Future protection from contamination

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Over the past year, QinetiQ scientists in the sensors and electronics division have been considering ways of using novel detection and processing techniques to tackle the problem of foreign objects in foods.

This has included a brief review of the techniques currently in use within the food processing industry, as well as other detection techniques which have not previously used in this area.

Consideration has been given to both the scientific aspect and to the business benefit to the industry which a new detection system may bring. Working along with a number of clients in the food production industry, including Marks & Spencer and their suppliers, the key stakeholders in the supply chain have been identified and a strategy for delivering a novel solution into this market is being developed.

The business need

Pre-prepared foods, such as sandwiches, ready meals and sliced cold meats are highly susceptible to the accidental inclusion of unwanted objects at some stage in their preparation (malicious insertion of foreign objects was not considered).

In this context a foreign object can be classed as anything that the customer would not want to find in the product and may therefore complain about, and so could range from plastic or metal to bones, eggshells or even unmixed ingredients.

A 2002 investigation by 'Which?' found one laboratory which says it sees approximately 2,000 objects found in food and medicines every year – and that the trend is upwards.

Notable examples in food include a chocolate-covered mouse, a metal chain section in a pasty and half a wasp in a mint.

Any complaint to a vendor or manufacturer has an associated cost, which will include not only the administration of recording the complaint but possibly an investigation into the source of the foreign object and some form of compensation for the customer such as free vouchers.

However, the true cost of a foreign object in a product could be much higher than this.

A single lost customer could cost the company thousands of pounds lost in sales, and as it is in the nature of people to disseminate bad experiences more readily than good, it may not just be a single customer lost but a number of their friends too. In the extreme, if a foreign body instance was serious enough to reach the press, the damage to the brand could be immense.

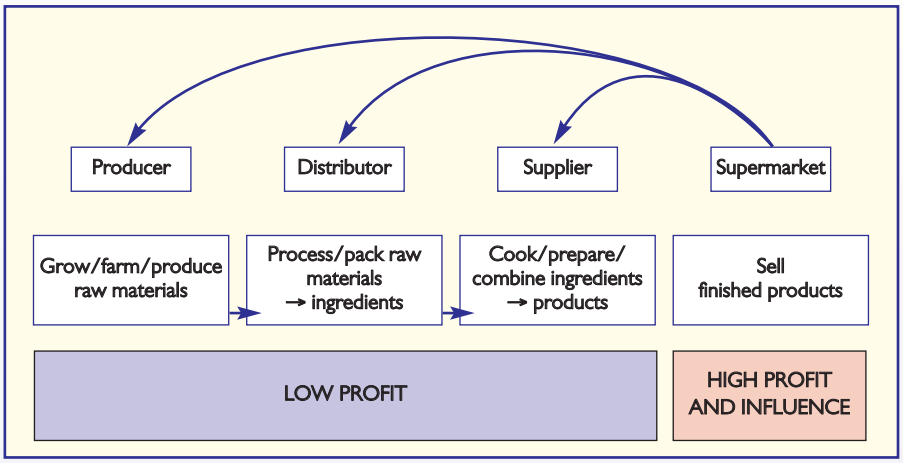

Fig. 1. The supply chain.

And this is where we find the nub of the business case for looking into this problem – brand protection.

In fact, the actual percentage of products which include a foreign object from most manufacturers is very small, and the administrative costs of dealing with these are bearable. However, the damage to the reputation of a manufacturer or retailer that even a small number of occurrences can do means that this is a problem the industry takes very seriously.

Given the amount of money that the top companies put into positive advertising and branding, and the fact that all this could be undone by a single news story headed 'Glass in baby food' means that manufacturers and retailers are willing to invest significantly in any potential new technique for lowering foreign object incidences.

The diagram of the supply chain for a supermarket's own brand pre-prepared foods (Fig. 1) shows that retailers are at risk from foreign object complaints, even if the goods are produced and packaged by others, which is why they will generally keep a very close control over the entire supply chain, having dedicated distributors and suppliers. This means that even though the users of any new detection equipment will be lower down the supply chain, the most interested party and the essential problem holder is the final retailer.

Therefore, there is a real problem which is damage to a well known brand caused by even a small number of foreign object complaints, and the beneficiary from a solution, (in this example) is the high street retailer.

Impact of new technology

A cost benefit model has been developed by QinetiQ to show the impact of a technology which would detect more objects. If the cost of the foreign object problem can be crudely measured in terms of the costs of dealing with customer complaints, the cost of lost business because of this complaint and the cost of wasted food which is rejected when there is no foreign object, then a 'cost per product unit' of the foreign object problem can be estimated.

Key considerations included in the model include the probabilities of:

- A foreign object being present in the first place.
- The foreign object being detected if it is present.
- The customer making a complaint if they find a foreign object.

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● The pack being rejected if no foreign object is present.

The model then predicts that an increase in detection probability from 8 out of 10 to 9 out of 10 will result in a 12% reduction in costs due to waste and handling complaints. If this is coupled with a reduction in false alarms from one in 100 to one in 200, the savings could exceed 30%.

Of course, this simple model does not take into account the 'catastrophic' complaint, such as the glass in baby food example, which can irreparably damage a brand.

Technical issues

The definition of a foreign object can be rather imprecise – 'anything that a customer does not want to find there'. The retailers generally prioritise foreign objects based on the numbers of complaints received, which does not necessarily correlate to the number of occurrences – it is recognised by the industry that not all foreign objects found result in a complaint.

As a starting point, a 'target list' has been drawn up based on both customer complaints and objects detected in the factory. This list includes glass, metal, bone, stones, plastic, polythene, wood, fruit stones, insects, hair, string and cardboard.

In addition, the background against which these must be detected also needs to be considered. In general, the more preparation that goes into a product, the more chance there is that a foreign object could get into it, so pre-prepared sandwiches and complex ready meals have a higher occurrence than bread or whole chicken.

To further define the problem, it was decided that only foreign objects that were not visible by eye would be considered, as the production lines include numerous manual stages at which a human worker could identify and reject such a product. Further, the detection had to be conducted on the end of a production line, with the food fully packaged; hence ensuring the product is 'clean' at a point at which no further objects could become introduced.

This is a challenging detection problem: the products will often be packaged in cardboard and plastic, which are also two of the possible foreign objects; the plastic foreign objects will often be very small, thin pieces; ready meals will give a complex background for any imaging technique; and all detections must be fully automated, and performed in real time on a production line operating at up to 60 products per minute.

Therefore, whilst industry will always strive to detect all foreign objects, any progress against the most difficult combinations such as plastic objects in a plastic container would be a significant step in the right direction.

The most widely used sensing technology in the food industry is metal detection. End of line metal detectors are now standard on virtually all lines, and have a number of advantageous characteristics: they can be used on any type of product, from complex ready meals to simple, single ingredient products; accepting the usual trade-offs between probability of detection and probability of false alarm, the kit can be sensitive enough to detect very small metal objects; operation is relatively simple; 'ferrous in foil' systems give some detection capability even if the packaging includes aluminium foil. Off the shelf end of line metal detectors can now be bought for less than £20k.

The key shortcoming of metal detection systems is that by definition they only have capability against a single type of object, and so even a 100% detection rate will not stop all foreign bodies.

To overcome this, x-ray machines are becoming more common in the industry. The standard mode of operation is a simple measurement of transmission through a product, although x-ray scattering has been considered. As the x-ray systems provide an image as the output, the associated processing is slightly more complex than that of the metal detector.

In order to keep the image processing task as simple as possible, x-ray systems have so far been used primarily on simple, homogeneous products such as flat packed meats rather than sandwiches and ready meals

which would give a much more complex background against which to perform the detection.

However, x-ray systems can reliably detect metal, bone, grit, glass and some plastics (if thick enough) against this simple background, and so on such lines are beginning to replace metal detectors.

Alternative solutions

In looking for new technical solutions, the net was cast as far and wide as possible, the problem was approached from a different angle to those currently used within the food industry. Thus, a great deal of time was saved by not looking into current research in the food industry.

Instead, a general review of any non-line-of-sight foreign body sensing technology was undertaken.

The techniques which not only had a capability against certain foreign objects, but which would also meet the cost and operational constraints of the industry would be identified to be taken further.

The initial search drew on techniques currently used in medical imaging, border security, explosive/narcotic detection and numerous other applications.

The results of this search are summarised in Table 1.

Conclusion

It is clear that when costs and operational constraints were taken into account options exist on how best to move forward with technology in the short, medium and long term. In the short term enhancing the image processing of x-rays would appear to be a cost effective and less complex approach.

QinetiQ have expertise in the development of algorithms that could improve the use of existing infrastructure, this is likely to improve the detection rates and protect the investments already made.

Additionally it would be worth investigating the appropriateness of active microwave and RF techniques. In the longer term the examination on the effectiveness of NQR as a way of targeting specific foreign objects could be a viable opportunity for customers who require very detailed and accurate targeting of specific compounds.

As a final point, it should be noted that a key driver for investment in new detection systems may eventually come not from these commercial pressures but from threat of litigation. In the US it is not uncommon for companies to spend many times more on detection system than UK counterparts.

This is driven by a need to defend the company against the strong culture of litigation, in which any failure to take all possible precautions against foreign objects could result in a law suit.

In this, as in many other instances, where the US goes the UK is likely to follow. ■

PASSIVE MILLIMETRE IMAGING

A technique which QinetiQ has been at the forefront of developing, this was originally used as an aid to helicopter pilots for poor weather landing as MMW systems can see through fog and cloud.

- **Pros:** Fabrics, paper, cardboard and thin plastics are also transparent, whilst metals, ceramics and dense plastics are not.
- **Cons:** For the food industry application, however, moisture content of the products could be an issue. Also, currently high cost.

ACTIVE RADIO FREQUENCY TECHNIQUES

At frequencies close to those used by microwave ovens (around 2 GHz), food packaging is virtually transparent and if very low powers are used, the radiation will penetrate the food without any heating effect. Any item with different dielectric properties to the food could potentially be detected.

- **Pros:** Has the potential to detect any object with sufficiently different dielectric properties to the food and packaging. Components are not expensive.
- **Cons:** May not have the resolution to detect very small objects.

MAGNETIC RESONANCE IMAGING

MRI is in common use in the medical imaging arena, and has the capability to give detailed 3D images.

- **Pros:** Could detect a number of different types of foreign object in 'difficult' products (complex ready meals etc).
- **Cons:** Current systems are expensive compared to industry norms for x-ray systems. Would require either a trained operator or very advanced image processing software.

NUCLEAR QUADRUPOLE RESONANCE (NQR)

A technique closely related to MRI, nuclear quadrupole resonance is often used for detection of hidden explosives and narcotics.

- **Pros:** Can be 'tuned' to detect quantities of specific chemical compounds, so possibility to look for specific plastics even through plastic packaging.
- **Cons:** Not yet used for this application, would require significant investigation into its capabilities, followed by a development programme.

ACOUSTIC IMAGING

Ultrasound imaging is again a commonplace medical technique. QinetiQ has developed a new imaging system (Deepscan) which allows extended ultrasound penetration through the use of a novel array focusing technique.

- **Pros:** Demonstrated non-line of sight imaging in medical and other applications, and some work has been done on objects in food. Component parts not expensive.
- **Cons**: The acoustic coupling into the product would cause a problem. Gels are used in the medical arena, though this would not be practical in the food industry.

TERAHERTZ IMAGING

Closely related to millimetre wave imaging, this technique utilises radiation between the infra red and microwave frequencies.

- **Pros:** Penetration of cardboard, plastic, wood and numerous other materials has been demonstrated.
- **Cons:** The use of this kind of radiation in an imaging device is in its early stages of development, and hardware remains relatively expensive.

NEUTRON/ GAMMA RAY PROBES

These techniques use high energy particles or EM radiation to give effective penetration, and are most commonly used in the detection of explosives and other contraban.

- **Pros:** Proven penetration and detection capability.
- **Cons:** It is unlikely that such high energy, ionising radiation techniques would be adopted by the food manufacturing industry.

K-40 DETECTION

Potassium 40 is a radioactive isotope which is present in plants and vegetation. It is used in detection of narcotics at borders, and is completely passive as the radiation is naturally occurring.

- **Pros:** Passive.
- **Cons:** Unlikely that the targets of interest in the food industry will be of this type.

NOVEL IMAGE PROCESSING

Although not strictly a new sensing technique, QinetiQ's know how and expertise in image and signal processing would be very likely to be able to improve on the automatic detection algorithms currently used in x-ray and metal detectors.

- **Pros:** QinetiQ has conducted many years of research into automatic detection of military targets in radar, sonar and IR imagery, and the base algorithms that underpin these capabilities could well be applicable to x-ray images of food. Could be implemented on existing hardware.
- **Cons:** Can only enhance the current systems – that is, the hardware must already be able to 'see' the object, improved algorithms will automate the detection robustly.

Table 1. The pros and cons of alternative detection technology.