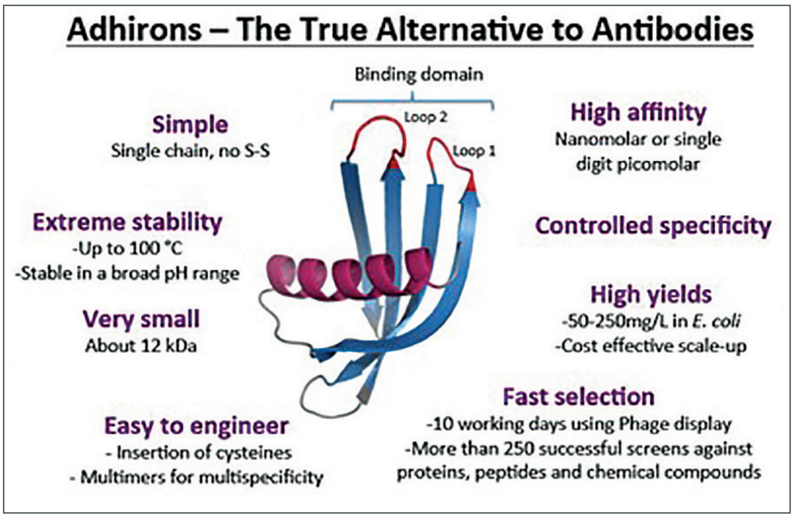


Figure 3 Adhirons (Tiede, Tang, Deacon, Mandal, & Nettleship, 2014)

> We expect to derive novel sensor, data fusion and data analytic methods leading to 'new ways of seeing'.'

dot technology (See Figure 3), where an Adhiron molecule is genetically engineered to attach to a specific protein and on binding reacts with its Quantum Dot, causing it to fluoresce at a specific wavelength.

Food safe sensor dye technology developed in Jiangsu (Figure 4) permits the introduction into food of edible sensors which change their colour in the presence of the target molecule [7].

Smart packaging

Smart packaging using Radio Frequency Identification Devices (RFID) and Food Safe Sensor Dye technology developed at Jiangsu initially in conjunction with Yuyun Group is already in use for inline sensing of food freshness. These technologies have also been adapted for use in animal husbandry.

Microwave sensing

Radar systems capable of mapping water mobility in fields, greenhouses and food lines, for example in processing of vegetables, such as potatoes, can be deployed either statically on a tower or on a UAV.

Robotics

Acoustic, microwave, electronic nose and optical sensors can be integrated on robots optimised for specific tasks, such as enhancing energy efficiency, manufacturability, mobility, robustness and reducing cost. The sensor platform will initially be deployed on robots, satellites and unmanned aerial vehicles (UAV) on University Farms and Greenhouses in the UK and China.

Satellite data for traceability

GPS, 2D barcode, RFID, PDA, Anti-counterfeit code and mobile phone based record-keeping systems can provide data for traceability and management of food information.

Data analytics and data fusion

The relational description of video images is highly relevant to the task of intelligent guidance of the robotic and UAV deployment of sensors; the data analytics and data fusion challenges posed by the potentially vast amount of data will lead to 'new ways of seeing'[7].

Authentication

Authentication technologies are widely deployed in other industries and have the potential to be adapted to use within the food industry.

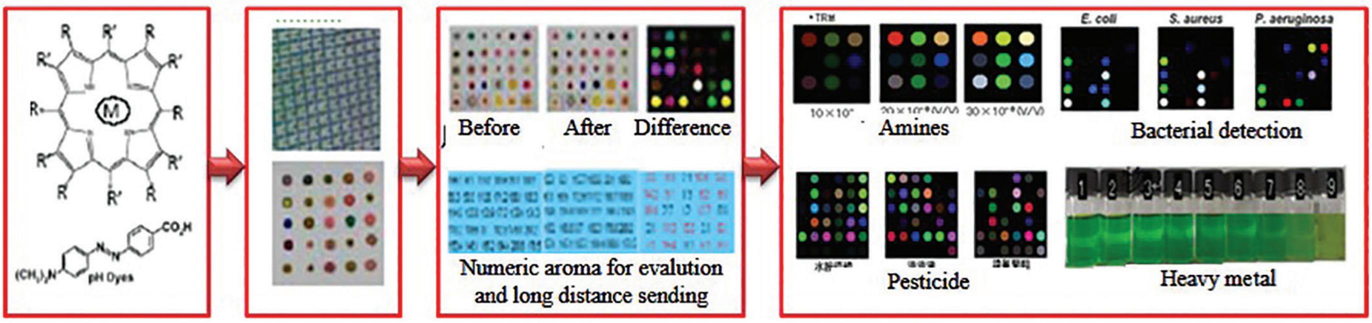
Supply chain analytics

The project is aiming to integrate supply chain analytics with satellite and process line (i.e. RFID) data and to apply data fusion and chain analytics across the supply networks for food reassurance and transparency. This work will address the development of appropriate regulatory, legal and economic frameworks for effective supply chain management.

Benefits of integrated sensing

A well-engineered, integrated sensor platform combining knowledge about UK food regulation with new supply chain methodology, resulting from sensor fusion, satellite and robotic technology and data analytics, will help ensure food quality and reassurance and lead to 'new ways of seeing'. Such a platform could be integrated into even more ambitious schemes to reduce waste and increase food security.

Figure 4 Chemoresponsive dyes sensing



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