Tarım Makinaları Bilimi Dergisi (Journal of Agricultural Machinery Science)
2009, 5 (1), 93 - 101

Fruit Grading Using Digital Image Processing Techniques

Güray TONGUÇ[1], Ali Kemal YAKUT[2]
[1]Süleyman Demirel Üniversitesi Keçiborlu MYO Bilgisayar Teknolojisi ve Programlama Programı, Isparta
[2]Süleyman Demirel Üniversitesi Teknik Eğitim Fakültesi Makine Eğitimi Bölümü, Isparta
gtonguc@sdu.edu.tr

Abstract: New safe and fast methods for grading of fruits have important place in agricultural economy. At the present time traditional grading methods have still been used broadly. But high costs and some inconsistencies guide post harvesting industry to automation applications in classification operations.
Recently, enterprises incline towards to automation systems for increasing working capacity and decreasing working costs. Inconsistencies associated with manual grading decrease when automated grading systems are used. Thus, error rate and costs decrease while speed increases.
As known; size, shape, color and tissue are base criteria in the classification process. In this study, automatic apple grading by size and color using digital cameras and computerized image processing techniques were studied. The assembled system has achieved basic tasks but it needs to be developed further.
Key words: Image process, Digital image process, Machine vision, Fruit classification

Bilgisayarlı Görüntü İşleme Yöntemleri ile Elma Tasnifi

Özet: Meyvelerin güvenilir ve hızlı bir şekilde sınıflandırılması için geliştirilen yeni yöntemler, tarımsal endüstride teknik ve ekonomik açıdan önemli bir yere sahiptir. Günümüzde halen yaygın olarak el ile sınıflandırma yöntemi kullanılmaktadır. El ile yapılan sınıflandırmadaki yüksek maliyet ve olası tutarsızlıklar hasat sonrası endüstriyi sınıflama operasyonlarında otomasyon uygulamasına gitmeye yönlendirmektedir.
Son yıllarda işletmeler iş kapasitelerini arttırmak ve işletme maliyetlerini düşürmek amacıyla otomasyon sistemlerine yönelmektedir. Otomatik sınıflandırma ile meyve tasnifi sayesinde el ile sınıflandırmada yaşanabilecek insan faktöründen kaynaklanan tutarsızlıklar en aza inerek hata oranı büyük ölçüde düşmekte, hız artmakta ve maliyet azalmaktadır.
Bilindiği gibi geleneksel yöntemlerle elmaların sınıflandırılmasında boyut, şekil, renk ve doku gibi özellikler sınıflandırmanın temel kriterleridir. Bu çalışmada dijital kameralar ve bilgisayarlı görüntü işleme teknikleri kullanılarak elmaların otomatik olarak boy ve renk ayrımı yapılmaya çalışılmıştır. Elde edilen düzenek temel olarak işlevlerini yerine getirmekle birlikte gelişime açıktır.
Anahtar kelimeler: Görüntü işleme, Sayısal Görüntü işleme, Makine görüsü, Meyve tasnifi.

INTRODUCTION

Summary of Literature

In the studies of non destructive fruit classification apple (Bern *et al.*., 2002; Bennedsen *et al.*., 2005; Rehkugler *et al.*., 1986), tomato (Wolfe *et al.*., 1989), orange (Pla *et al.*., 1995), wild myrtle and pepper (Wolfe *et al.*., 1985), prune (Delwiche *et al.*, 1993), wild grass (Haggar *et al.*, 1983), potato (McClure *et al.*, 1988) was examined.

To detect the fruit in front of camera, in some studies images taking from the camera are processing continuously (Haggar *et al.*, 1983, 1984) on the other hand some studies use sensor (Shropshire *et al.*, 1988).

Various studies have been done on the colors of fruit. Bern (2002), make color classification using RGB color components and CIE chromaticity with Matlab, make size classification with form factor and box structure methods.

McClure (1988) works with white potatoes to detect size and shape information, Rehkugler and Throop (1986) works with "Red Delicious" apples to detect defects of apples. Monochrome camera was used in both studies. At the end of works greens and other scars of potatoes creases and blemishes (reddish brown) of apples couldn't detected with monochrome camera. Thomas and Connoly (1986) used pictures taken by RGB signals.

If we look works in general Rehkugler (1986) able to detect 30 apples per minutes. While Bennedsen (2005) reach to 92% accuracy rate, Li (2002) reach 93 % by artificial neural network approach.

Fruit Classification

Fruits classifies according to color, size and defect conditions after harvesting. So, quantity of produced fruits categorized and stocked can be known. Fruits can be find buyer in the market after categorization and price determination.

Manual Classification

In traditional classification, workers classifies fruits manually by fruits' desired size. Basic disadvantages of this process are high costs, fruit damage may occur, workers not being objective while inspecting.

High costs occur for grading workers. This cost is taken by farmer and returns to the consumer as price increase.

Different workers can be classifying the same fruit to the different size class. This situation may decrease accuracy of grading process. On the other hand mixing good fruits among to bad and bad among to good cause loss of money and product.

Apple can easily vulnerable and damageable fruit as physically. Any wrong touch to the fruit may be cause crushes, rots and bruises. These conditions cause loss of money and product too.

Automatic Classification

Different methods can be use to classify size, bruise, blemish and color of fruit with machine vision.

These methods based on detecting and processing color-shape feature of fruit. Processed images are obtained by digital image devices and computer. Obtained images become ready after some preprocessing. Images are processed at the decision phase by computer software that algorithm was previously prepared. Every inspected fruit is guides to the related area by controlled mechanism.

In experimental works certain amount of fruit was classified by workers and then same fruits classified by grading system. According to these work results, accuracy rate reach 69-75% depending on the kind of fruit. Accuracy rate can be increased to 94-98 % by applying NNA (Neural network algorithm) approach (Nagata *et al.*, 1997; Unay *et al.*, 2002).

In addition fruit prices in the markets may be reduced by using these systems.

One of the indispensable element developing fruit classification systems is able to fast and accurate analysis of fruit. As mentioned above, process time varies depend on to the fruit type. Addition to this, according to some resources, a second three is enough for all processes (Nagata *et al.*, 1997).

World, our country and our region situation

According to 2007 data of the Food and Agriculture Organization (FAO), in 2007 3.53% of the world produced 64,255,520 tons of apples were produced in Turkey. Our country takes 4th place in the world with production of 2,266,437 tons (FAO, 2009).

Isparta region is approximately 500 thousand tons (496,596 tons, 2007) with apple production in our country are in first place (Yıkar, 2003; Karamandan, 2009; IspartaTarım, 2009).

In below graphics in our country and world apple production data can be seen.

In Europe agricultural products are expected to meet certain standards before taking part in market. The United Nations has set standards for these products and related them to the announced. United Nations Economic Commission for Europe (UNECE), announces and controls these standards. These rules determine quality, size, packaging, etc. feature of many fruits and vegetables with lower and upper limits. These rules was defined in 2003 and made correction in 2004. Quality and size definitions, quality and size tolerances, uniformity and packaging definitions, marking or labeling, color and rusty definitions of apples are included in this book.

Apples evaluates classifies according to these standards before taking part in market. These classifications are basic criteria while pricing of products.

According to UNECE standards (UNECE STANDARD FFV-50), apples are divided into three terms of shape and size. Shape standards are Extra, Class I and Class II; size standards are Extra (60-65mm), Class I (55-60mm) and Class II (50-60mm). A, B and C groups were created primarily in color classification. Every kind of apple were included to these groups in the another table.

Table 1. Amount of apple production in Turkey (FAO, 2009)

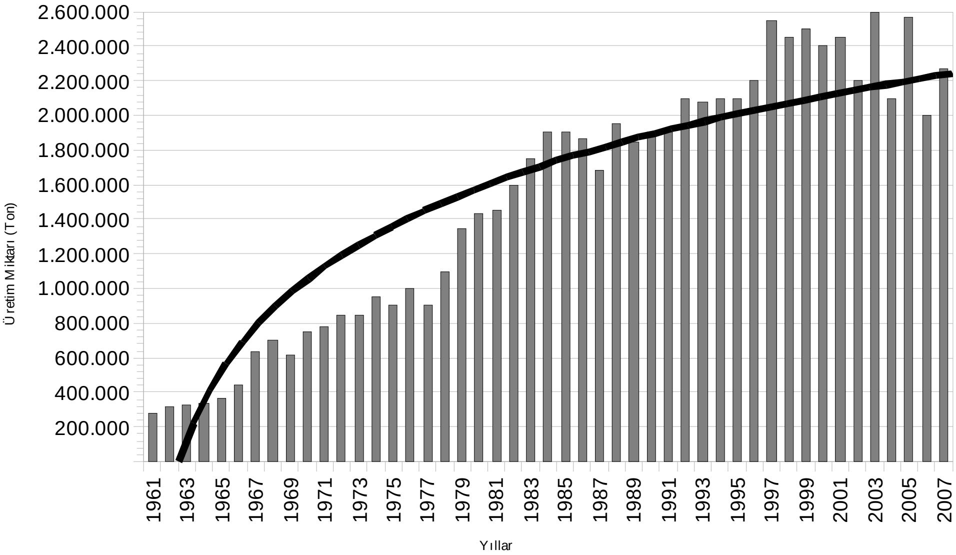


Table 2. The amount of production in Turkey to the world rate (FAO, 2009)

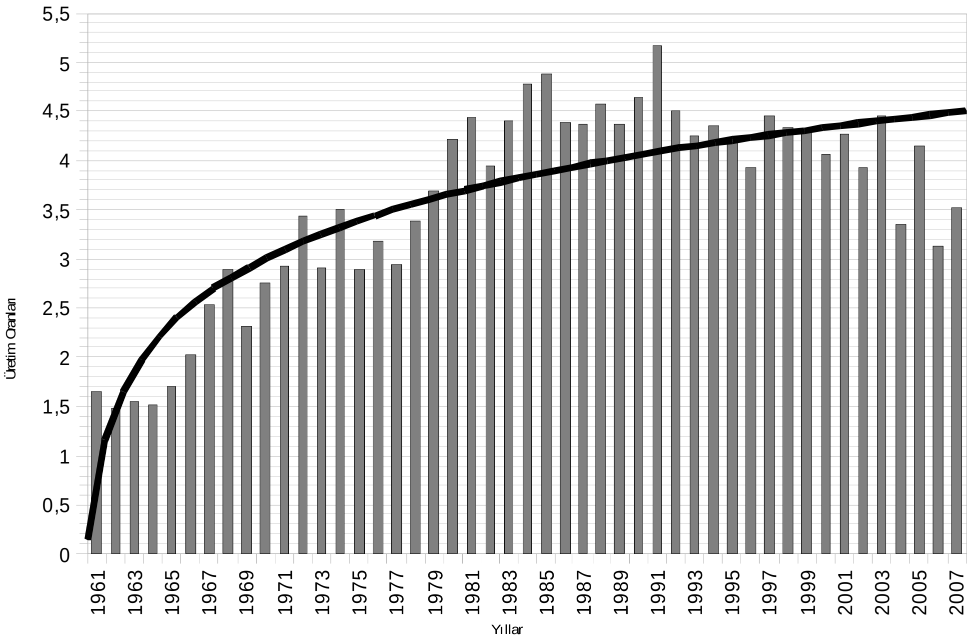


Table 3. Classification of apples according to UN/ECE criteria

Color Group	A	B	C
	Red characteristic of type the total surface	Mixed red characteristic of type the total surface	Light red, fried or striped view of type the total surface
Class Extra	3/4	1/2	1/3
Class I	1/2	1/3	1/10
Class II	1/4	1/10	–

A small portion of the table can be seen below. In this table (table 4), Amasya Apple takes places in the group B and Starking Apple takes places in the group A. Golden and Granny Smith apples not included in the table (UNECE, 2009).

Table 4. Classification some types of apples grown on the world according to UN/ECE criteria

Variety	Synonyms	Tradenames	Colour group	Russeting	Size
African Red		African Carmine	B		
Akane	Tohoku 3	Primerouge	B		
Alborz Seedling			C		
Aldas			B		
Alice			B		
Alkmene	Early Windsor		C		
*Alro			B		
Alwa			B		
*Amasya			B		
Starking			A		L

World Apple and Pear Association, WAPA, represents apple and pear manufacturers over the world. WAPA supports this standard (WAPA, 2009).

Our country and region must comply with these rules to apple production potential to turn into opportunities. Therefore, automation based apple classification is very important country and region economy.

System is expected to achieve the following objectives,

1. Size and color analysis
2. Working in real-time
3. Reach to sufficient speed and accuracy rate economically

MATERIAL AND METHOD

System was developed as prototype in the experimental work. Created computer software shows apples size and color info taken images in the monitor according to system embedded sensors.

Material

Experimental mechanism consists of two parts; conveyor band and protective box. Box is located on the conveyor band and provides insulation against light conditions. Conveyor band carries fruits to the partially closed box. Sensor inside the box detects the fruit that come the relevant region. Camera takes image of fruit in front of the sensor and sends to the computer to process.

System installation was started with mounting rubber band to the carrier frame. DC motor was used to ensure the movement of band.

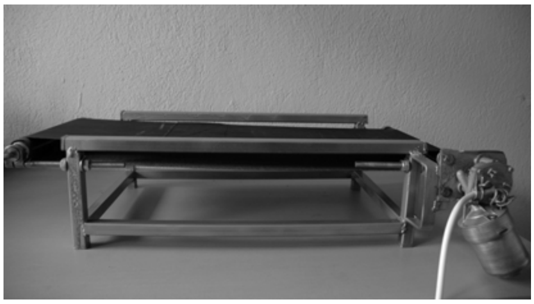


Figure 1. General view of conveyor band

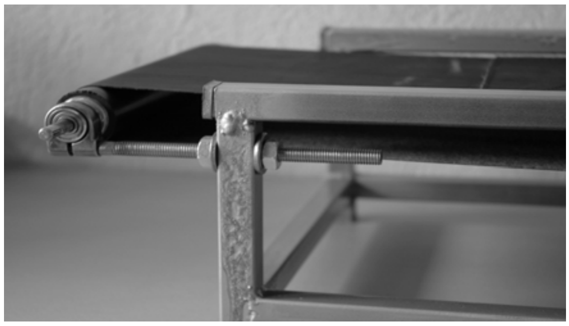


Figure 2. Shafts of carrier band

Used camera was Philips SPC900NC. This device has 1.3 MP CCD sensor. It can take 90 frames per second with 24 bit color and 800x600 spatial resolutions. In addition, has a "flicker free" feature against to fluorescent light flickers.

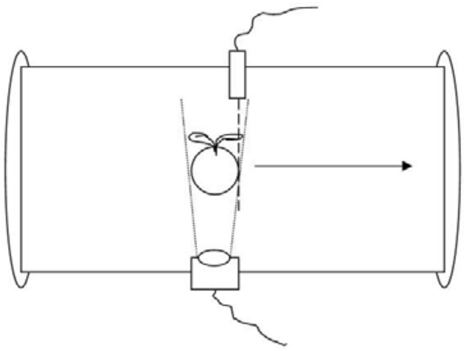
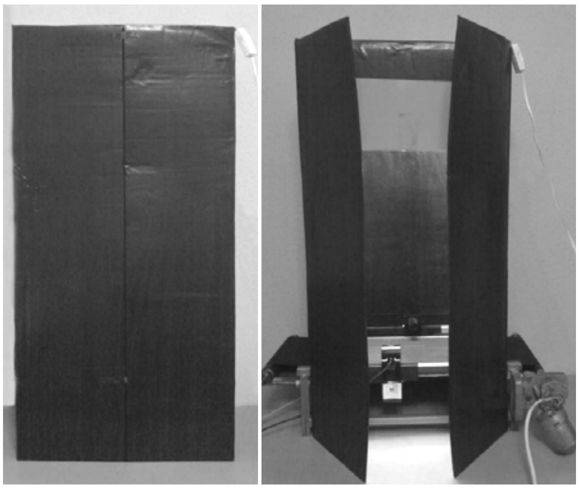


Figure 3. Placement of sensor

After mounting camera SICK brand photo sensor was mounted to the system to detect object in front of camera. This device sends signal over parallel port when any object in front of sensor. Sensor is used for only time when any object in front of camera instead continuous loop.

Figure 4. Sensor

Images taken by camera are far from natural images if any light source light comes to fruit heterogeneous and not able to illuminate fruit homogeneous. Against this situation partially closed box added to the system. Box has its own lighting equipment not to affected environmental light conditions.



(a) **(b)**

Figure 1. The box used for light insulation: (a) Closed view, (b) Open view

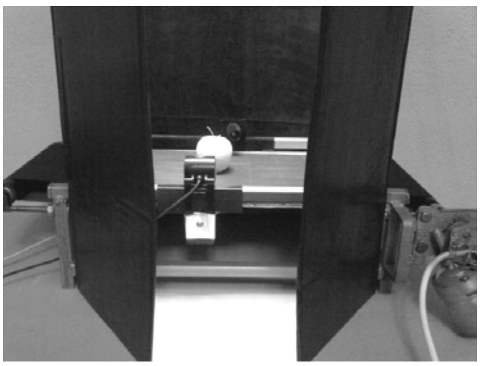


Figure 2. View of the system during operation

Computer Software

The software to decide size and color of inspected apples was created with MS Visual C# programming language in the light of data obtained from experimental work. Software can be worked with stored images in the computer as offline or taking image from camera real time as online.

When the system is run spends approximately 1.3 seconds for inspecting each apple. Detailed information about software algorithm will be provided in next chapter.

Method

Software starts working with taking image from camera when take signal from sensor through parallel port. Processes were specified in the software algorithm. In the algorithm, firstly inspects apple's size and then color by using size information. After completion of transaction size and color information of apples shown in the monitor.

In Figure 7, shown a dark area in background. This area did not cause insufficient light. Reason of this dark area is not to reflect coating material in the background. It's easy to gather only inspected object (apple) image with not to reflect light this material. In addition, camera can view moving band from sidelong easily with this approach.

In the studies, inspecting and evaluating of taken images from camera has been performed. Matlab program, Matlab Image Processing Toolbox, ImageJ software and SigmaScan Software were used to make sense images for computer.

Software algorithm was developed in the light of obtained data. Processes in the algorithm can be figurize as follows.

Figure 3. Overall functioning of the fruit grading system

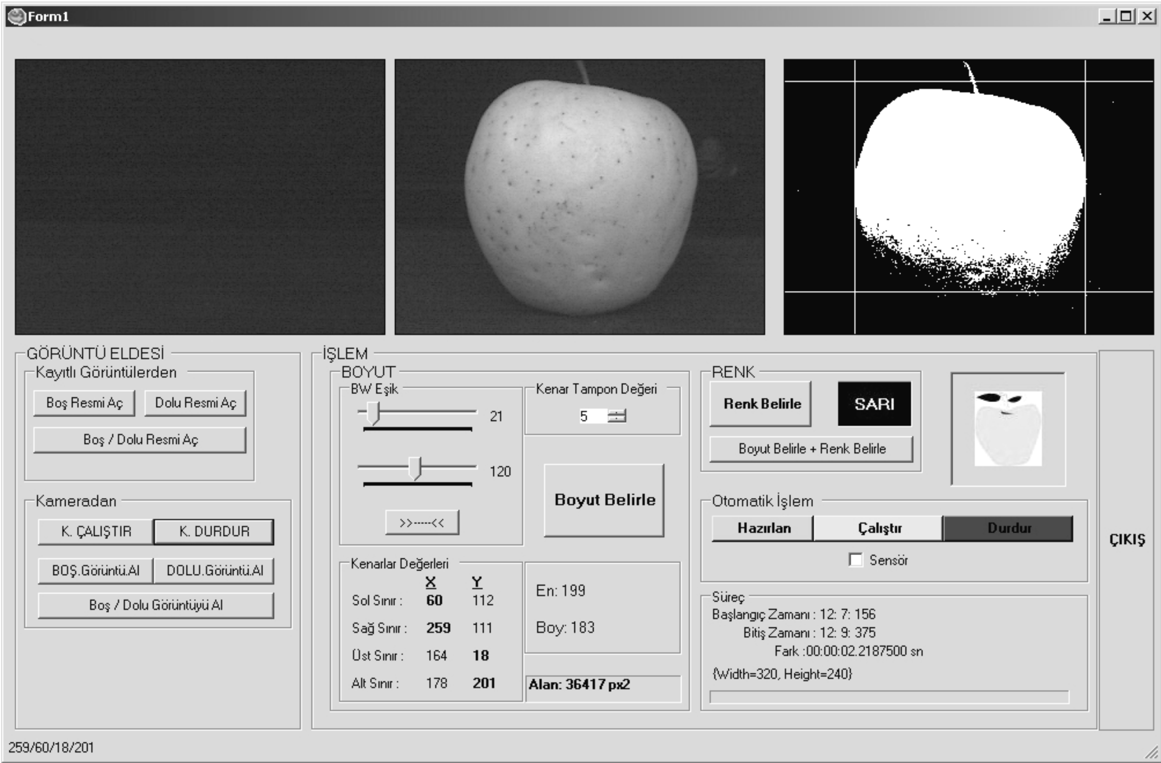


Figure 4. Inspecting yellow apple with software

In the software algorithm, platform-independent apple image is obtaining by comparing taken image with empty platform image. Apple's edges and size determines by processing this image. Some color values obtain by doing second process on the pure apple image. These values are compared pre-defined color values and color class of apple is determined. Algorithm work in this stage is similar to the fuzzy logic system.

For shortening each images processing time process load tried to decreased by physically methods while experimental mechanism developing. In addition some arrangements made to increase software accuracy.

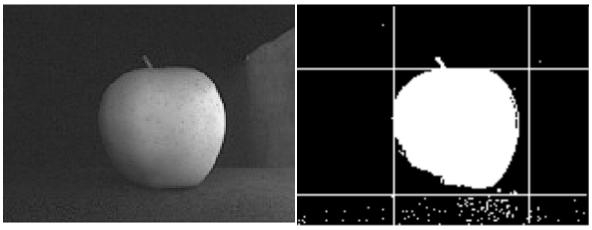
RESEARCH FINDINGS

In the studies, some techniques previously applied enhanced and some of the techniques are replaced with more suitable.

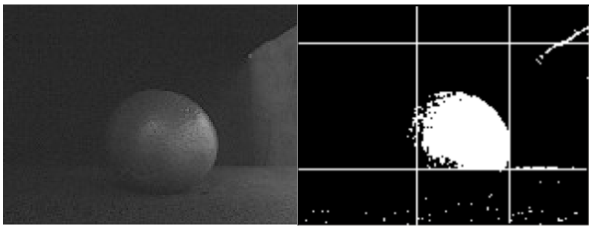
Gathering Images

In first studies camera positioned at the top of the fruit similar to Bern (2002), Bennedsen (2005) and Rehkugler (1986). It's realized that conveyor becoming dirty by the time. Camera was positioned on the side of conveyor. So, traces of pollution have been disabled.

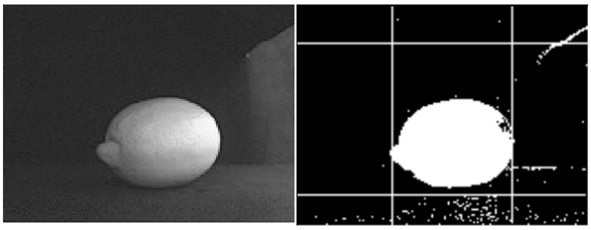
Apple being taken image has been illuminated homogenous inside the box. The two different methods were applied together on this issue. The methods are the box that isolates system from environment lighting conditions and the equipment that prevents apple come to light.



(a) (b)



(c) (d)



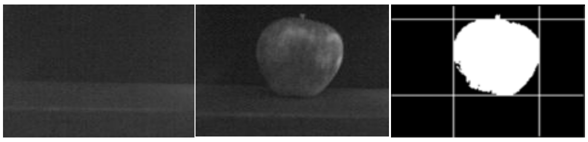
(e) (f)

(g) (h) (i)

Figure 5. Size analysis and results in the fine and poor lighting conditions: (a) Poor illuminated green apple, (b) Size analysis result of green apple at poor illumination, (c) Poor illuminated green tangerine, (d) Size analysis result of green tangerine at poor illumination, (e) Poor illuminated yellow lemon, (f) Size analysis result of yellow lemon at poor illumination, (g) Image taken at fine illumination, (h) Image taken when the light is shining, (i) Size analysis result of light shining image

Size Determination

In size determination first, the necessary transformations made over RGB image of fruit. Edges of the fruit taken images are determined and marked as pixel over image. Area of the edge detected fruit provides information about the actual size is very close to real size.



(a) (b) (c)

Figure 6. Size analysis process: (a) Empty view of platform, (b) Red apple, (c) Result of size analysis

Size of apple can be obtained by multiplying height and width values gathered from size inspection. Apples are divided into three classes and classified as small, medium and big after evaluation results.

Color Determination

One of the most important data in the process of color determination is edge values obtained from size determination process.

While determining color, size values calculated previous step are taken into account. Process is performed only on the rectangle area fruit cover on the image. This prevents the color determination algorithm to produce wrong result by taking action over unnecessary areas. Moreover, loss of time will also be reduced.

At the algorithm development stage histogram of pure apple images was extracted according to several color models. Detailed numerical analysis has been done on them. Green, yellow and red apple images inspected according to Yuv, RGB, HSB, Lab, XYZ, Luv, CMY color models.

RBG color space is determined as more compatible method for color classification when processing time is taken into account.

Software, classifies apples as yellow, red and green by doing necessary process according to data coming from camera on RGB color space.

Figure 8 shows screenshot of software during running. This image shows that inspected apple is middle and yellow.

DISCUSSION AND CONCLUSION

To get the image of apples in the system used to change the camera position and carrier tape formed by pollution to a great extent, these disadvantages are resolved.

An important problem was tried to solve by making homogenous lighting inside the box and by preventing fruit illuminating directly (Yang, 1993; Penman, 2001). So, software prevented to wrong.

First, the process determines the size. Color was determined with numerical data obtained here. Color of the image to determine the process by preventing unnecessary work in the area to increase the accuracy of the decisions and processes to reduce time is right.

To evaluate the RGB, the color mode is based on computer media, in terms of working hours has been determined to be appropriate. Decision-making process similar to RGB color, other color modes are available. To use these color modes RGB values through the first to do some mathematical operations are needed. And this is a disadvantage to use this color mode.

The system in the classification process has been addressed to reach the following objectives are required.

1. Systems analysis of the size and color,
2. The system is running in real time,
3. Just as the speed and accuracy rate of economic access.

When the system working hardware and software together, the first process is dimension of analysis, and then does the color analysis. This process received from the camera to view in real time is done.

In this basic study the mechanism is making size and color classification basically. System's accuracy rate is around 80%. Unable to view more apple surface and being distinctive challenges apple's stem and calyx by computer software were affecting this ratio.

While determining accuracy rate, the aim was to determine both color and size feature truly by the software at the same time. If the software make a true decision on both issue, grading process was accepted as correct. Size and color analysis processes takes 1.3 second approximately. In this study, to obtain higher accuracy rates and various lighting techniques can be used (Lefcout, 2006; Moshou, 2003; Xing, 2006). Moreover, the platform mechanically moved over the fruit of the fruit surface to display a better variety of improvements should be made (Growe *et al.*, 1996; Tao., 1996; Bennedsen *et al.*, 2005; Rehkugler *et al.*, 1986; Throop *et al.*, 1997). All of this work is supported by ANN and some custom programming method is possible to shorten the decision-making process also increases the accuracy rate of decision-making process (Nakano, 1997).

According to data obtained from size and color determination, damage, blemish, sugar contaminant, density and weight analysis can be done over apple or other fruit-vegetable types.

United Nations Economic Commission for Europe sets standards and controls for fruits in Europe. These rules determine quality, size, packaging, etc. feature of many fruits and vegetables with lower and upper limits. Results can be quite successful with machine vision based systems.

Machine vision based fruit grading systems are currently used many countries. In our country, all or part of the systems that financial sum buying from abroad. But very high prices are demanded for sales of these systems. It is possible to produce similar systems in our country with very low costs. These studies are very important for our county's future and development.

Importance and necessity of computerized grading systems clearly come in view when taking into consideration the place of Isparta region in the apple production of Turkey and world, new criteria in the classification process, costs of this operation.

ACKNOWLEDGEMENT

This project supported by Suleyman Demirel University, Scientific Research Projects Coordination Unit (1289YL-09).

REFERENCES

Bennedsen, B.S., Peterson, D.L., Tabb, A., 2005, Identifying defects in images of rotating apples. Computers and Electronics in Agriculture, 48, 92–102.

Bern, A., Kuzivanov, I., 2002. Classification of Fruits. Machine Vision 2002, Course Report Project v0.1, 04.04.2002, Laboratory of Data Processing, Department of Information Technology, Lappeenranta University of Technology, 16s., Finland.

Delwiche, M. J., Tang, S., Thompson, J. F., 1993. A High Speed Sorting System for Dried Prunes. Transactions of the ASAE, 36(1), 195–200.

FAO, 2009. Food and Agriculture Organisation, FAOSTAT. Area Harvested data is in hectares; yield in hectogram/hectare; production and seed data in tonnes. http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor. Erişim: Nisan 2009.

Growe, T.G., Delwiche, M.J., 1996. Real-time defect detection in fruit – part I: design concepts and development of prototype hardware. Trans. ASAE 39(6), 2299–2308.

Haggar, R. J., Stent, C. J., Issac S., 1983. A Prototype Hand-Held Patch Sprayer for Killing Weeds, Activated by Spectral Differences in Crop/Weed Canopies. Journal of Agricultural Engineering Research, 28, 349–358.

Haggar, R.J., Stent, C.J., Rose, J., 1984. Measuring Spectral Differences in Vegetation Canopies by a Reflectance Radio Meter. Weed Res., 24, 59–65.

IspartaTarım, 2009. Isparta Tarım İl Müdürlüğü. http://www.ispartatarim.gov.tr. Erişim: Nisan 2009.

Karamandan, 2009. Karaman'dan yerel haberler. http://www.karamandan.com. Erişim: Nisan 2009.

Li, Q., Wang, M., Gu, W., 2002, Computer Vision Based System for Apple Surface Defect Detection. Computers and Electronics in Agriculture, 36 (2002), 215–223.

McClure, J. E., 1988. Computer Vision Sorting of Potatoes. Ph.D diss., Pennsylvania State University, University Park.

Nagata, M., Cao, Q., Study on Grade Judgment of Fruit Vegetables Using Machine Vision. http://ss.jircas.affrc.go.jp/engpage/jarq/32-4/nagata/nagata.htm Erişim Tarihi: 1997.

Penman, D. W., 2001. Determination of Stem and Calyx Location on Apples Using Automatic Visual Inspection. Computer and Electronics in Agriculture, 33 (2001), 7–18.

Pla, F., Juste, F., 1995. A thinning-based algorithm to characterize fruit stems from profile images. Computer and Electronics in Agriculture, 13, 301–314.

Rehkugler, G. E., Throop J. A., 1986. Apple Sorting With Machine Vision. Transaction of ASAE, 29 (5), 1388–1397.

Shropshire, G., Von Bargen, K., Rundquist, D., 1988. Fourire and Hadamart transforms for Weed Population Estimates from Video Images. ASAE Paper No.88 – 3039. St.Joseph, Mich.: ASAE.

Tao, Y., 1996. Spherical transform of fruit images for on-line defect extraction of mass objects. Optical Engineering, 35(2), 344 – 350.

Thomas, W. V., Connoly, C., 1986. Applications of Color Processing in Optical Inspection. Applications of Digital Image Processing, SPIE 654, 116–122.

Throop, J.A., Aneshansley, D.J., Upchurch, B.L., 1997. Apple orientation on automatic sorting equipment. Proceedings of the Sensors for Nondestructive Testing International Conference, NRAES, Ithaca, NY, pp. 328–342.

Unay, D., Gosselin, B., 2002, Apple Defect Detection and Quality Classification with MLP-Neural Networks. Proc. of PRORISC, Eindhoven, the Netherlands.

UNECE, 2009. United Nations Economic Commission for Europe. http://www.unece.org/trade/agr/standard/fresh/fresh_e/50apples.doc. Erişim: Mart 2009.

WAPA, 2009. The world apple and pear association. http://www.wapa-association.org/content/Marketing%20standard%20for%20apples%20Feb%2006.pdf. Erişim: Mart 2009.

Wolfe, R.R., Bhatt, S., 1989. Compensation of projected image measurements for obtaining defect areas on tomatoes. ASAE Paper 89-6020, presented at the 1989 International Summer meeting sponsored by ASAE and the Canadian Municipal Convention Center, Quebec, Canada. ASAE, MI, USA.

Wolfe, R.R., Sandler, W.E., 1985. An algorithm for stem detection using digital image analysis. Transactions of ASAE, 28, 641–644.

Woods, M., 2005. EU Tree Fruit Production and Trends. West Central Spring Horticulture Meeting. Beijing, China, February, 2005.

Yang, Q., 1993. Finding stalk and calyx of apples using structured lighting. Computer and Electronic in Agriculture, 8, 31 – 42.