

## **A Review: Machine vision and its Applications.**

**Kirtan B. Patel<sup>1</sup>, M. B. Zalte<sup>2</sup>, S. R. Panchal<sup>3</sup>**

*1,2(Dept: Electronics & Telecommunication, K. J. Somaiya College of Engineering, Vidhyavihar, Mumbai, India)*

*3(Dept: Electronics & Communication, Sardar Vallabhbhai Patel Institute of Technology, Vasad, Gujarat, India)*

---

**Abstract:** *The machine vision has been used in the industrial machine designing by using the intelligent character recognition. Due to its increased use, it makes the significant contribution to ensure the competitiveness in modern development. The state of art in machine vision inspection and a critical overview of applications in various industries are presented in this paper. In its restricted sense it is also known as the computer vision or the robot vision. This paper gives the overview of Machine Vision Technology in the first section, followed by various industrial application and the future trends in Machine Vision.*

**Keywords:** *CCD- charged coupled devices, Fruit harvesting system, HIS- Hue Saturation Intensity, Image analysis, Image enhancement, Image feature extraction, Image feature classification processing, Intelligent Vehicle tracking, Isodiscrimination Contour, Machine Vision.*

---

### **I. Introduction**

Machine vision is the technology to replace or complement manual inspections and measurements with digital cameras and image processing. Machine vision had emerged with the high effectiveness and success in the development of industrial area. Machine vision works basically in four steps: 1) imaging, 2) processing and analysis, 3) communication and 4) action. The applications of machine vision can be classified according to the industries i.e. automotive, electronics, food, logistics, manufacturing, robotics, packaging, pharmaceutical, steel & mining and wood industry. According to the survey of Frost & Sullivan, the technology of emergence of 3D Vision applicability of 3D Vision in robotic guidance, automotive and advanced inspection, which was till 2007 got upgraded with higher data rates and greater real time image processing, greater use of imaging beyond the visible light range till 2010 and recently machine vision is the field of interest for many industries due to its greater robotic and autonomous vehicle capabilities. Recent advances in high performance computing coupled with the decreasing cost of hardware now makes the machine vision a financially viable inspection option for small and medium sized firms. From the traditional algorithms to the recent technologies in this field, there are various applications in different area of the industry; however this suffers from constant acquisition and modelling problems. Machine vision requires expertise in multiple fields as it is composition of different technologies.

Machine vision has become one of the fastest growing fields in the industrial automation markets. By [1] the applications of machine vision is classified into inspection of dimension quality, inspection of surface quality, inspection of structural quality and the inspection of accurate operation also called as correct operation. Each and every application of machine vision will be related to at least one of the above categories. The paper is structured as follows: First will be the introductory section on Machine Vision followed by its applications in various industries that focuses on the growth of revenue for most of the industrial and non-industrial markets. Finally the paper is concluded by exploring the future applications with Machine Vision Technologies.

### **II. Machine Vision**

Machine vision technology based on pattern matching, feature parameter, window and silt light methods are being used in the industry. However, recent applications require more effective use of knowledge based processing, combined with application specific method [2]. Machine Vision is the technology to replace or complement manual inspections and measurements with digital cameras and image processing. The technology is used in the variety of different industries to automate the production, increase production speed and yield, and to improve product quality. Machine vision in operation can be followed by four steps 1) Imaging, 2) Processing and Analysis, 3) Communication and 4) Action. The basic applications of machine vision is to locate, i. e. to find the object and report its position and orientation., to measure, means to measure the physical dimensions, to inspect, means to validate certain features, and to identify means to read various codes and alphanumeric characters. But to get in touch with the present needs and to develop the applications Machine Vision have been immersed in almost all the fields weather industrial or non- industrial, that are discussed in further paper.

Machine Vision has been defined as the “automatic acquisition and analysis of images to obtain desired data for interpreting a scene or controlling an activity”. Justification of machine vision has undergone

three evolutionary phases. Phase 1) justifications based on labour savings, Phase 2) justifications based on quality improvements alone and, Phase 3) justification based on manufacturing yield and quality improvements. The detailed analysis for this phases is described in [3]. According to [4], machine vision is also defined as "The use of devices for optical non-coherent sensing to automatically receive and interpret an image of real scene, in order to obtain information and/or control machines or processes." To achieve higher level machine vision for the wide variety of applications it is necessary to further research on computer vision and image processing that from the practical machine vision technology.

### **III. Applications**

#### **3.1 Consumer safety applications**

##### **3.1.1 Vehicle detection and tracking for safety purposes [5]**

Every nation of the world is trying to develop their Intelligent Transportation System (ITS), it increase the vehicle safety and traffic efficient. Important part of ITS is Intelligent Vehicle (IV) which include the autonomous navigation and safety insurance. This leads us to the safe vehicle detection and vehicle tracking algorithms.

**3.1.1.1** The **detection methods** is shown in two steps 1) hypothesis generation(HG) and 2) hypothesis verification(HV) that verifies the correctness of hypothesis in step 1.

Three known methods for the potential detection of the vehicle under HG are 1) Knowledge based method, 2) stereo based method and 3) motion based method.

In knowledge based method the prior knowledge of the vehicle is used that includes symmetry, color, edges and so on. Here in this method the edges of the road is detected that would reduce the area of search. Then by taking the advantage of the daylight that yields to the shadow of the vehicle darker than that of the road will detect the location. The issue is that the threshold values for edge detector would change a lot since the dynamic range of acquired images is big in an on road vehicle detection system. But the drawback is that the potential objects in both near and far scenes, the faraway objects are easy to be submerged by that nearby the ego vehicle. For this problem the solution proposed was a multi resolution method which considers three different interest areas for far vehicles, vehicles in medium distance and close vehicles respectively. During nighttime, headlines and taillights are usually used for vehicle detections.

In the stereo vision based method the distance can be calculated by the stereo vision system, it consists of two methods: disparity map model inverse perspective mapping model. In the disparity map model the matching between the two methods id carried out by the stereo matching. According to the matching primitives it is classified in area based, feature based and phased matching. The problem with this is how to reduce the ambiguity in matching and increase the anti-interface ability and how to reduce the complexity and calculations in complex scenes. In inverse perspective mapping model complexity is much lower than that of the disparity map method, but the assumption here made is that the road is flat.

In motion based method the optical flow to estimate the relative motion of vehicles is detected. The optical flow can be estimated according to the corresponding pixels in image sequence, where the pixels are processed independently and the computational cost is high. Also by the feature detection which uses high level information and is less sensitive to noise. Under HV methods the template based methods and appearance based method are developed but the multi features fusion based methods are adopted by various researchers. In template based methods there are predefined patterns and correlation operation is performed on the images. Appearance based methods, consists of the two steps 1) extract some features from the object hypothesis as the classification basis. 2) Train the classifier with a series of training data then input the extracted features to the classifier to identify the object. In Multi features fusion based methods, when the single extracted features are not enough to identify the object by fusing different kinds of features the comprehensive character is obtained with high reliability and adaptable to different kinds of environment.

**3.1.1.2 Vehicle tracking** algorithm is the process of hypothesizing the probable locations in future frames according to the detected vehicle locations.

Tracking is done by Kalman filter, particle filters or by mean-shift tracking. The main assumption in the method by Kalman filters is that the targets moves with the uniform velocities in straight lines or the uniform accelerations and takes least square to get the target. This assumption is the drawback with respect to the method by particle filters where each part of the vehicle is considered as the particle. But particle filter method is justified only when the particles reaches to infinity, which will increase the computation cost hence the Kalman filtering is the suitable choice. The mean-shift algorithm builds the model using histogram of kernel function. The main disadvantage of this method is it tracks the object by the color information only and is not robust enough with too little information.

Here in this application the machine vision is used in each and every step. This application can be placed in all the categories mentioned in [1] except inspection by surface quality, as the application includes inspection of dimension quality by the detection of the road (path detection), the detection of vehicle with different algorithms is included in the inspection by the surface quality, and finally the operation of the camera inbuilt in the vehicle will be under the inspection of the operational quality.

### **3.1.2 Machine vision in railcar safety[6]**

The survey gives us an idea of the effectiveness and efficiency for safety appliance that can be improved by the Machine vision technology. Field experiments have been carried out under natural and artificial lighting conditions to observe the proper function of the algorithms related to machine vision. The main aim in this application is to detect the ladder rungs, handholds and break wheels and to classify this detected appliance as Federal Railroad Administration (FRA) defects, non- FRA deformations or no deformation. According to [6], the algorithm follows the following steps: firstly from the input video, the selection should be a optimal frame that provides the best view of a car passing by camera. Then due to foreshortening effect caused by the camera position or from the angle from which the railcar is viewed, the far parts of the car are distortedly viewed, hence we conduct the perspective correction that yields two views of the car and each appear as if they are taken by the two cameras perpendicular to the car's side and ends. The benefits of this algorithm is low cost due to dual functionality of the single camera, the perspective correlation is obtained accomplished using homography. Here also the application is categorized under the inspection of operational quality due to working of cameras. The inspection of the surface and structural quality will be applied during the proper scanning of the railcar and also during the scanning of the brake wheel.

### **3.2 Textile industry(inspection of the cotton)[7]**

The survey gives the detailed understanding of machine vision in textile industry. Here the inspection of the cotton quality is done by detecting the impurities. To identify the impurities the colour video camera, an image acquisition board working within the PC and the lighting system is required. The cotton is illuminated in the daylight (D65- one of the standard light sources used by CIE) lamps under controlled environment because illumination or colour of the light sources affects the apparent cotton colour. Then the image acquisition system will convert the video input into RGB format and then the computer identifies the impurities in cotton by colour discrimination between cotton and impurities using isodiscrimination. The experimental results of [7] describes, the images captured is in 24 bit RGB format with 180\*126 pixels and occupies 180 square centimetres of area. The image had the resolution of 0.089 cm. Edge detection is used for the image analysis and finding areas and finding impurities.

Similar to the above applications this application of machine vision is also under the inspection of the operational quality due to the use of camera for colour video. It is also categorized under the inspection of surface quality due to the random surface of cotton.

### **3.3 Application in agriculture and food industry**

Many applications of machine vision has been developed in agricultural field as it does not only recognize size, shape, colour, and texture of objects, but also provide numerical attributes of the objects or scene being imaged. Accuracy, non-destructive, and yielding consistent results are the core advantages of the imaging technology. Applications in machine vision technology will improve industry's productivity, thereby reducing cost and making agriculture operations and processions safer for farmers and processing line workers. In agriculture the machine vision is limited to camera machine vision systems. Its application is limited because of the high cost of equipment investment and low operational speed. A basic machine vision system would consist of the camera, a computer equipped with an image acquisition board, and a lightning system. Also, computer software is required for transmitting electronic signals to computers, acquiring images, and performing storage and processing of the images. Image processing in the agricultural applications always consists of three steps: 1) image enhancement 2) image feature extraction and 3) image feature classification. Image enhancement is commonly applied to the digital image to correct problems such poor contrast or noise. Statistical procedures such as mean, standard deviation and variance are applied for the feature extraction. Numerical techniques such as a neural networks and fuzzy logic interface systems can be applied for the image feature classifications [8].

#### **3.3.1 Recognizing and locating the ripen tomato**

To reduce the human work in the agriculture industry [9], had presented the algorithm of the harvesting robot to recognize and localize the fruit or vegetable on the plant. The navigation of the robot was carried out using the machine vision based system. From [10], the method of development of vision system to pick up orange was described using the harvesting robot. An algorithm for the automatic recognition of Fuji apples on the tree was developed for a robotic harvesting system discussed in [11]. The tomato is the only plants which do

not ripe simultaneously; on each plant we find green, yellow, orange and red tomatoes. Hence the harvesting robot must pick the tomato which is ripped from many. The algorithm on which the harvesting robot will work for picking up the ripped tomatoes will be totally dependent on image segmentation [9]. Image segmentation will divide the whole image into parts and the processing is done. Here the aim of segmentation will be to recognize the ripped tomato (RT), from the background. The processing time depends on the size of the image, larger the image longer the processing time. The segmentation process is initiated first by removing the background. The removal of background takes several steps: firstly the colour data of the objects such as background, RT and unripe tomatoes (UT) are extracted in the RGB colour model. Now the equations that are defined for removal of the background colour are  $D1 = R - G$ , and  $D2 = R - B$ . Secondly the grey image obtained from D1 is converted to the binary image. Then to remove the background, the binary image was multiplied in R, G and B channels separately. Then the colour image was reconstructed by comparison of R, G and B channels. Finally the recognition of the RT was carried out in two steps: Firstly the comparison of extracted colour data from the UT and RT showed that red pixels are only present in RT and it was located in the bottom part of the tomato as tomato begins to ripe from the bottom to top. These pixels could be used for the recognition of RT. The RGB components change when the intensity changes, hence the image was first transformed to YIO model that can partly neutralize the correlation of red, blue and green components in an image. Secondly the images are transformed from RGB to the HSI colour model and then the reflected light on RT is reduced. The tomatoes are grown in the rows and the columns. Hence the problem of extraction of the tomato of the interested row than the behind row was to be solved. This uses the fact that the near thing appears big and the far things appear small. Hence the algorithm was developed to remove the extracted tomatoes as noise if its size is smaller than certain value, this uses OR operation [12].

Finally the location of the fruit was the another task to perform, hence by [9], first connected objects in the binary image were computed by labelling function, then the row and column indices were found for all of the pixels belonging to each connected component. Finally, mean value of found row and column indices was computed as centre of area of each connected component [12]. But here the problem is that, in some cases the fruit is glued together. To overcome this problem the watershed algorithm is applied [12], which is able to separate the joined fruit into the separate ones.

Here in this application the inspection of correctness of the process will be included due to the application of robot in harvesting which includes the use of real time cameras. Moreover this application is also characterized under the inspection of surface, structure and dimension qualities due to the dependence of the algorithm on size of the fruit, shape and the background. The inspection of the surface quality is included in such applications because to detect the correct fruit, the possibility of presence of some other object on the plant with the same dimensions as of fruit but with different surface properties is also considered.

### **3.3.2 Fruit detection[13]**

By the survey of the algorithm detection the efficient fruit on the tree is observed. It is required in the fruit harvesting system. It was primarily developed for the robotic fruit harvesting. However this technology can easily be used for the application in the crop health status monitoring, disease detection, maturity detection and other operations which require vision as a sensor. Colour, intensity, edge and orientation are the four basic features which characterize fruits. The fusion based approach for the fruit detection and vegetables detection is validated. The development for fruit detection algorithm with combined multiple viewing techniques for a tree canopy. The colour and the texture features are used for the colour recognitions and an efficient fusion of colour and texture is used for fruit recognition. With the use of the machine vision systems in the citrus manufacturing company calliper and the colour are successfully used for the automatic classification of fruits, its recognition algorithm consists of the segmentation, region labelling, filtering, parameter extraction and parameter based detection. Due to the lack of efficiency in detecting the fruit with the single feature, multiple feature extraction like colour, intensity, edge and orientation are used. They are then integrated according to their weights. After integrating we will get the final image map. The flow follows as, firstly the extraction of intensity and colour features in which the tree fruit image is converted to HSV colour model, which is followed by the extraction of orientation features where the orientation feature map are obtained by filtering the intensity feature map. Then the extraction of the edge features is done which refers to the process of identifying and locating sharp discontinuities in the image. Then the extraction of the fruit region from the feature region is done in which after extracting the low level visual features, in the form of intensity, colour, edge and orientation features, and the integrated feature maps are computed. Finally in the phase of fruit detection the extracted fruit region is now used for generating the binary mask by computing each pixel values with the global threshold of fruit region.

Here in this application if the input image is too complex and do not contain different colours then the algorithm will fail to detect the fruit. However this method is robust under complex and clustered background.

In this application of fruit detection the fruit is first scanned from the tree that categorizes this application under the inspection of dimension quality because it is necessary to find the dimension as there is the possibility of the

presence of some other thing that is not the surrounding, but not fruit also. Hence the dimension quality is to be inspected. The similar application in 3D fruit detection includes the inspection of the surface quality and the inspection of structural quality. Hence such applications fall under the category of inspection in surface and structural quality. Finally the camera that carries out the procedure should be monitored and well operated and this forces such applications to fall under the category of inspection of operational quality.

Machine vision techniques have been applied in the food industry for the assessment of the fruits and nuts [14]. Vision techniques had been applied in such industries for shape classification, defects detections, and quality grading and verity classification. In survey of [14], it is shown that four images per apple were needed to quantify the average shape of a randomly chosen apple. The analysis found that as the classification involved more product properties and become more complex, the error of human classification increased. Leemans et al. (1998) instigated the defect segmentation of 'Golden Delicious' apples using machine vision. To segment the defects, each pixel of an apple image was compared with the global model of healthy fruits by making use of the Mahalanobis distances. The proposed algorithm was found to be effective in detecting various defects such as bruises, russet, scab, fungi or wounds. Earlier there was the use of the 'flooding' algorithm (Yang, 1994) to segment patch like defects, but it was only applicable for the uniform skin colour. This technique was improved by Yang and Merchant (1995), who applied the snake algorithm to closely surrounding the effects. To discriminate russets in Golden Delicious apples a global approach was used and the mean hue on the apples was computed (Heinemann et al., 1995). An online system with the use of a robotic device (Molto et al., 1997) resulted in the running time of a 3.5 s per fruit for the technique. Moreover the machine vision have also been applied in the classification of oranges, strawberries, nuts, peaches and pears, of which the review is presented in [14]. Ruitz et al., (1996), studied three images analysis method to solve the problem of long stems attached to mechanically harvested oranges. The techniques include color segmentation based on linear discrimination analysis, contour curvature analysis and a thinning process which involves integrating until the stem becomes the skeleton. In the samples tested the stem location was correctly estimated in 93, 90 and 98% respectively. Kondo (1995) invested the quality evaluation and its results could effectively predict the sweetness of the oranges with a 87% correlation efficiency between measured and calculated sugar content obtained from neural networks. Computer vision is used in the shorting of the fresh strawberries based on the shape and size (Nagata et al., 1997). A recent study by Dewulf et al., (1999) combined image processing with the finite element model to determine the firmness of the pears. Similarly like fruits the inspection of vegetables and grains (classification and quality evaluation) was based on the computer vision technology.

### **3.3.3 Seedling Transplanter and Identification of variety of rice seeds**

The state of seedlings in the plug tray was detected by the machine vision technology by guiding the manipulator to transplant the seedlings. Image processing algorithms were used for capturing the seedlings characters, the result showed that the success rate of identification was good. But overlapping of the broader seedlings and extruding leaves from neighbouring cells leads to failure in identification. The study on the tomato seedlings was carried out and the second method was found suitable [15]. The automatic inspection machine and image processing unit was also developed for the identification of the different variety of rice seeds. Here the rice seeds were positioned, carried through photographing sections for image inspections and then shorted into collections containers according to their colour feature and appearance quality. Special rice variety inspection software was developed to prepare grading parameters, and to tune the sorting precision and machine operation. This system was enough to use for inspection of varieties of different rice based on its appearance characters of seeds [16].

### **3.4 Other Applications**

Not only in the above described industries but the machine vision have also been implemented in the Forest product Industry[17], in Pearl- Quality Evaluation based on the Kansei Machine Vision[18], in the detection of the fire bricks [19], identification of wheels [20], whose results obtained were constraint free system with real time recognition rate and considerable increase in recognition accuracy and many more in various fields.

## **IV. Future trends**

With advancement in the new technologies and tools the, machine vision will be upcoming investing technology in the near future. From the Frost & Sullivan analysis of trends on machine vision market, in the duration of 2009 to 2014, in components side the dynamically reconfigurable processors might displace FPGA's, Industrial interests and applications might make the use of Multi Spectral sensors, the need of frame grabbers will decrease and finally the CMOS sensors will gain advantage over CCDs due to lower consumption, lower price and higher speed. In the manufacturing side high accurate measurements in 3D and real till will be

possible. Machine vision will aid the statistical analysis, diagnostics maintenance in factories and the monitoring & control of the machine vision will become common. In the robotics vision the cycle time will decrease.

Predictive evaluation during 2015 to 2020 might cover the replacement of PC based systems by the Embedded, industry oriented systems and the multi spectral sensors might go closed to long IR wavelengths and will be limited by the lens material. In the manufacturing market in this span the industrial vision systems will become indispensable part of flexible automation systems. With the advances in the safety applications the rapid manufacturing will be aided by the machine vision technology. In the field of Robotics, during this span the predictive increase in the precision of the applied algorithms is that the cycle time of vision guided robots shall fall below 1 sec enabling flexible and fast robot operation. Visual serving might enable robots to aid flexible precision machining and other operations. Applications in the robotics after 2021 might develop the autonomy in machine vision systems for human and obstacle detection, object tracking, navigation and localization. Moreover, robotics will be ready to intelligently pick different objects from a moving line, perform certain machining operations and place objects in given locations. Adoptive algorithms will be used to visually guide and teach robots [21].

## V. Conclusion

In this paper the importance of machine vision is discussed in the recent industrial applications and its application algorithms have been evaluated. However, futurology is always vague and involves many pros and cons like other engineering problems, machine vision will also somehow contribute to prosperity of future human society and the conservation of its natural environment. Hence in the light of above discussions and examples it can be stated that Machine Vision have been immersed and will be immersed in almost all the fields weather industrial or non- industrial markets, resulting in the considerable amount of increase in revenue.

## Acknowledgement

We thank Rochan Patel (Maruti Industrial & Engineering Co.) for his long and continued support in completing this survey.

## References

- [1] Elias N. Malamas Euripides G.M. Petrakis, MichalisZervakis, Laurent Petit, and Jean Didier Legat "A SURVEY ON INDUSTRIAL VISION SYSTEMS, APPLICATIONS AND TOOLS",Pg 1- 38.
- [2] Masakazu Ejiri," Machine Vision Technology: Past, Present and Future ", *Central Research Laboratory, Hitachi Ltd.* Pg. XXIX-XXXX.
- [3] Toni M. Harms," Machine Vision: What Can It Do For You" ,*AVCA Corporation* (1992).Pg. 30-34.
- [4] HenrikHaggren," Real Time Photogrammetry as used for machine vision applications", *Technical Research Centre of Finland*, Pg. 374- 382.
- [5] Zhou Junjing, DuanJianmin and Yu Hongxiao. "Machine-Vision Based Preceding Vehicle Detection Algorithm: A Review" ,*Proceedings of the 10<sup>th</sup> World Congress on Intelligent Control and Automation* July 6-8, 2012, pg. 4617-4622.
- [6] J. Riley Edwards\*, John M. Hart\*, SinisaTodorovic\* Christopher P.L. Barkan, NarendraAhuja\*, ZeZiong Chua, Nicholas Kocher, John Zeman, "Development of Machine Vision Technology for Railcar Safety Appliance Inspection", *Current Affiliation: Human Professional Services, Inc.* Pg. 1-8.
- [7] PrinyaTantaswadi , "Machine Vision for Automated Visual Inspection of Cotton Quality in Textile Industries Using ColorIsodiscrimination Contour", *Technical Journal vol 1 No. 3* , July august 1999 pg. 110 to 113
- [8] Yud-Ren Chen, Kuanglin Chao, Moon S. Kim , "Machine vision technology for agricultural applications" *Computer and Electronics in Agriculture* 36(2002) 173-191.
- [9] ArmanArefi ,AsadModarresMotlagh , KavehMollazade and RahmanFarrokhiTeimourlou,"Recognition and localization of ripen tomato based on machine vision ", (*AJCS-2011*). Pg No. 1144 to 1149.
- [10] Hanan MW, Burks TF, Bulanon DM (2009) ,"A machine vision algorithm combining adaptive segmentation and shape analysis for orange fruit detection". *CIGR Ejournal Vol. XI*.
- [11] Bulanon DM, Kataoka T, Ota Y, Hiroma T (2002) ,"A Segmentation Algorithm for the Automatic Recognition of Fuji Apples at Harvest". *BiosistEng* 83(4):405-412.
- [12] Gonzalez CR, Woods ER (2002) Digital image processing. *In: Prentice-Hall, 2edn. Upper Saddle River, New Jersey.*
- [13] Hetal N. Patel ,Dr.R.K.Jain, Dr.M.V.Joshi, "Fruit Detection using Improved Multiple Features based Algorithm", *International Journal of Computer Applications* (0975 – 8887) *Volume 13– No.2*, January 2011.
- [14] TadhgBrosnan, Da-Wen Sun "Inspection and grading of agricultural and food products by computer vision systems\*/a re view", *Computers and Electronics in Agriculture* 36 (2002) 193-213
- [15] Junhua Tong, Huanyu Jiang, Wei Zhou, "Development of automatic system for the seedling transplanter based on machine vision technology " (2012) 742-746
- [16] Ai- GuoOuYang, Rong- JieGao, Yan De Liu, and Xiao-Ling Dong , "An Automatic Method for identifying Different Variety of Rice seeds using Machine Vision Technology" 2010 *Sixth International Conference on Natural Computation(ICNC2010)* pg. 84-88.
- [17] Richards W. Conners, D. Earl Kline, Philip A. Aramnan and Thomas H. Drayer,"Machine Vision Technology for the forest products Industry"(July 1997) pg 43- 48.
- [18] Hiroyasu Koshimizu and Noriko Nagata," <Survey> New Kansei Machine Vision Application – A Prospect for human sensory factors in machine vision"(1998) pg. 185-192.
- [19] He Junji, Shi Li, Xiao Jianli, Cheng Jun, Zhu Ying," Size detection of firebricks based on machine vision technology", (*ICMTMA-2010*), pg. 394-397.
- [20] Behrouz N. Shabestari, John W. V. Miller and Victoria Wedding,"Wheels Identification using Machine Vision Technology", (1991), 273-275.
- [21] Frost & Sullivan analysis of future trends on the Machine Vision Market.