

Robotic automation for pork primal cutting

A newly developed carcass-cutting system has demonstrated speed, consistency, accuracy and control improvements over manual labour, thus proving the technical feasibility of robotic pork butchery.

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Industrial butchery tasks are typically repetitive, arduous and involve heavy and sharp cutting tools. The production environment is hazardous and unpleasant. Unsurprisingly, the meat industry has continuing problems with finding and retaining staff for butchery work.

For over ten years, the University of Bristol has been heavily involved in R&D of automated systems to fulfil this need. The project presented here represents a culmination of studies into the development of a commercially viable robotic carcass cutting system.

Background

Two previous EU-funded R&D projects have laid the foundations for commercially viable robotic carcass cutting. Brite Euram BE4420 (1991–1996) produced a robotic system illustrating the principle of robotic butchery for pork carcasses. A second project, Craft CR1582 (1994–1997), addressed carcass fixturing issues found to be of prime importance in BE4420.

In this work, machine vision techniques were used to determine cut paths for a fixtured pork carcass. A purpose-built cartesian food-grade robot then wielded a pneumatic cutting tool to make the cuts required (see Figure 1).

While successful cutting was achieved with the system, several factors limited its exploitation potential:

- ❖ The gantry-based cartesian robot was large and did not withstand the rigours of the food production environment.
- ❖ Spare parts and engineering support were not readily available.
- ❖ The pneumatic cutting tool was prone to stalling at high cutting duty, thus limiting the cutting rates possible.
- ❖ The cut path generator used model-based machine vision, where the current carcass was compared to a 'standard carcass' and the differences used to generate the cutting paths.
- ❖ The cutting technique was computationally intensive and relatively slow.
- ❖ The 'standard carcass' model would require tuning for the pig supply to each plant where the system was installed.

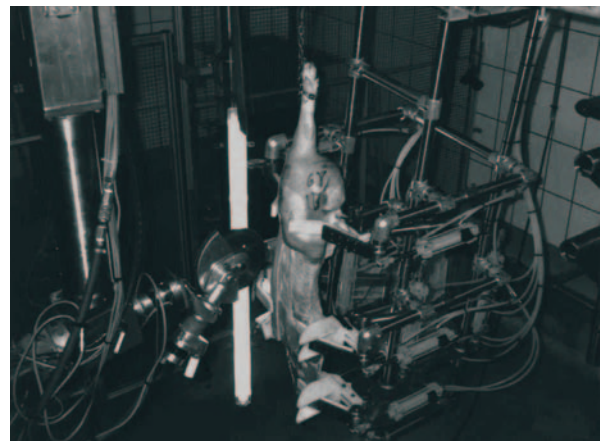


Figure 1. BE4420/CR1582 robotic cutting system.

- ❖ The system was functionally satisfactory for R&D equipment, but system cleanability and hygiene were poor for commercial use.

A third EU-funded project, Automated Robotic Technology for Efficient Pork Production (ARTEPP) FAIR CT98-3545, was initiated to build on this work.

ARTEPP system overview

The key objective of the ARTEPP project was to provide a supportable, hygienic system that could integrate with the process lines and cutting strategies found worldwide. Off-the-shelf equipment was used where possible to minimise development time and costs, and to produce a system with readily available spare parts and engineering support. The cooperation of potential sub-system suppliers was important in achieving this. It was intended that the system architecture remain unchanged from previous work.

A modular approach was adopted to accommodate the huge range of butchery schemes. Common sub-systems would form the core of each ARTEPP system, with additional sub-systems developed to account for variations at each site. Over time, a



Figure 2. A demonstration project showed that robot cutting is superior to manual cutting in terms of cut accuracy.

stock of standard sub-system modules would be developed, reducing the costs and complexity of subsequent installations.

Robot and cutting tool

A 6-axis KUKA KR125 anthropomorphic robot was enclosed in a food-grade cover for cleanability. Dry air is ducted into and away from the cover to maintain positive pressure, keep the cover away from robot joints and trapping points, and prevent ingress of any food materials.

The initial cover design completely enclosed the robot with gussets and extra material to allow for robot movement. This was difficult to clean due to wrinkles of the extra material. An improved design had the robot inside a rigid food-grade enclosure with the robot arm protruding through one side. Here the 'cover' is fitted to form a flexible wall from the robot wrist to the enclosure. A cleaning position was then defined where the robot was extended, thus tensioning the cover, removing wrinkles and allowing effective cleaning.

A powerful three-phase electric saw replaced the pneumatic saw used previously. The blade used was developed specifically for robot cutting of meat and bone. It produces low cutting forces, high-quality cut surfaces, and less bone dust than standard saw blades. This gives a lower yield loss and better hygiene.

Handling and fixturing

Separate approaches were adopted for the 'hot' and 'cold' butchery styles. Common factors in the handling and fixturing sub-systems are required for the remainder of the system to be standard:

- ❖ Carcass sides must be presented split side showing to the vision system on a contrasting (blue) background.
- ❖ The fixturing must resist the cutting forces for the cuts performed.
- ❖ The side must be in a known position before the start of each cut.

- ❖ The fixture must accommodate the full-size range of carcass sides.
- ❖ The position of all carcass sides within the ARTEPP system must be known.

System operation

In the butchery system, sides are orientated to travel sideways (with split plane parallel to the overhead rail). At an orientation station, the hook through the Achilles tendon is made to face the split plane. An inductive sensor detects the hook and the side is rotated if the split plane is not facing the vision system side of the rail. The side moves on to the cutting station where adaptive gripper fingers grasp the side and prevent lateral motion, and a fixture board moves in from behind to clamp the side against the fingers and partially support the carcass side at an angle of 10°. Shaped features on the fixture board aid lifting, side location and resist cutting forces.

Vision processing and cutting then take place, the clamps are released and the side ejected from the system. An indexing overhead conveyor drives the carcass motion through the robotic cell and inductive sensors detecting the gambrels track carcass position within the cell.

Cutting results

For analysis, 110 sides were cut manually or robotically. The cuts were compared with the optimal definition of the cut. For manual butchery, cut placement was within $\pm 20\text{mm}$ of the correct location and 89 per cent of the carcasses had a cut accuracy that was better than $\pm 5\text{mm}$. The ARTEPP system performed to better than $\pm 5\text{mm}$ for 97 per cent of cuts (see Figures 2 and 3).

The reduced spread of cutting positions improves control, thus reducing the risk of out-of-specification products. Furthermore, the desired cut position can be shifted to suit market conditions,

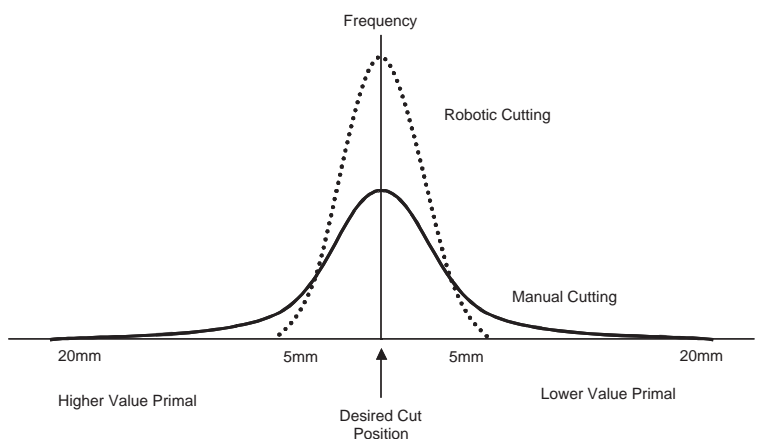


Figure 3. Robot vs human cutting performance.

individual customers and other commercial factors. The robot cut more evenly and cuts were placed anatomically accurately every time. The placement of the H-bone cut and angle of ham cut were substantially better than with manual cutting.

Commercial feasibility

The production system used in this demonstration project has proven capable of improving on manual pork carcass cutting. It can produce consistent, anatomically accurate cuts and eliminates other 'human' limitations such as availability for work, absenteeism, holidays and so on. The robotic system's most important commercial feature, however, is that it can be adjusted in response to seasonal and market price fluctuations. And shifting cuts to favour high-value primals can result in significant value improvements for each carcass. Even a modest shift towards the higher value primal is expected to yield potential annual benefits of over €290,000.

The price for the core system (excluding plant modifications and installation costs) will be €250,000. Add €100,000 for

installation and this gives a payback of 15 months from cutting improvements only. Other cost benefits connected with not having to find, train and retain human staff for the task will be a bonus. ❖

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The Food Refrigeration and Process Engineering Research Centre is a multidisciplinary process engineering R&D centre based at the University of Bristol. Its expertise covers a wide range of broadly related food processing areas: heating, cooling, modelling, refrigeration research, microwaves, food decontamination, separation processes and automation. Funding is derived from research grants and commercial consultancy, ranging from a few days of expert advice to major design and build projects such as those described above.