USING GRA FOR 2D INVARIANT OBJECT RECOGNITION

T.-H. Sun[1], J. C. Liu[2], C.-H. Tang[2] and F.-C. Tien[2]

[1] *Department of Industrial Engineering and Management, Chaoyang University of Technology, Taiwan, R.O.C.*

[2] *Department of Industrial Engineering and Management, National Taipei University of Technology Section 3, Chung-Hsiao E. Road, Taipei 106, Taiwan, R.O.C.*

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Abstract: Invariant features are vital to domain of pattern recognition. This research develops a vision-based invariant recognizer for 2D object. We perform a recognition method which adopted KRA invariant feature extractor and used grey relational analysis. The feature extraction is to derive translation, rotation, and scaling-free features through the sequential boundary and is described with its K-curvature. Our work represents the object profile with the K-curvature to obtain the position invariant property; and then the transformation of autocorrelation is to ensure orientation-invariant property. Experimental also reveals that proposed method with either GRA or MD methods offers distinctiveness and effectiveness for part recognition.

1 INTRODUCTION

Various working environments suggest that automatic part recognition with invariant properties is of priority concern issue. Khalil and Bayoumi (2002a) developed a 2D invariant object recognition method using continuous wavelet transform and neural networks. After that, they defined three invariant functions with dyadic wavelet transformation of the object boundary to object recognition (Khalil and Bayoumi 2002b). Zhang et al. (2003) proposed an invariant 2D object recognition approach by measuring the geodesic distance between the observed object and a model in the shape space. Cao et al. (2004) employed the direction basis function (DBF) neural networks for successful invariant object recognition. Kyrki et al. (2004) utilized a Gabor filter to extract invariant features for object recognition. Li and Lee (2004) presented a Hopfield neural network model for invariant object recognition using projective transformations and the projective invariance was embedded into the compatibility constraint for finding point correspondences such that the problem was formulated by minimizing the predefined energy function through a Hopfield network. Huang et al. (2005) proposed a scheme based on independent component analysis (ICA) for object recognition with affine transformation and for affine motion estimation between video frames. Sookhanaphibarn and Lursinsap (2006) proposed a method for extracting the invariant features of a color image based on the concept of principal component analysis and a competitive learning algorithm. Yu and Bennamoun (2007) developed two complete sets of similarity invariant descriptors using Fourier-Mellin transform and the analytical Fourier-Mellin transform frameworks, and then adopted 2D-PCA to simplify the invariant descriptor for face recognition. Sun and Tien (2007) proposed an invariant object recognition method by incorporating the eigenvalue of covariance matrix and autocorrelation with backpropagation neural networks.

Using object profiles for object recognition is one of the major fields in pattern recognition. Therefore, boundary descriptor becomes an important role to represent objects' profiles. Curvature, defined as the change rate of the slope, has been widely employed in different applications such as shape representation, feature extraction, corner detection and object recognition. Different numeric curvature estimation approaches have been discussed in literature. Rosenfeld and Johnston (1973) initially defined curvature as a K-cosine function, where K denotes a region of support on the boundary. Sohn et al. (1994) expressed curvature with a formula involving its first- and second-order directional derivatives. Tsai (1997) computed

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directly the curvature by measuring the first- and second-order derivatives of the continuous functions. Later, Tsai et al. (1999) employed the eigenvalue of covariance matrices to measure the curvature and detect the sharp corners in a contour. Tien et al. (2004) applied K-curvature to represent the boundary of microdrills in order to detect the defects. Sun (2008) adopted K-cosine to detect corner of 2D digital objects in order to conduct industrial inspection.

This study proposes a position, orientation, and scale-invariant 2D object recognition method which adopted a so-called KRA invariant feature extractor and used grey relational analysis to recognize objects.

2 GREY RELATIONAL ANALYSIS

2.1 Grey Relational Analysis

Grey system theory (GTS) was first initiated by Deng in 1982 (Deng, 1982; Deng, 1989). The fundamentals of GRA can found in Chang and Yeh (2005) and Jiang et al. (2002). The basic idea of GRA is a ranking scheme that ranks the order of the grey relationship among several subsystems. Jiang et al. (2002) proposed a machine vision-based IC marking identification using GRA. Chang and Yeh (2005) developed a clustering algorithm based on GRA. Song and Jamalipour (2005) developed a network selection scheme that comprised AHP and GRA for an integrated cellular/wireless LAN system. Yeh and Chiang (2005) incorporated grey relational analysis into the ART-2 network to construct a GreyART network. Chen et al. (2007) proposed a data-mining-based learning performance assessment scheme by combining four computational intelligence theories, including gray relational analysis (GRA), K-means clustering scheme, fuzzy association rule mining, and fuzzy inference, in order to identify the learning performance assessment rules using the gathered Web-based learning portfolios of an individual learner. Kung and Wen (2007) used six financial indicators to classify twenty items of financial ratios as research variables through the Globalization Grey Relational Analysis (GRA), to find the significant financial ratio variables and other financial indicators affecting the financial performance of venture capital enterprises. Hunag et al. (2008) examined the potentials of the software effort estimation model by integrating a genetic algorithm (GA) to the GRA.

3 PROPOSED METHOD

The objective of this study is to develop an invariant 2D object recognition method for 2D object. The framework of the proposed method is broadly divided into: image acquisition and segmentation, boundary representation and feature extraction, and decision making, as shown in Figure 1.

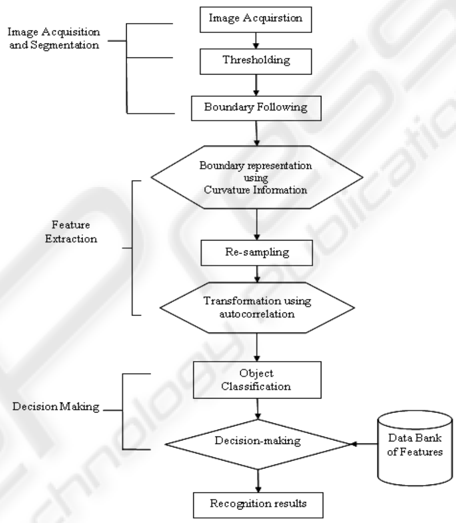


Figure 1: Flow of the proposed method.

3.1 Image Acquisition and Segmentation

Image acquisition is to acquire the digital information of objects through a digitizer. Once images are acquired, the image segmentation procedure separates the digitized object from its background. Thresholding is one of the most commonly used methods for segmentation, in which each pixel is converted into a binary value using a pre-specified value (T). Pixels whose grey values are higher than the threshold are given the binary value 255 (white), while pixels whose grey values are lower than the threshold are given the binary value 0 (black). The thresholding process is usually conducted using the following rule (Gonzalez and Woods, 2003)

$$f_a(i, j) = \begin{cases} 255 & \text{if } f(i, j) \geq T \\ 0 & \text{if } f(i, j) < T \end{cases} \quad (1)$$

where $f(i, j)$ is the grey value at coordinates (i, j); $f_a(i, j)$ denotes the new grey value after segmentation; and T is the specified threshold. After that, the boundary following algorithm is used to extract the boundary information and store them in a sequential array.

3.2 KRA Feature Extractor

The proposed KRA feature extraction is to derive translation, rotation, and scaling-free features through the sequential boundary.

3.2.1 Boundary Representation using *K*-Curvature

K-curvature (also called *K*-cosine) is a curvature-based boundary descriptor developed by Rosenfeld and Johnston (1973). Accordly, the *K*-curvature (or say *K*-cosine) is defined as below.

<Definition > *K-curvature*

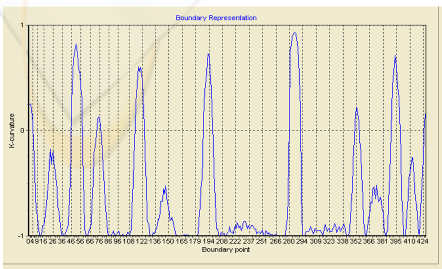
Given an object whose boundary is defined by $S=\{P_i \mid i=1, 2, 3, \ldots, m\}$, *the curvature (K-cosine) of each boundary point* P_i *is defined as*

$$c_i(K) = \cos\theta_i = \frac{\vec{a}_i(K)\cdot\vec{b}_i(K)}{\|\vec{a}_i(K)\|\cdot\|\vec{b}_i(K)\|} \qquad (2)$$

As depicted in Figure 4, $\vec{a}_i(K) = \vec{P}_{i+K} - \vec{P}_i$, $\vec{b}_i(K) = \vec{P}_{i-K} - \vec{P}_i$, θ denotes the angle between $\vec{a}_i(K)$ and $\vec{b}_i(K)$, and K is a natural number (N).

3.2.2 Re-sampling of *K*-Curvature

The boundary representation derived previously is scale dependent. Figure 2 shows the boundary representation of the original object (912 points) when the size is reduced to 1/4 (428 points). The total number of boundary point is approximately reduced to 1/2, but its profile remains similar. Thus, this study re-samples the boundaries of digital objects with different scales and converts them into the same number such that the scaling-invariant property is obtained. This process is achieved by simply sampling the *K*-curvature proportionally to the numbers of $c_i(K)$ extracted.



Note: Totally, there are 428 boundary points (s=30)

Figure 2: Boundary representation with different scales.

3.2.3 Autocorrelation Transformation

Autocorrelations have been widely used features for 1D and 2D signal classification in a range of applications such as character recognition, texture classification, face detection and recognition, signal classification and so forth (Popovici and Thiran, 2004). Autocorrelation coefficient provides important information about matching pattern in time series data. The formula of autocorrelation coefficient of time lag L is as follow:

$$\rho_L = \frac{\sum_{t=1}^{n-L}(r_t - \bar{r})(r_{t+L} - \bar{r})}{\sum_{t=1}^{n}(r_t - \bar{r})^2} \qquad (3)$$

where ρ_K denotes autocorrelation coefficient, L is the length of the time lag (L =1, 2,…, n); n is the number of observations; r_t denotes the value of the variable at time t; and $\bar{r}$ denotes the mean of r_t.

4 IMPLEMENTATION

The proposed method was implemented on a personal computer (PC) with a USB controlled *X-Y* Table and 2D objects were digitized through a black/white CCD connected to a frame grabber. Fifty synthetic testing images were first scanned at resolution 640 × 480 (pixels) as shown in Figure 4 for verification. For each standard pattern, 10 test patterns with various positions (T_1, and T_2, randomly), orientations (30°, 60°, 90°, 150°, 200°, 300°) and scales (S_1=1/4 reduction, 50% and S_2=1/8 reduction, 25%) were created. Therefore, there were 500 test patterns for validation. All standard and test patterns then were segmented with a pre-determined threshold and stored as binary images. For the image pre-processing such as color image thresholding and boundary following, the library of *e*-Vision image processing software (EasyAccess 6.5) was used. The rest of the recognition processes were implemented

Figure 3: Standard part patterns and testing images.

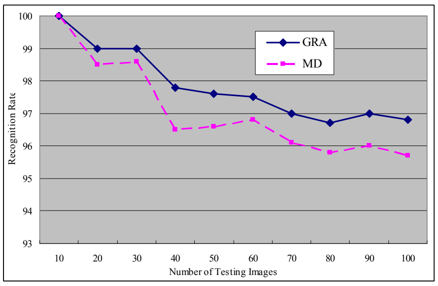


Figure 4: Recognition trends of different methods.

in *C*++ language under Borland *C*++ Builder 6.0 environment.

An experiment was conducted to demonstrate the effect for the proposed two classifiers when the number of the testing objects increased from 10 to 100 to reveal the effect of number of objects. Combining synthetic and real object images, the study had 1000 testing images for validation. The experimental results is shown in Figure 4. Accordingly, the GRA-based method outperformed minimum distance method (MD), even though the MD method still owned 95% of recognition rate when the number of patterns reaches 100.

5 CONCLUSIONS

Deriving invariant features is a crucial task in the area of pattern recognition. This study proposes a new translation, rotation, and scaling-free 2D object recognition method, which adopts *K*-curvature boundary representation to derive position-invariant property, re-sampling to achieve scaling-invariant property, and autocorrelation transform to obtain orientation-invariant property. In addition, the proposed method incorporated with Grey Relational Analysis method to recognize the 2D digital objects with a high recognition rate. A set of fifty synthetic images, each of them was acquiring with ten different positions, orientations and scales, were used for validation, and another fifty real objects were obtained for validation. Experimental results also reveal that the proposed method with either GRA or MD methods is effective and reliable for part recognition. Conclusively, the proposed KRA feature extractor incorporated with GRA classifier, not only successfully obtained position, orientation, and scaling- invariant features, but also classified the features in an excellent performance. It is also expected that the proposed method may be applied to various applications such as part sorting, automated visual inspection, robot positioning, control and monitoring system.

REFERENCES

Cao, W., Hao, F., & Wang, S. (2004). The application of DBF neural networks for object recognition. Information Sciences, 160, 153–160.

Chang, K.-C., Yeh, M.-F. (2005). Grey relational analysis based approach for data clustering, IEE Proc.- Vis. Image Signal Process 152 (2), April 2005, 165-172.

Chen, C.-M.; Chen, Y.-Y., Liu, C.-Y. (2007). Learning Performance Assessment Approach Using Web-Based Learning Portfolios for E-learning Systems. IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews 37 (6), 1349 – 1359.

Deng, L.-L. (1982). Control problems of grey systems, Systems and Control Letters 5(1), 288-294.

Deng, J.-L. (1989). Introduction to grey system theory, Journal of Grey System 1, 1-24.

Huang, X., Wang, B., Zhang, L. (2005). A new scheme for extraction of affine invariant descriptor and affine motion estimation based on independent component analysis. Pattern Recognition Letters, 26, 1244–1255. 499

Jiang, B.C., Tasi, S.L, Wang, C.C. (2002), Machine vision-based grey relational theory applied to IC marking inspection, IEEE Transaction on Semiconductor Manufacturing 15 (4), 531-530.

Jones, G., III, & Bhanu, B. (2001). Recognizing articulated objects in SAR images. Pattern Recognition, 34, 469–485.

Khalil, M. I., & Bayoumi, M. M. (2002a). Affine invariants for object recognition using the wavelet transform. Pattern Recognition Letters 23, 57–72.

Khalil, M. I., & Bayoumi, M. M. (2002b). Invariant 2D object recognition using the wavelet modulus maxima. Pattern Recognition Letters, 21, 863–872.

Kung, C.-Y., Wen, K.-L. (2007). Applying Grey Relational Analysis and Grey Decision-Making to evaluate the relationship between company attributes and its financial performance- A case study of venture capital enterprises in Taiwan. Decision Support Systems Volume: 43, Issue:3, April, 2007, pp.842-852

Kyrki, V., Kamarainen, J.-K., and Kavianen, H. (2004). Simple Gabor feature space for invariant object recognition. Pattern Recognition Letters, 25, 311–318.

Li, W., and Lee, T. (2004). Projective invariant object recognition by a Hopfield network. Neurocomputing, 30, 1–18.

Popovici, V., & Thiran, J.-P. (2004). Pattern recognition using higher-order local autocorrelation coefficients. Pattern Recognition Letters, 25, 1107–1113.

Rosenfeld, A., Johnson, E. (1973), Angle detection on digital curves, IEEE Transactions on Computers C-22, 875-878.

Sohn, K., Alexander, W.E., Kim, J.H., Snyder, W.E. (1994) A constrained regularization approach to robust corner detection. IEEE Transactions on Systems, Man, and Cybernetics. 24 (5), 820-828.

Song Q.Y., Jamalipour, A. (2005). Network selection in an integrated wireless LAN and UMTS environment using mathematical modeling and computing techniques. IEEE Wireless Communications 12(3), 42- 48

Sookhanaphibarn, K., & Lursinsap, C. (2006). A new feature extractor invariant to intensity, rotation, and scaling of color images. Information Sciences, 176, 2097–2119.

Sun, T.-H. (2008). K-cosine corner detection. Journal of Computers. In press.

Sun, T.-H., Tien, F.C. (2007). Invariant 2D object recognition using eigenvalues of covariance matrices, re-sampling and autocorrelation, Expert Systems with Applications, doi:10.1016/j.eswa.2007.08.106

Tien, F. C., Yeh, C. H., & Hsieh, K. H. (2004). Automated visual inspection of microdrill for PCB production. International Journal of Production Research, 15(42), 2477–2495.

Tsai, D.M. (1997). Boundary-based corner detection using neural networks, Pattern Recognition 30 (1), 85-97.

Tsai, D. M., Hou, H.-T., & Su, H.-J. (1999). Boundary-based corner detection using eigenvalues of covariance matrices. Pattern Recognition Letters, 20, 31–40.

Yeh, M.-F., Chiang, S.-S. (2005). GreyART network for data clustering. Neurocomputing 67, 313-320

Yu, H., & Bennamoun, M. (2007). Complete invariants for robust face recognition. Pattern Recognition, 40, 1579–1591.

Zhang, J, Zhang, X, Krim, H., Walter, G.G. (2003), Object representation and recognition in shape spaces, Pattern Recognition 36, 1143-1154.