Robotica (1990) volume 8, pp 267–268

Introduction to the special issue on robots and food-handling

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(Received in Final Form: May 29, 1990)

Ever since the first Unimate was installed in a General Motors factory in 1961, the overwhelming majority of the world's robots have been used in manfacturing. A feature of all the common applications – welding (spot and arc), machine loading/unloading, palletising, spray coating – is that the objects manipulated are rigid materials: metals, plastic, filled cartons.

Since 1961, technology has advanced considerably. Robots now can manipulate soft, fragile, easily deformable products without damaging or blemishing them. This special issue of *Robotica* demonstrates that technology is at the stage where it is feasible for robots to manipulate food.

The food industry – which inclues food production (primary industry), food processing (secondary industry) and food service (tertiary industry) – spans all three sectors of the traditional economic partition. Robot food-handling applications are feasible in all three.

Indeed, the traditional division of this industry into three sectors is unhelpful from a robotics perspective. Inspection and manipulation methods used for robotic picking of apples (primary industry) may be applicable to robotic handling of apples when they are made into tarts (secondary industry), or to robotic selection and placing of apples onto airline meal trays (tertiary industry).

For historical reasons, the initial applications of robots in the food industry derived from manufacturing technology then available. Accordingly, robots at first were utilised to manipulate food containers rather than food itself. Thus, for many years, robots have palletised cartons of soft drinks. In a comparatively recent application, a robot picks up loaves of bread just after they are wrapped and places them in trays. In each of these cases the robot handles a carton or a wrapper rather than food itself.

Contrastively, this special issue factors upon robot applications to *food-handling,* i.e., on situations where the objects manipulated are food itself rather than food containers. Because the technology is novel, the applications still are mainly at the research and development stage (Robotic chocolate packing is a commercially successful exception). However, this research and development increasingly is being carried out by, or in collaboration with industrial firms. Substantial industrial utilisation can be anticipated within five years.

Many opportunities for robotic food-handling arise from operations that presently are performed labour-intensively and demand little or no human creativity. Examples include picking, inspecting, sorting and grading, peeling and cutting, portioning and packing of a wide variety of food items.

The incentive for automation arises not only from advances in robot capabilities but also, and especially, from the increasing scarcity and cost of people willing to do repetitive uncreative tasks hour after hour, day after day. Besides the usual advantages of automation, such as increased productivity resulting from multiple-shift operation, a further incentive of particular relevance to the food industry is that the use of appropriate machinery may lessen the risk of contamination which arises when food is handled by people.

The first article, by Professor Harrell and his colleagues in the University of Florida, documents an ambitious endeavour to develop a robot system capable of picking oranges. This research established that oranges can be reliably discriminated from foliage on the basis of colour (although different techniques will be required to distinguish green limes from green leaves) and demonstrated the technical feasibility of tracking oranges as they move in a breeze. Although oranges are picked and packed labour-intensively in Florida, the U.S. citrus industry has provided little support for research to automate these processes. The reason, apparently, is the ready availability of low-cost (often not legally sanctioned) labour there to do this work. As a consequence, further development of the research described in this article has been suspended. However, robot fruit-picking systems are under development in Japan and Europe (notably by CEMAGREF in France), where reliable cheap labour for fruit picking no longer can be found. The French apple-picking robot MAGALI has undergone field trials in an orchard, and commerical systems are expected in a few years.

After fruit is picked, it generally is inspected and sorted into grades according to quality and size. While lower-quality fruits (e.g., those with visible skin defects) often are sent to processors for manufacture into juice or other products, higher-quality fruits usually are sold as fresh fruit. These fruits must be packed to ensure that they are not damaged during transport. In some cases (e.g., Australian pears) every fruit is individually wrapped; in other cases each fruit is placed in its own compartment. Although machinery is commerically available for bulk packing of some comparatively hard fruits, soft fruits which can be easily damaged or blemished are packed today only by hand. Dr Tedford's paper describes efforts in New Zealand to develop a robot gripper mechanism that is capable of manipulating soft fruits without marring or marking them.

Mr Khodabandehloo discusses how a robotic cell – comprising a vision system, a special-purpose gripper mechanism attached to a robot arm, and appropriate software – can be designed to automate aspects of poultry processing. One particularly promising application is the robotic placement of chicken portions into packs which sell for a fixed price. These packs include a fixed number of portions that together have a stated minimum net weight. In addition to the customary advantages accruing from labour saving, Mr Khodabandehloo notes that automating this application can substanitally reduce product giveaway by selecting particular portions to minimise excess weight.

Although a prawn's silhouette is an imperfect correlate of its mass, my article indicates that a machine-vision system utilising silhouette data alone can estimate mass better than people who sort prawns by hand all day long. Packing prawns after they have been sorted is presently also a labour-intensive operation. With current technology it seems infeasible to reproduce automatically what people now do by hand. However, if the industry is willing to change packing patterns, and in particular to abandon multi-layer fixed-weight packs, there are significant opportunities for automation.

The transformation of carcasses into meat involves numerous processes. Several of these products – cutting, boning and packaging (again often into fixed-weight cartons) – are done extremely labour-intensively in boning rooms attached to abattoirs and in other butcheries. Mr Purnell and his colleagues in the University of Bristol describe research to enable a robot wielding a knife to bone beef forequarters. An attraction of this task from a robotics perspective is that successful performance does not require preservation of the aesthetic qualities of conventional meat cuts. Before it is sold to consumers, this meat will be processed further into sausages or pies.

A number of European researchers have been striving to develop technology that will enable cows to be robotically milked. In addition to saving labour, one advantage projected of robotic milking is that the cows themselves can decide when to be milked rather than having to comply, as at present, with a milking régime imposed upon them by the management of the dairy. It is suggested that devolving the decision when to be milked to each individual cow should in general make the cows happier and therefore will yield more milk.

Owing to commerical considerations, comparatively little has been published on the technology for robotic milking now being developed by competing groups in the U.K., France, Netherlands and Germany. Andy Frost of AFRC Engineering in the U.K. reviews the available literature regarding this task which lies at the interface between robotic animal handling and robotic food handling.

I acknowledge gratefully the assistance of Peter Clarke, Peter Corke, John Marchant and James Trevelyan in reading and commenting upon the articles, and the encouragement of Professor J. Rose which enabled a special issue of *Robotica* to be devoted to this important application area.