Summary of Roy's Contributions to Machine Vision

Roy has been particularly interested in shape analysis and the sensitive detection of objects in images. These interests fall under the broad headings **feature detection** and **intermediate level analysis**. His interest in noise elimination can be broadened to **image filtering**. Another important aspect has been how to achieve **real-time operation**, which is necessary in applications including **automated visual inspection**. His deep involvement in educational aspects has led to three books [19, 29, 42] and numerous chapters and encyclopaedia articles. The five main headings highlighted above are *inextricably linked* both to each other and to the theory aspects mentioned earlier.

The achievements under the five numeric headings are summarised below, with reference to the 50 most important papers: most of those mentioned are journal publications: conference publications are largely excluded in order to concentrate the discussion.

1. Image filtering

This programme of work established that:

- Median filters distort images, producing edge shifts which can be understood on a continuum model [12] and predicted accurately using discrete analysis [38].
- Trainable noise elimination filters can be produced with negligible edge shift or corner filling [21].
- Mode filters *enhance* images as well as eliminating noise – but have to be specially designed to cope with sparsely populated windows [28, 42].
- Mode filters can be extended to colour, and they show astonishing effectiveness at removing 70% impulse noise [41].
- The edge shifts produced by mode filters [41] and by the *whole* family of rank-order filters can be explained quantitatively – a result of key importance for mathematical morphology [33].

[40] integrates all these discoveries into a solid body of knowledge, covering *all* the types of filter mentioned above.

2. Feature detection

This programme of work established how to:

- achieve high accuracy with edge and other detectors [1, 2, 15, 25];
- determine the effects of occlusion [27] and noise [6];
- accurately identify valley positions in intensity distributions [22, 44, 47];
- discriminate motion and even pedestrian behaviour using low-level operations [49, 50];
- design ideal template masks using a training approach and (optimal) matched filtering [17];
- optimally position a template to detect features using a new 'equal area' rule [26];
- accurately interpolate between the responses of orientation masks [30];
- model the Plessey detector's effectiveness (e.g. its sensitivity to corner angle) [43].

Back to top

3. Intermediate level analysis

This programme of work established how to:

- overcome the effects of incomplete image data using improved inference techniques [42];
- aid understanding by modelling Hough transform peaks [14];
- make inference algorithms more general [7], more efficient [4, 36], faster [13, 16], or more accurate [8, 18];
- increase sensitivity by gradient weighting (the theory starts by considering (optimal) matched filtering) [5].

[42] covers all these discoveries and integrates them into a coherent body of knowledge.

Back to top

4. Real-time operation

This programme of work established how to:

- systematically speed up vision algorithms by employing 2-stage matching [10], special hardware [23], or selecting cost-efficient combinations of hardware modules using two new cost–speed functions [11];
- rapidly locate objects using a new sampling strategy representing the lowest computation bounds [24, 34];
- mimic the saccades of the eye by 'guided' sampling, using entropy to determine locations giving the highest gain in information [46, 48].

Back to top

5. Automated visual inspection

This programme of work developed the following:

- a variety of techniques for performing 100% inspection of products, including biscuit [3] and X-ray inspection of frozen food packs [42];
- inspection of wheat grains – including detection of insects, ergot, and rodent droppings [35, 37]; the insect detection algorithms employ bar and streak detectors and have wide generic capability;
- means for detecting insect larvae growing inside wheat grains from infra-red images [29].

Professor Davies's monograph *Image Processing for the Food Industry* [29], review [39] and invited papers [a-d] sum up much of his work in this area.

Back to top

50 Key Publications on Machine Vision

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Back to top

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Back to top

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Back to top

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Back to top