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젤라틴 캡슐의 분류를 위한 에지 기반 방법 성능 평가

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Performance evaluation of Edge-based Method for classification of Gelatin Capsules

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[요 약]

태블릿 캡슐의 품질 검사를 자동으로 해내기 위해서는 효율적인 이미지 처리기법, 적절한 임계치 설정, 에지 검출 그리고 세그멘테이션 방법 등이 필요하다. 그리고 기 존재하는 태블릿 캡슐의 품질 자동 검사 장비는 매우 고가이므로 품질 검사의 용이성을 높이기 위해서 저가의 하드웨어 시스템이 도입 되어야하다. 본 연구에서는 저가 카메라 모듈을 사용하여 이미지를 취득하고 전최소자승법 커브 피팅, 에지기반 이미지 세그멘테이션 방법을 사용하여 태블릿 캡슐의 함몰을 검사한다. 제안한 방법의 성능을 보이기 위해서 주요 분류 알고리즘인 PCA, ICA, SVM 방법을 사용하여 캡슐이미지 영역 데이터세트와 커브 피팅 에지 데이터세트에 대하여 훈련시간, 테스트시간 그리고 분류 정확도를 구하였다.

[Abstract]

In order to solve problems in automatic quality inspection of tablet capsules, computation-efficient image processing technique, appropriate threshold setting, edge detection and segmentation methods are required. And since existing automatic system for quality inspection of tablet capsules is of very high cost, it needs to be reduced through the realization of low-price hardware system. This study suggests a technique that uses low-cost camera module to obtain image and inspects dents on tablet capsules and sorting them by applying TLS curve fitting technique and edge-based image segmentation. In order to assess the performance, the major classifications algorithm of PCA, ICA and SVM are used to evaluate training time, test time and accuracy for capsule image area and curve fitting edge data sets.

색인어 : 캡슐 에지, 커브 피팅, 전최소자승법, 독립성분분석, 주성분분석, 서포트벡터머신

Key word : Capsule Edge, Curve Fitting, Total Least Square, ICA, PCA, SVM

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Ⅰ. Introduction

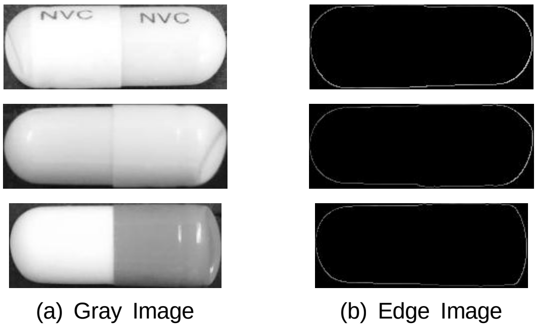


그림 1. 함몰 캡슐의 그레이 이미지와 에지 이미지
Fig. 1. Gray and Edge Image of Dented Capsule

In the application of pharmaceutical industry, real-time quality inspection of capsules is important in terms of productivity and competitiveness, and computer vision-based automatic quality inspection is one of methods to solve this problem. And this machine vision provides real-time feedback on quality control and industrial process, overcoming physical limitations and subjective judgments of humans.

In case of pharmaceutical capsules, various defects can occur in the process of production, such as color defect, dent, or crack, which may lead to decrease in company profit, increase in production time and unit cost, and uncertainty in the quality of product in the market, so the development of quality controller that processes quickly at low cost strengthens competitiveness[1]. Fig. 1 shows gray images and edge image of dented capsule.

In computer vision-based system, digital images obtained from digital camera are usually 24-bit color image. Analysis of image that includes multiple levels requires a complex image-processing technique. However, in real-time application, capsule inspection must be done in a few milliseconds that images need to be resized smaller and changed into gray level as controllable number. What is important is here to find and apply the optimum threshold value.

Previous studies related to quality inspection through capsule images include studies on image-based nondestructive inspection and surface study[2][3], studies related to image segmentation through the technique that finds boundary based on similar region, and image analysis and visualization[4]-[6], studies on inspection method for colored capsules using multivariate image analysis[7][8], and studies on segmentation technique by applying simple weighted threshold[9][10].

In this image, the optimum threshold based on histogram is applied to the capsule image obtained from camera to separate the background and capsule. And in order to segment both sides of capsule, where dents usually occur, as area of interest, curve fitting method is used to find the center of round capsule surface, and dented capsule area is obtained using image segmentation method.

For classification of obtained area of interest, the edge of the cap and body of left and right sides of capsules in quarter, and curve fitting edge, the main algorithm in pattern recognition, which are PCA(Principal Component Analysis)[11], ICA (Independent Component Analysis)[12] and SVM (Support Vector Machine)[13], were used to get 3 separate data sets for classification and comparison. The first classifies dented capsules and normal capsules, the second classifies left and right of capsules including the classification of dented and normal capsules, and the last classifies dented capsules and normal capsules, left and right of capsules and the type of capsules; each of their accuracy was obtained in terms of how far they can classify, and the efficiency of the algorithm is suggested in terms of recognition rate and run time.

Chapter 2 describes the method to obtain capsule area from entire image, curve fitting edge and separation of dented capsule area. Chapter 3 describes system implementation and performance evaluation, and Chapter 4 concludes the study.

Ⅱ. Capsule Processing Methods

2-1 Processing Flow

The flow of dented capsule image reading process is as seen in Fig. 2. First step is to set the threshold through histogram on the image obtained from camera, separate the background and

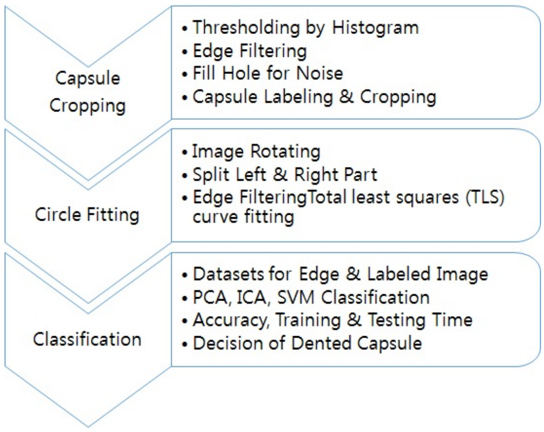


그림 2. 처리 흐름
Fig. 2. Processing Flow

foreground, and perform processes like edge filtering and noise removal. Next, the capsule is cropped through the labeling of capsule area. Second step rotates tilted capsule image and separates the image into cap and body parts. Edge filtering and noise removal are performed for the second time on separated image and TLS (Total least squares) curve fitting is performed on the round area of the cap and body of capsule to find the center of round area.

As the last step, cap and body are classified into dented capsule area and curve fitting edge to set the data set, and training time, test time and recognition accuracy are obtained using pattern recognition algorithms- PCA, ICA and SVM – to decide capsule denture.

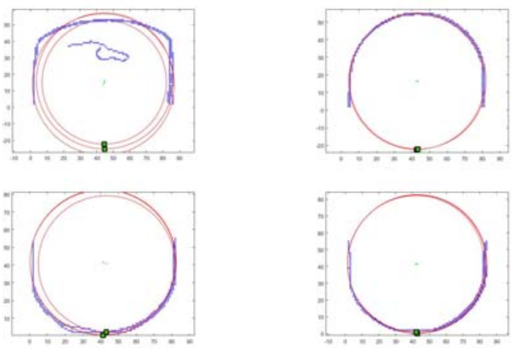
2-2 Labeling of Dented Area

Labeling of dented area begin with capsule image cropping, which includes obtaining histogram from the original image, which is obtained from each capsule, and finding the optimum threshold. In order to obtain the optimum threshold, threshold needs to be applied through calibration each time the subject capsule changes. After, Canny filter is used to separate the foreground from the background and obtain the edge, and fill-hole process is performed to remove tiny noise or letters on the surface of the capsule.

On the processed edge image, the object is defined through labeling and the area of capsule image is obtained. Using this image, the capsule image is cropped from the original image.

2-3 Curve Fitting

When necessary, horizontal leveling is done on cropped image. After, the image is separated into the cap part and body part.



(a) Edge of Dented Capsule (b) Edge of Normal Capsule

그림 3. TLS 커브 피팅
Fig. 3. Curve Fitting by TLS

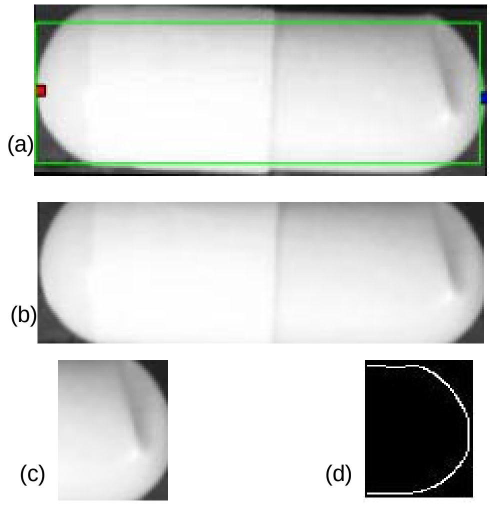


그림 4. TLS 커브 피팅에 의한 이미지 크롭
Fig. 4. Image Cropping by TLS Curve Fitting
(a) Area by TLS, (b) Cropped Original Image, (c) Quad Cropped Image, (d) Edge Image

After the edge filtering and noise removal on separated image, TLS (Total least squares) curve fitting is performed in the round area of cap and body [14] to get the center point and radius of circle, and compare the capsule's edge coordinates with that of ideal circle to decide the degree of dent. Fig. 3 displays TLS (Total least squares) curve fitting applied to (a) Dented capsule, (b) Normal capsule, the estimated line of circle is more even in (a) compared to (b).

The left and right border of the image that was cropped through TLS curve fitting were marked with red and blue squares respectively, and the inner square area of capsule was set as green in order to reduce the noise near the border of background and capsule (Fig. 4-(a).). The green square area was cropped (Fig. 4-(b)), the dented area of interest in quarter was obtained (Fig. 4-(c)), and lastly, the curve fitting edge were obtained (Fig. 4-(d)).

Ⅲ. Performance Evaluation

The image sets on cap part and body part of dented capsule, which were obtained from the previous step, and the curve fitting edge were applied to PCA, ICA and SVM classification algorithms to obtain recognition accuracy and running time.

3-1 Experimental Condition

Specifications of the camera used to obtain image and processing system hardware are displayed in Table 1.

In order to obtain training time, test time and recognition rate of normal capsule and dented capsule through PCA, ICA and SVM algorithm, 3 types of capsules were separated to the left and right, and the histogram threshold of (135, 150), (130, 135), (100, 200) was applied to the dark side and bright side respectively.

표 1. 하드웨어 스펙
Table. 1. Hardware Specification

Item	Value
Camera Spec.	· APTINA MT9M021 1.2M pixels CMOS Sensor · Active pixel: 1280H x 960V · Frame rate: 60fps · Optical format: 1/3" · Pixel size: 3.75x3.75um
System Spec.	· OS: Windows 7 · Intel(R) Core(TM) i7-3770 CPU @ 3.40GHz · 4G RAM

Images were obtained after repeating DATA1 at 7cm of measuring distance and DATA2 at 10cm of measuring distance 100 times each, and the data set of dented capsule area and curve fitting edge were obtained, in which 60% was used for training and 40% was used for test. The size of image of capsule area was 1200x900 pixel and the data size of curve fitting edge was generally 2x350, with a slight deviation.

3-2 Accuracy and Processing Time

Data set was prepared by classifying obtained capsule areas and curve fitting edges into 3 types: data set for classification of dented capsule and normal capsule, data set to classify left/right of capsule including classification of dented/normal capsule, and data set to classify capsule type including classification of left/right and dented/normal capsule.

1) Training & Testing Time

Difference in training time between dented capsule and normal capsule is seen shown in Fig. 5. ICA took the longest training time, and SVM and PCA took relatively shorter time; and in terms of the difference between obtained capsule image area (I-DATA) and curve fitting edge (E-DATA), curve fitting edge took shorter as expected.

In terms of test time, PCA showed deviations and took relatively longer time, whereas ICA and SVM showed smaller deviation between data sets and took relatively shorter time (Fig. 6). With respect to the difference according to data set type, curve fitting edge (E-DATA) took less time.

2) Dented & Normal Capsule(2 parts)

Classification accuracy between dented capsule and normal capsule is displayed in Fig. 7. While PCA and ICA show lower accuracy, SVM shows outstanding accuracy. Since it sorts between dented capsules and normal capsules, SVM recognition is all 100%, excluding curve fitting edge data set 1 (E-DATA1). Curve fitting edge data set 1 seems to occur less in case of insufficient edge information in dented area of curve fitting edge, and the accuracy is expected to increase as more data is accumulated.

3) Cap & Body Part Separation(4 parts)

Classification accuracy of cap and body parts of left/right of capsules, including dented and normal capsules was displayed in Fig. 8. Recognition accuracy of SVM for dented/normal/cap/body areas was 100% for curve fitting edge data set, and 87% and 90% for obtained capsule image area (I-DATA1, I-DATA1) respectively. Curve fitting edge information seems to contribute in judging the dent rather than the image of dented area of capsule.

4) Capsules Separation(12 parts)

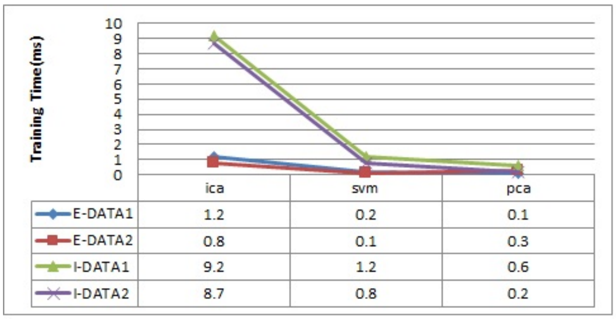
Recognition accuracy of SVM for dented/normal/cap/body/3 capsule types was 100% for curve fitting edge data set, and 88.6% and 85.7% for obtained capsule image area (I-DATA1, I-DATA1) respectively(Fig. 9). This shows that the accuracy decreases in obtained capsule image area as classification level increases, but curve fitting edge information shows strong performance regardless of classification level.

In terms of the evaluation of performance of applied classification algorithms, PCA and ICA would lead to high recognition rate for smaller data set and well-scattered case, so their recognition rate for capsule data is rather low, and SVM runs in binary classifier format that it does not base on distribution, hence resulting in high recognition rate.

For dented capsule area and curve fitting edge, SVM accuracy for 3 types of data set (2/4/12 part classification) is compared in Fig. 10. When classifying dented and normal capsules, most showed 100% accuracy, and the accuracy of curve fitting edge data set (E-DATA) was mostly 100% as well. This shows that the use of curve fitting edge data set (E-DATA) resulted in better results than the use of capsule image area as data set.

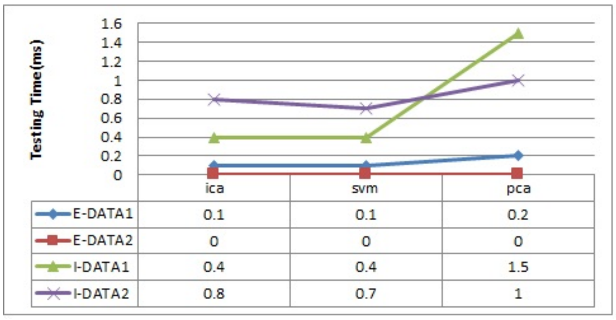
Ⅳ. Conclusions

Images were obtained from 3 types of capsules using low-cost miniature camera, which the threshold was set for through histogram and cropped image on capsule area was obtained. Through TLS (Total Least Squares) curve fitting, the edge, information, and the cap and body parts of both sides of capsule were obtained, and dentures in the round area were classified through classification algorithm.



	ica	svm	pca
E-DATA1	1.2	0.2	0.1
E-DATA2	0.8	0.1	0.3
I-DATA1	9.2	1.2	0.6
I-DATA2	8.7	0.8	0.2

그림 5. 관심영역 이미지와 에지에 대한 훈련 시간
Fig. 5. The Training Time for Labeled Area & Edge



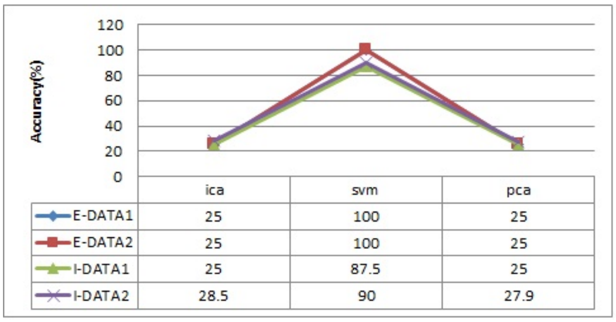
	ica	svm	pca
E-DATA1	0.1	0.1	0.2
E-DATA2	0	0	0
I-DATA1	0.4	0.4	1.5
I-DATA2	0.8	0.7	1

그림 6. 관심영역 이미지와 에지에 대한 테스팅 시간
Fig. 6. The Testing Time for Labeled Area & Edge

	ica	svm	pca
E-DATA1	53.7	80.5	53.7
E-DATA2	53.7	100	53.7
I-DATA1	55.3	100	55.4
I-DATA2	53.7	100	53.7

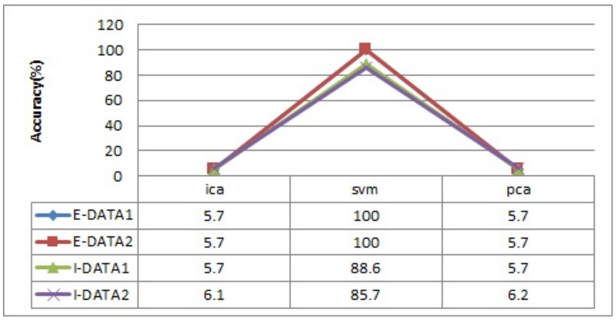
그림 7. 관심영역 이미지와 에지에 대한 정확도
Fig. 7. The Accuracy of Labeled Area & Edge

For the classification of dented capsules and normal capsules, SVM generally showed 100% classification accuracy. For left/right classification of capsule including dented/normal capsule classification, curve fitting edge data set showed 100% classification accuracy, showing outstanding performance when using capsule image are as data set. Also, for classification of dented/normal capsule, left/right of capsule and type of capsule, curve fitting edge data set showed 100% accuracy, but capsule



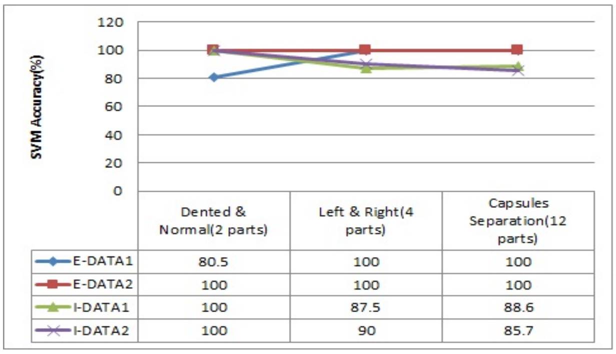
	ica	svm	pca
E-DATA1	25	100	25
E-DATA2	25	100	25
I-DATA1	25	87.5	25
I-DATA2	28.5	90	27.9

그림 8. 관심영역 이미지와 에지에 대한 정확도(캡과 몸체 구분)
Fig. 8. The Accuracy of Labeled Area & Edge with Cap & Body Part Separation



	ica	svm	pca
E-DATA1	5.7	100	5.7
E-DATA2	5.7	100	5.7
I-DATA1	5.7	88.6	5.7
I-DATA2	6.1	85.7	6.2

그림 9. 관심영역 이미지와 에지에 대한 정확도(캡슐 종류 구분)
Fig. 9. The Accuracy of Labeled Area & Edge with Capsules Separation



	Dented & Normal(2 parts)	Left & Right(4 parts)	Capsules Separation(12 parts)
E-DATA1	80.5	100	100
E-DATA2	100	100	100
I-DATA1	100	87.5	88.6
I-DATA2	100	90	85.7

그림 10. 관심영역 이미지와 에지에 대한 SVM 정확도
Fig. 10. The Accuracy of SVM Classifications for Labeled Area & Edge

image area data set showed lowered accuracy compared to smaller area division.

In terms of training time, SVM and PCA took relatively shorter period, and for test time, SVM had smaller deviation among data sets and took relatively shorter period as well.

This study shows that sorting normal capsules is capable without using high-cost image sensor, by applying the optimum threshold to label capsule area, extract capsule area of interest and edge information through TLS curve fitting and recognizing dents on capsules through SVM classification algorithm. When multiple types of capsules are mixed, the accuracy tends to decrease, therefore, additional supplementation of algorithm is necessary.

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