E

TWC/22/7
ORIGINAL: English
DATE: May 17, 2004

UPOV

INTERNATIONAL UNION FOR THE PROTECTION OF NEW VARIETIES OF PLANTS
GENEVA

TECHNICAL WORKING PARTY ON AUTOMATION AND COMPUTER PROGRAMS

Twenty-Second Session
Tsukuba, Japan, June 14 to 17, 2004

AUTOMATIC MEASUREMENT OF PEA CHARACTERISTICS

Document prepared by experts from the United Kingdom

AUTOMATIC MEASUREMENT OF PEA CHARACTERISTICS

G.W. Horgan, A.M.I. Roberts, & A. Mann, Biomathematics and Statistics Scotland,
and N. Green, Scottish Agricultural Science Agency, UK

Introduction

1. In 2000, the Scottish Agricultural Science Agency (SASA) and Biomathematics and Statistics Scotland (BioSS) initiated a project to examine the potential of automated measurement of plant characteristics for distinctness, uniformity and stability (DUS) assessment.

2. There is currently a drive to reduce the costs of DUS tests, whilst maintaining their effectiveness in distinguishing varieties. In concept, automated measurement offers the potential to:

- Reduce costs.
- Maintain or increase the precision of measurement.
- Improve consistency (no operator effect).
- Add new and valuable characteristics.
- As a by-product, produce a library of images that may be used for reference collection management, quality assurance and research.

3. The aim of the project has been to evaluate the degree to which this potential can be realised, and to develop tools for routine use of automatic measurement. The basis has been to take digital images of plant parts and to use image analysis (Glasbey and Horgan, 1995) to extract information and make measurements.

4. To date, we have been looking at the automatic measurement of pea and parsnip characteristics. This paper describes progress for pea.

Characteristics that have been automated

5. To date, automated characteristics have been developed for pods, stipules and leaflets. These characteristics are a mixture of those listed in the current UPOV Test Guidelines and others that might be useful but are difficult to measure manually (Table 1). Some of these are measured in more than one way, e.g. leaflet and stipule dentation.

6. The characteristics used can be classified according to type: simple dimensions including area; more complex shape and features; and colour-based.

7. Simple dimensions are measured by identifying landmarks (Figure 1) on the image of the plant part, counting the numbers of pixels between them and then converting this pixel-distance into a metric distance. We include a coin on the image for calibration of distances. Area is usually quite difficult to assess visually but can easily be measured automatically by counting the pixels that constitute the object.

Table 1: Automated characteristics for pea

Type of characteristic	Characteristics in the UPOV Test Guidelines (TG/7/9)	Other characteristics
Simple dimensions	Stipule length (31) Stipule width (32) Leaflet length (23) Leaflet width (24) Pod length (48) Pod width (49) Leaflet size (area) (22)	Stipule dimensions × 3 Stipule area Pod area
More complex shape and features	(26) Leaflet dentation × 6 (52) Pod curvature × 2 (25) Leaflet widest point to base	Pod CJ shape Pod bluntness × 2 Pod knuckle height Pod tip height Leaflet tip shape Stipule dentation × 6
Colour based	(33) Stipule flecking	Stipule redness Leaflet redness Pod redness Stipule greenness Leaflet greenness Pod greenness Stipule blueness Leaflet blueness Pod blueness

8. Colour-based characteristics are measured using the RGB (Red-Green-Blue) values typically stored for each pixel in digital images. The average level of redness (or greenness or blueness) is calculated within that part of the image corresponding to the plant part. Flecking of stipules is measured as the variance of the green intensities of the object.

9. The procedures for measuring the other more complex characteristics are more tailored. Some are really just more specific dimensions. An example is pod ‘knuckle’ height, which is defined as the height of the peduncle ‘knuckle’ (A in Figure 2) above the centre of the pod, defined as a point (C) midway between top and bottom, midway between base and tip.

Figure 1. Landmark points on a stipule outline.

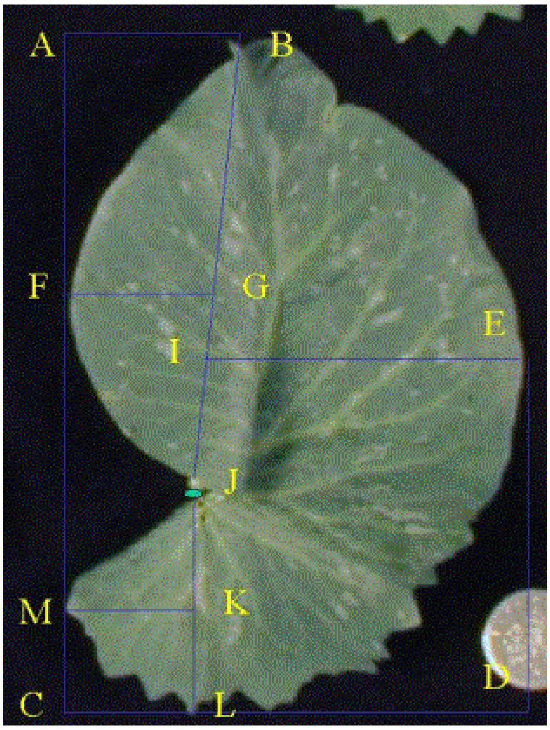
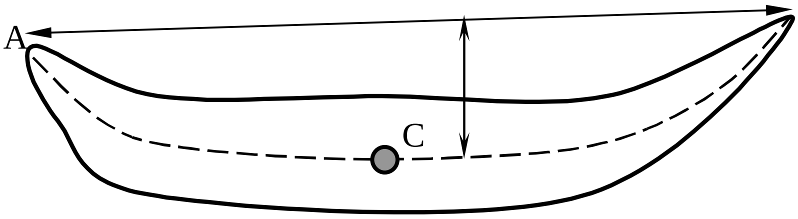
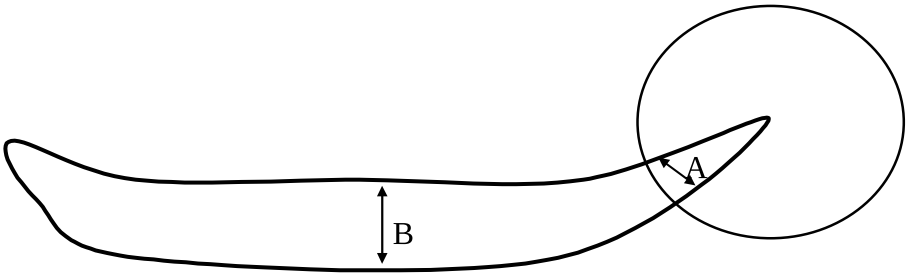


Figure 2: Pea pod showing how knuckle height is measured.



10. Bluntness of the pod tip is measured in two ways. One way is to draw a disc centred on the tip with radius 16% of the pod length (Figure 3), and to calculate how much is occupied by the pod. Another is to measure the width of the pod at a point 10% of the distance from tip to base (A in Figure 3). This may be compared with the pod width (B) to indicate bluntness.

Figure 3: Pea pod showing how bluntness is measured



11. Measuring dentation of the leaflet or stipule (Figure 4) highlights the rigour imposed by using image analysis. The Test Guidelines do not indicate whether the leaflet dentation characteristic relates to the density or the size of the dentations. We have developed several ways of measuring different aspects of dentation. This should allow us to study the processes that a crop expert uses to make their visual assessment of dentation. The six measurements are:

- the number of sharp points;
- the variation from a smooth curve;
- the number of local maxima;
- the mean angle at the peaks;
- the mean angle at the troughs;
- the mean height of peaks.

Figure 4: An example of a pea stipule showing dentation

Evaluation of automatic measurement

12. In 2001 and 2002, images were taken from a section of the field pea DUS trial at SASA, allowing parallel testing of manual and automated measurement. Each image consisted of a sample of parts harvested from different plants in a single plot; there were two replicates per trial. 44 varieties were included, six of which were leafless and thus had no leaflets.

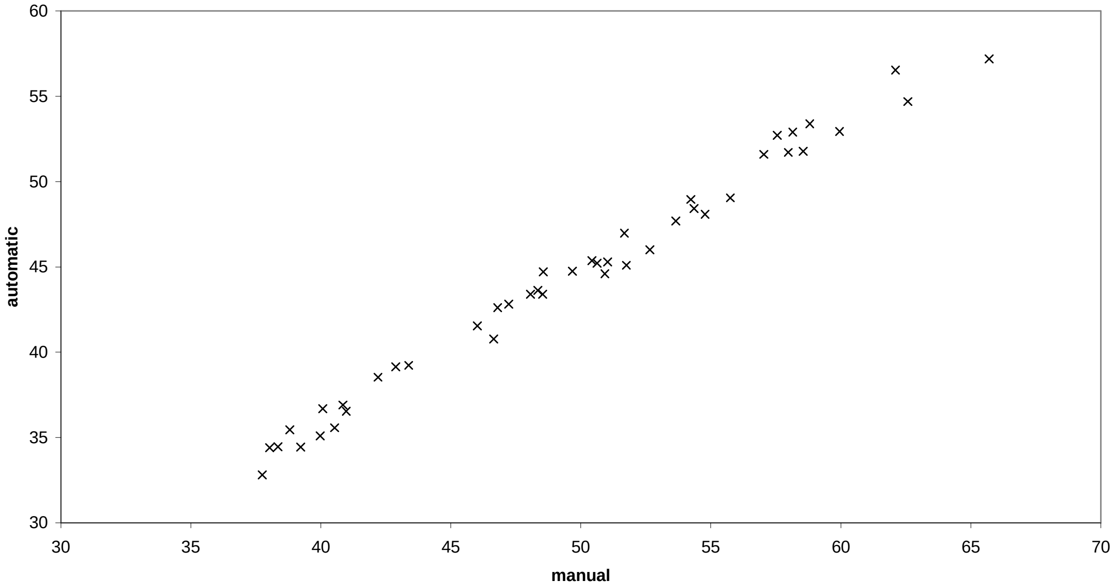
13. Images were taken in a photographic laboratory using a fixed lighting protocol and a conventional SLR camera. The photographs were digitised commercially. Each image included a coin for scaling and a label and a black background was used. An example image is given in Figure 5.

14. The performances of the automated characteristics were evaluated by applying a COYD analysis and noting both the F-statistic for variety differences and the number of pairs of varieties that were distinct. For those characteristics measured manually, results were compared directly using correlations as well as by comparing the discriminatory performance.

Figure 5: An example of an image of stipules

15. For existing simple dimensions, correlations between automatic and manual measurements were very high. The number of disagreements in COYD distinctness decisions was low, with automated measurement generally having slightly higher discrimination. For example, for stipule width the correlation between automatic and manual measurements was 0.994 (Figure 6; note scaling of automatic measurement needs to be improved). The manual method discriminated 47% of pairs of varieties by the 2% COYD criterion and the automatic method discriminated 57%. New simple dimension and area characteristics also gave high levels of discrimination between varieties.

Figure 6: Comparison of automatic and manual stipule width measurements



16. For the more complex characteristics (leaflet widest-point-to-base, leaflet dentation and pod curvature), correlations between automatic and manual were more moderate. There were good levels of varietal discrimination for both existing and new characteristics. However, there were some differences in the varieties discriminated by the manual and automatic methods. This is likely to be due to the more complex nature of the characteristics and the

consequent difficulty in defining the manual measurements precisely. There will be further investigation of these characteristics, particularly for dentation.

17. Results for automated colour-based characteristics were disappointing, perhaps due to the difficulty in representing colours consistently with the current process of imaging. However, these characteristics are quick and easy to score manually in pea.

18. A cost-benefit study has indicated that automatic measurement offers the opportunity for cost reductions, particularly when improvements are made to the efficiency of image capture.

Discussion

19. This evaluation of automatic measurement for pea has been most positive, with automatic measurement of existing UPOV Test Guidelines characteristics (with the exception of colour-based characteristics) being comparable with manual recording. The approach may also offer cost reductions as well as the benefits of new characteristics and images for a library.

20. SASA now plans to implement automatic measurement for field pea. Further investigations will continue for pea and parsnip. We will be looking at how imaging of plant parts can be made more efficient, e.g. by use of scanners in the field.

21. The benefits of automatic measurement will be most apparent in crops with large numbers of varieties, particularly where measurements rather than scores are required for establishing distinctness. It will also be useful for complex characters that are difficult to assess visually.

22. The use of images extends to reference collection management (see e.g. Roberts et al, 2001). As the number of images increases, we intend to develop image analysis tools for managing the pea reference collection.

REFERENCES

Glasbey, C.A. & Horgan, G.W. (1995) *Image Analysis for the Biological Sciences*, Wiley, Chichester.

Roberts. A.M.I., Horgan, G.W., Talbot, M., & Davey, J. (2001) “Matching photographs of plant varieties” *Plant Varieties and Seeds* 2001, Vol 14, pp 151-161.

[End of document]