

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](#)
2. [Feature detection](#)
3. [Intermediate level analysis](#)
4. [Real-time operation](#)
5. [Automated visual inspection](#)

- [50 Key Publications on Machine Vision](#)
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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].

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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.

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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].

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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.

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50 Key Publications on Machine Vision

- [1] Davies, E.R. and Plummer, A.P.N. (1981) "Thinning algorithms: a critique and a new methodology", *Pattern Recogn.*, **14**, nos. 1–6, 53–63
- [2] Davies, E.R. (1984) "Circularity – a new principle underlying the design of accurate edge orientation operators", *Image Vision Comput.*, **2**, no. 3, 134–142
- [3] Davies, E.R. (1985) "Radial histograms as an aid in the inspection of circular objects", *IEE Proc. D*, **132**, no. 4, Special Issue on Robotics, 158–163
- [4] Davies, E.R. (1986) "Image space transforms for detecting straight edges in industrial images", *Pattern Recogn. Lett.*, **4**, no. 3, 185–192
- [5] Davies, E.R. (1987) "A new framework for analysing the properties of the generalised Hough transform", *Pattern Recogn. Lett.*, **6**, no. 1, 1–7
- [6] Davies, E.R. (1987) "The effect of noise on edge orientation computations", *Pattern Recogn. Lett.*, **6**, no. 5, 315–322
- [7] Davies, E.R. (1988) "A modified Hough scheme for general circle location", *Pattern Recogn. Lett.*, **7**, no. 1, 37–43
- [8] Davies, E.R. (1988) "A hybrid sequential-parallel approach to accurate circle centre location", *Pattern Recogn. Lett.*, **7**, no. 5, 279–290
- [9] Davies, E.R. (1988) "Training sets and a priori probabilities with the nearest neighbour method of pattern recognition", *Pattern Recogn. Lett.*, **8**, no. 1, 11–13
- [10] Davies, E.R. (1988) "Tradeoffs between speed and accuracy in two-stage template matching", *Signal Process.*, **15**, no. 4, 351–363
- [11] Davies, E.R. and Johnstone, A.I.C. (1989) "Methodology for optimising cost/speed tradeoffs in real-time inspection hardware", *IEE Proc. E*, **136**, no. 1, 62–69
- [12] Davies, E.R. (1989) "Edge location shifts produced by median filters: theoretical bounds and experimental results", *Signal Process.*, **16**, no. 2, 83–96
- [13] Davies, E.R. (1991) "Alternative to abstract graph matching for locating objects from their salient features", *Image Vision Comput.*, **9**, no. 4, 252–261
- [14] Davies, E.R. (1992) "Modelling peak shapes obtained by Hough transform", *IEE Proc. E*, **139**, no. 1, 9–12
- [15] Davies, E.R. (1992) "A skimming technique for fast accurate edge detection", *Signal Process.*, **26**, no. 1, 1–16
- [16] Davies, E.R. (1992) "Locating objects from their point features using an optimised Hough-like accumulation technique", *Pattern Recogn. Lett.*, **13**, no. 2, 113–121
- [17] Davies, E.R. (1992) "Procedure for generating template masks for detecting variable signals", *Image Vision Comput.*, **10**, no. 4, 241–249
- [18] Davies, E.R. (1992) "Simple two-stage method for the accurate location of Hough transform peaks", *IEE Proc. E*, **139**, no. 3, 242–248
- [19] Davies, E.R. (1993) *Electronics, Noise and Signal Recovery*, Academic Press, London
- [20] Davies, E.R. and Celano, D. (1993) "Analysis of skeleton junctions in 3×3 windows", *Electronics Letters*, **29**, no. 16, 1440–1441
- [21] Greenhill, D. and Davies, E.R. (1994) "Relative effectiveness of neural networks for image noise suppression", in Gelsema, E.S. and Kanal, L.N. (eds.) *Pattern Recognition in Practice IV*, Elsevier Science B.V., pp. 367–378
- [22] Hannah, I., Patel, D. and Davies, E.R. (1995) "The use of variance and entropic thresholding methods for image segmentation", *Pattern Recognition*, **28**, no. 8, 1135–1143
- [23] Davies, E.R., Patel, D. and Johnstone, A.I.C. (1995) "Crucial issues in the design of a real-time contaminant detection system for food products", *Real-Time Imaging*, **1**, no. 6, 397–407
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- [25] Davies, E.R. (1997) "Vectorial strategy for designing line segment detectors with high orientation accuracy", *Electronics Letters*, **33**, no. 21, 1775–1777
- [26] Davies, E.R. (1999) "Designing optimal image feature detection masks: equal area rule", *Electronics Letters*, **35**, no. 6, 463–465
- [27] Davies, E.R. (1999) "Effect of foreground and background occlusion on feature matching for target location", *Electronics Letters*, **35**, no. 11, 887–889
- [28] Davies, E.R. (1999) "Image distortions produced by mean, median and mode filters", *IEE Proceedings - Vision Image and Signal Processing*, **146**, no. 5, 279–285
- [29] Davies, E.R. (2000) *Image Processing for the Food Industry*, World Scientific, Singapore, pp. xx + 289
- [30] Davies, E.R. (2000) "Obtaining optimum signal from set of directional template masks", *Electronics Letters*, **36**, no. 15, 1271–1272
- [31] Davies, E.R. (2000) "Resolution of problem with use of closing for texture segmentation", *Electronics Letters*, **36**, no. 20, 1694–1696

- [32] Davies, E.R. (2000) “Accuracy of multichannel median filter”, *Electronics Letters*, **36**, no. 25, 2068–2069
- [33] Davies, E.R. (2000) “A generalized model of the geometric distortions produced by rank-order filters”, *Imaging Science Journal*, **48**, no. 3, 121–130
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- [42] Davies, E.R. (2005) *Machine Vision: Theory, Algorithms, Practicalities*, Morgan Kaufmann (3rd edition), pp. xxxiii + 934
- [43] Davies, E.R. (2005) “Using an edge-based model of the Plessey operator to determine localisation properties”, *Proc. IEE Int. Conference on Visual Information Engineering (VIE 2005)*, University of Glasgow, Glasgow (4–6 April), pp. 385–391
- [44] Davies, E.R. (2007) “Efficient transformation for identifying global valley locations in 1D data”, *Electronics Letters*, **43**, no. 6, 332–333
- [45] Davies, E.R. (2007) “Fast implementation of generalised median filter”, *Electronics Letters*, **43**, no. 9, 505–507
- [46] Davies, E.R. (2007) “Guided sampling for rapid object location using biologically motivated model”, *Electronics Letters*, **43**, no. 9, 508–510
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- [49] Sugrue and Davies (2007) “Motion signals provide rapid discernment of pedestrians and pedestrian behaviour”, *Electronics Letters*, **43**, no. 23, 1267–1269
- [50] Sugrue and Davies (2007) “Contrast independent motion detection using ‘inverse pair’ spatio-temporal edge detectors”, *Electronics Letters*, **43**, no. 24, 1346–1348

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Special Issues of Journals

- [A] Davies, E.R. and Atiquzzaman, M. (1998) Guest Editorial in Special Issue on *Projection-Based Transforms*, *Image Vision Comput.*, **16**, nos. 9–10, 593–595
- [B] Davies, E.R. and Ip, H.H.S. (1998) Guest Editorial in Special Issue on *Real-Time Visual Monitoring and Inspection*, *Real-Time Imaging*, **4**, 313–315
- [C] Davies, E.R. and Velastin, S. (eds.) (2006) Guest Editorial in Special Issue on *Vision for Crime Detection and Prevention*, *Pattern Recognition Letters*, **27**, no. 15, 1755–1757

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Most Important Invited Papers at Conferences

- [a] Davies, E.R. (1987) “Design of robust algorithms for automated visual inspection”, *Proc. Royal Swedish Academy of Engineering Sciences Symposium on Machine Vision – the Eyes of Automation*, Stockholm (27 Aug.), IVA – Rapport 336, pp. 55–81
- [b] Davies, E.R. (1995) “Machine vision in manufacturing – what are the real problems?”, *Proc. 2nd Int. Conf. on Mechatronics and Machine Vision in Practice*, Hong Kong (12–14 Sept.), pp. 15–24
- [c] Davies, E.R. (2001) “Some problems in food and cereals inspection and methods for their solution”, *Proc. Int. Conf. on Quality Control by Artificial Vision – 2001*, Le Creusot, France (21–23 May), pp. 35–46
- [d] Davies, E.R. (2004) “Automatic analysis of food images”, *Rank Prize Funds Symposium on The Assessment of Foodstuffs by the Eye and by Instrumentation*, 12–15 January, Grasmere, UK
- [e] Davies, E.R. (2005) “Image Analysis in Crime: Progress, Problems and Prospects”, *Proc. IEE Int. Symposium on Imaging for Crime Detection and Prevention (ICDP 2005)*, IEE, London (7–8 June), pp. 105–112

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Area Editor of Dictionary

- Davies, E.R. (1999) Associate Area Editor and Contributor to Laplante, P.A. (ed.) *Comprehensive Dictionary of Electrical Engineering*, CRC Press and IEEE Press,

Roy managed and edited over 1000 terms in this dictionary.

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- Davies, E.R. (1987) “Industrial vision systems: segmentation of gray-scale images”, invited article in *Encyclopedia of Systems and Control*, Vol. 4, pp. 2479–2484
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- Davies, E.R. (2003) “Design of object location algorithms and their use for food and cereals inspection”, invited Chapter in Graves, M. and Batchelor, B.G. (eds.), *Machine Vision Techniques for Inspecting Natural Products*, Springer Verlag, pp. 395–420
- Davies, E.R. (2003) “Machine Vision – Image Processing”, invited article in Johnson, R.B. and Driggers, R.G. (eds.), *Encyclopedia of Optical Engineering*, Marcel Dekker, pp. 1215–1226
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- Davies, E.R. and Charles, D. (2006) “Colour Image Processing: Problems, Progress and Perspectives”, Chapter 11 in *Advances on Nonlinear Signal and Image Processing*, Marshall, S. and Sicuranza, G.L. (eds.), EURASIP book series on Signal Processing and Communication, Hindawi Publishing Corporation, New York, pp. 299–325

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