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USE OF HARRIS DETECTOR FOR DETERMINATION OF ORIENTATION OF ACORNS IN THE PROCESS OF AUTOMATED SCARIFICATION

Summary

The article proposes an algorithm for detection of orientation of acorns during scarification process. This task is necessary for proper cut off of a part of acorn. Described algorithm uses Harris corner detector for location of acorn's remain of style. The performed tests have shown that proposed method is characterized by a sufficient sensitivity value as a unit of efficiency.. Its specificity and precision are also high.
***Key words**: image analysis, image recognition, characteristic points, corner detector, acorns scarification*

ZASTOSOWANIE DETEKTORA HARRISA DO OKREŚLANIA ORIENTACJI ŻOŁĘDZI W PROCESIE ZAUTOMATYZOWANEJ SKARYFIKACJI

Streszczenie

W artykule przedstawiono propozycję algorytmu detekcji orientacji żołędzi w procesie automatycznej skaryfikacji żołędzi. Określenie orientacji jest konieczne w celu właściwego wykonania odcięcia części nasiona. Opisany algorytm wykorzystuje detektor Harrisa do wykrywania korzenia zarodkowego. Przeprowadzone testy pokazały, że metoda cechuje się wystarczającą wartością czułości jako miary wydajności. Specyficzność oraz precyzja również są wysokie.
***Słowa kluczowe**: analiza obrazów, rozpoznawanie obrazów, punkty charakterystyczne, detekcja narożników, skaryfikacja żołędzi*

1. Introduction

During scarification it is necessary to cut off only distal end of acorn [1]. Automatic localization of distal end can be achieved by detection of acorn’s orientation. The simplest method for detection of orientation consists in locating the remains of style. This part of an acorn has the highest curvature. Some methods of characteristic points detection, used in vision systems, depend on curvature checking [3, 6, 8]. One of them is Harris corner detector [2], which is often used in agricultural applications [9, 10]. Very useful feature of this detector is its positive value for corners and negative for edges. It means that analysis of acorn’s contour for presence of positive and negative values obtained by Harris detector should allow to locate acorn's remains of style.

Complexity of Harris-detector-based algorithm is significant and thus related computation is time-consuming. Recently it was shown however, that when real-time applications are sought, its implementation can be highly accelerated by means of FPGA [4] or GPU [5] platforms.

2. Harris corner detector

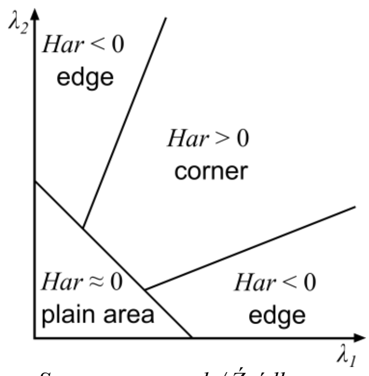
Harris corner detector is based on autocorrelation matrix defined by equation (1),

$$M = \sum_{x,y} w(x,y) \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix}, \qquad (1)$$

where I are directional derivatives, (x,y) define size of an analyzed point neighborhood and adequate values of weighting function $w(x,y)$. Eigenvalues (λ_1,λ_2) of matrix M are correlated with curvature in analyzed point neighborhood. If the curvature of the point is significant, both eigenvalues render high positive values. Instead of calculation of eigenvalues, Harris analyzed determinant and trace of matrix M (Eq. 2), since both of them depend on eigenvalues.

$$Har = \det(M) - \mathrm{tr}(M)^2 k\,. \qquad (2)$$

Fig. 1 shows dependency of Harris detector value on eigenvalues. It clearly shows that edge (contour) of an object should have a high negative values of Harris detector except points of high curvature – then value is high positive.



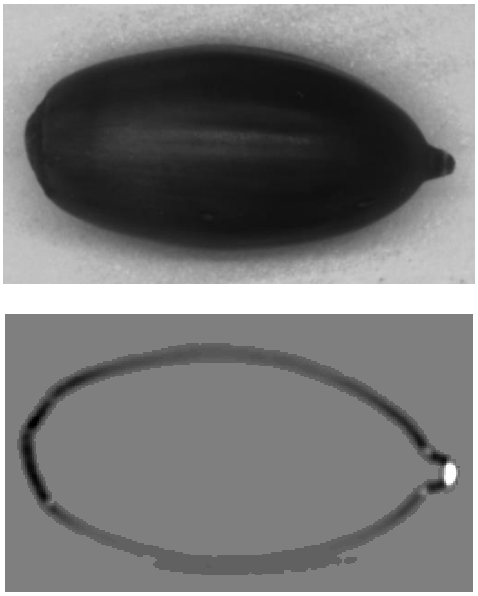
Source: own work / Źródło: opracowanie własne

Fig. 1. The Harris detector values depend on eigenvalues λ_1 and λ_2

Rys. 1. Zależność wartości detektora Harrisa od wartości własnych λ_1 i λ_2

a)

b)

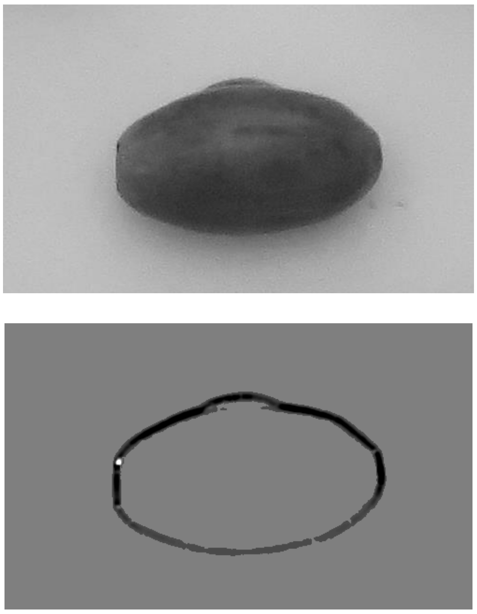


Source: own work / Źródło: opracowanie własne

Fig. 2. Exemplary image of analyzed acorn: a) output of Harris detector, b) white – positive *Har*, black – negative *Har*, gray – *Har* ≈ 0.
Rys. 2. Przykładowy obraz analizowanego żołędzia: a) rezultat detektora Harrisa, b) kolor biały – wartości dodatnie, kolor czarny – wartości ujemne, kolor szary – wartości bliskie 0

a)

b)



Source: own work / Źródło: opracowanie własne

Fig. 3. a) Exemplary image of analyzed acorn without remains of style, b) output of Harris detector (Legend: see Fig. 2b)
Rys. 3. a) Przykładowy obraz analizowanego żołędzia bez widocznego korzenia zarodkowego, b) rezultat detektora Harrisa (Legenda: patrz Rys. 2b)

As can be seen on Fig. 2b) positive value of Harris detector easy locates acorn's remains of style. However, it happens that other points of contour have positive value of Harris detector. It can lead to improper detection of acorn orientation, especially if there is no remains of style visible at all (see Fig. 3).

For all above reasons an algorithm for checking contour points is proposed. The algorithm consists of following steps:
1. calculation of Harris detector values for acorn image,
2. finding of contour and maximum diameter,
3. calculation of the weighted center of gravity for these contour points for which the Harris detector value is positive,
4. finding a shortest distance from ends of the diameter to center of gravity,
5. if this distance is too long then orientation is not detected.

As can be seen on Fig. 3b, improper detection of remains of style does not lead to improper orientation detection – the algorithm rejected this image (orientation is not detected).

3. Results

The set of 88 images of acorns were used in test. On 21 images remains of style is not visible. For these images orientation based on remains of style cannot be detected. On 67 images orientation was detected and assigned.

Table shows that orientation was properly detected on the set of 58 images.

Table. Results of orientation's detection
Tabela. Wyniki detekcji orientacji

	Remains of style is present (visible)	Remains of style is absent (not visible)
Orientation detected	**58** (TP)	**0** (FP)
Orientation not detected	**9** (FN)	**21** (TN)

Source: own work / Źródło: opracowanie własne

On 8 images, with visible remains of style, the algorithm has not found them and refused to indicate the orientation. Accuracy, sensitivity, specificity and precision are statistical measures of performance of detection. Their values are following:
– accuracy: (TP+TN)/(P+N) = (79/88)*100% = 89.8%,
– sensitivity: TP/(TP+FN) = (58/67)*100% = 86.6%,
– specificity: TN/(FP+TN) = (21/21)*100% = 100.0%,
– precision: TP/(TP+FP) = (58/58)*100% = 100.0%.

In detection of orientation some of these measures are more meaningful than the others. In real scarification process of a single acorn a sequence of consecutive images will be analyzed. In this case, if remains of style is not visible and the algorithm refuses to detect an orientation of an acorn, there can be an another try on the next image from the sequence. So, it is safer to refuse decision than to make unsure detection. Otherwise, if orientation cannot be detected and algorithm nevertheless produces some orientation, then there is a risk of improper cut off of the part of acorn. Therefore specificity and precision are more meaningful measures of proposed algorithm, and sensitivity is less important (although it should not be too high for reason of too many wasted acorns). As can be seen in Table 1 – presented algorithm has 100% specificity and precision. Sensitivity value equal to 86% means that less than every fifth acorn needs to be checked again on the subsequent images.

4. Conclusions

The article presents the algorithm for detection of acorn's orientation in scarification process. It was shown that the proposed algorithm has a very high specificity and precision. Achieved sensitivity is high enough for needs of scarification. However, it can be increased by application of other methods of orientation detection based on properties of the contour of an acorn without remain of style. Such a method, was developed for analysis of barley kernels [7].

The main source of false negative (FN) responses is binarization performed during contour finding. Obtaining contour by means of binarization is one of the fastest methods but it is sensitive to illumination conditions. It is possible to increase the sensitivity by using other, more sophisticated, algorithms for finding contour but this can slow down detection of orientation. Further investigation and testing is required for evaluation of other methods and searching for the more robust one.

5. References

[1] Giertych M.J., Suszka J.: Consequences of cutting off distal ends of cotyledons of *Quercus robur* acorns before sowing. Annuals of Forest Science, 2011, Volume 68, Issue 2, 433-442.

[2] Harris C., Stephens M J.: A Combined Corner and Edge Detector. Alvey Vision Conference, 1988, 147-152.

[3] He X.C., Yung N.H.C.: Curvature scale space corner detector with adaptive threshold and dynamic region of support. Int. Conf. on Pattern Recognition, 2004, 791-794.

[4] Lentaris G., Stamoulias I., Soudris D., Lourakis M.: HW/SW Codesign and FPGA Acceleration of Visual Odometry Algorithms for Rover Navigation on Mars. IEEE Trans. on Circuits and Systems for Video Technology, 2016, Vol. 26 (8), 1563-1577.

[5] Luo S., Zhang J.: Accelerating Harris Algorithm with GPU for Corner Detection. Int. Conf. on Image and Graphics (ICIG), 2013, 149-153.

[6] Mokhtarian F., Suomela R.: Robust image corner detection through curvature scale-space. IEEE Trans. on Pattern Analysis and Machine Intelligence, 1998, Vol. 20(12), 1376-1381.

[7] Szczypiński P.M., Zapotoczny P.: Computer vision algorithm for barley kernel identification, orientation estimation and surface structure assessment. Computers and Electronics in Agriculture, 2012, Vol. 87, 32-38.

[8] Worring M., Smeulders A.W.M.: Digital curvature estimation. CVGIP: Image Understanding, 1993, Vol. 58(3), 366-382.

[9] Xu S., Xun Y., Jia T., Yang Q.: Detection Method for the Buds on Winter Vines Based on Computer Vision. Seventh Int. Symp. on Computational Intelligence and Design (ISCID), 2014, 44-48.

[10] Zhang W., Li W., Yang Z., Han J.: Height information acquisition method of seedling with machine vision. IEEE Int. Conf. on Cyber Technology in Automation, Control, and Intelligent Systems (CYBER), 2015, 1446-1449.