PAPER • OPEN ACCESS

Studies on application of image processing in various fields: An overview

View the article online for updates and enhancements.

Studies on application of image processing in various fields: An overview

T Prabaharan[1], P Periasamy[2],V Mugendiran[3],Ramanan[4]

[1]Research Scholar, St. Peter's Institute of Higher Education and Research, Chennai, India

[2]Professor, Department of Mechanical Engineering, St. Peter's Institute of Higher Education and Research, Chennai, India

[3]Professor, Department of Production Technology, Madras Institute of Technology, Anna University, Chennai, India

[4] Sr Engineer Synce Engineering Service, Chennai

Email:prabaezhile1977@gmail.com

AbstractQuality inspection and evaluation is a vital role in producing quality products in a shorter span. Computer-aided estimation of quality products in different fields of engineering is a constructive advancement happening. Image processing is one of the most promising areas, which is applied for quality inspection of products where the challenging task lies in recognition of the object and feature extraction. This paper made attempt to provide an overview of the application of image processing and their methodology with few algorithms that have been used in different fields of engineering which falls under three important phases: acquisition of images, the region of interest and identification of defects. This paper concentrates on applications like construction, fluid flow, thermal imaging, medical industries, fruit and vegetable industry, rock carvings, and other applications. Applying image processing different fields leads to quality products by a qualitative process which leads to a reduction in inspection time and cost involved.

Keywords: Image processing; Machine vision; Data acquisition; Strain measurement; Thermal; Fluid flow;

1. Introduction

Image processing technique can be used for processing images, 3d models, printouts and to obtain the required data from the images. Researchers use a broad range of basic procedure of image interpretation while adopting analog visual techniques. This type of image processing is just restricted within the area of knowledge of the analyst. So analysts may apply a blend of personal knowledge and data in image processing. In digital image processing, computer based algorithms are developed to perform image processing technique. Considering the advantages of digital image processing against analog image processing and due to huge number of algorithms available that can be used with the input data. In digital image processing, few problems during processing such as noise creation, signal distortion etc., can be minimized and removed during preprocessing technique called signal processing. In late 2000, due to the advancement that happened in digital image processing with aid of computers has become the emerging form of image processing which is more versatile, and also the cheapest one. Image processing has strong relation with computer vision and computer graphics. The

following steps describe the procedure for image processing: Hallucination (identifying the hidden objects), Image restoration and sharpening (for creating sharpened image), Image repossession (search for the area of interest), Measurement of pattern (calculating the color range of objects) and Image acknowledgment (differentiating the region of interest). In this study, a review on digital image processing, applied in various field has been given with suitable algorithms.

2. Image processing in different fields

It can be noticed that substantial amount of investments has been going on civil infrastructures since past few decades. To assure the safety of the civilians, the priority has to be given to maintenance and the interventions should be defined to reduce both environmental impacts and costs. Due to climatic changes, the former leads to different new maintenance strategies. To achieve quick and reliable diagnostics, focused solution has to be developed to maintain the structures' robust. Thus the developed solution ought to ensure be effective, reliable and economical forever. The availability of the digital and optical equipment's gained importance in structural assessment. Currently, in construction sector to perform land survey, structural damage monitoring, structural health assessment, deformation and damage study [2]. Terrestrial Laser Scanning (TLS) method has been widely adopted. By means of 3D images of structures, this accurately collects both qualitative and quantitative information. For characterization and monitoring, Terrestrial Photogrammetry (TP) has been widely adopted [3]. Photogrammetry allows cost effective high-resolution 3D structural imaging systems. [4] It is not possible to characterize fluid flow pattern with high velocity. Image processing technique is most widely adopted to visualize and characterize complicated 3D fluid flow to acquire clear image of the physical phenomena for further processing. The foremost interests for researchers in fluid flow are pattern formation and flow structures, by analysis the phenomena through acquired images. Much more study has been carried out on jet origination, propagation, hypersonic jet flows, flow structures and patterns and also morphological flow properties, and their emission, by means of image processing [10]. Severe heat generation occurs in case of friction during machining, generation of electricity and flow of electricity. Even in building construction too, heat loss occurs due to poor wall finishing, roof performance and poor insulation. If the insulation provided is too weak then it loses its effectiveness, and can lead to even worst damage to the structure and also to the interior of the building. For example, motors running at a same load conditions continuously, should be inspected for change in thermal properties, so that early detection may avoid catastrophic failure[24]. The diagnosis of various human diseases can be completed through common available medical tests. Biomedical images are acquired from living beings and they are used for clinical diagnostics, disease treatment and continuous monitoring. Medical imaging can be applied to observe and study thefunction and behavior of internal organs without the need of surgery. Computer Tomography (CT), Magnetic Resonance Imaging (MRI) and X-ray inspection are the few commonly used imaging techniques in contemporary medical field. Virtual reality and augmented reality are the innovation that has been applied to save and improve the quality of life. Several sensors can be also being employed to study and monitor the health condition of the human like blood pressure, body temperature, air respiratory, glucose level, skin perspiration etc., however molecular analysis study using microscopic images can be used to recognize the symptom of the diseases. Study of strain developed on a specimen during different types of loading, say tensile, compression, shear, bending, twisting, etc., and plays an important role in prediction of life of the specimen. Even fluctuating stresses causes a major problem on components subjected to dynamic loads. The prediction of strain distribution and evaluation of strain localization behavior before the failure of the components is the major area that has to be concentrated. In this method, a random pattern is etched on the top layer of the sample, in order to determine the spatial displacement of the pattern on the sample due to different loading conditions using digital correlation calculation. The deviation of the electrochemically or laser etched grid patterns on the sample has been analyzed by developing computer based algorithms [11].

3. Algorithms used in Image Processing

3.1 Image processing in construction industry

Image processing can be seen as automated system to perform the health monitoring and evaluation system to assess the damage occurring in concretes and structures due to natural calamities [5]. This deals with the characterization of crack patterns, measurement of strain fields subjected to different loads. The automation in characterization leads to measuring and comparing the entire crack length over a period of time, eliminating the human error with high accuracy [6]. The main drawback is the resolution quality of the image obtained which has a vital role in image acquisition [7]. Algorithms has been developed to detect a crack developed on the surface of the concrete structure based on image acquired using an automated robot [1,8,9]. The processes involved in image acquisition and image processing on concrete structures are shown as a flow chart in figure 3.

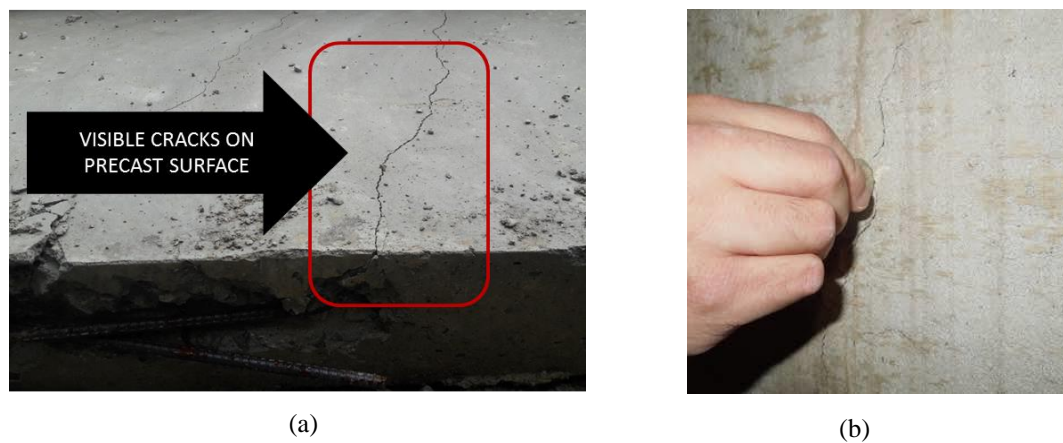(a)   (b)
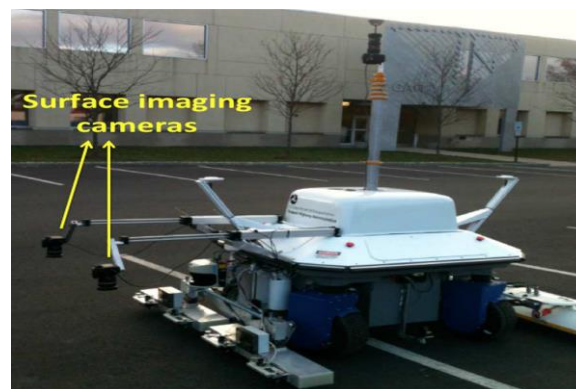
Fig 1. (a) and (b) Visible cracks on Pre-cast surface.
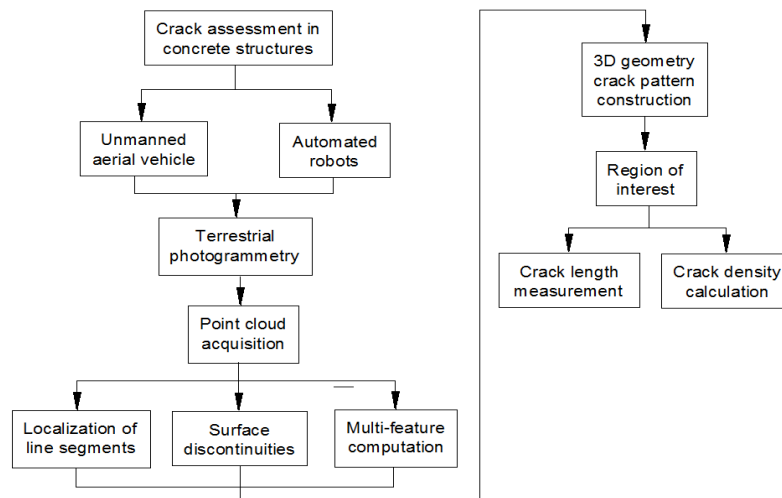

Fig 2. Mobile robot for image acquisition.

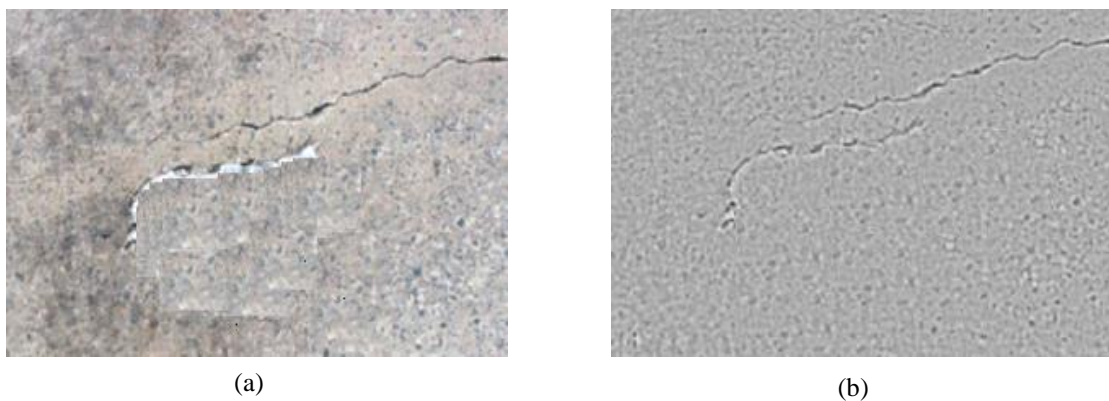Fig 3. Flow chart to process crack detection and analysis in construction.

| (a) | (b) |

Fig 4. (a) Original image with crack;(b) converted image with image processing for further analysis.
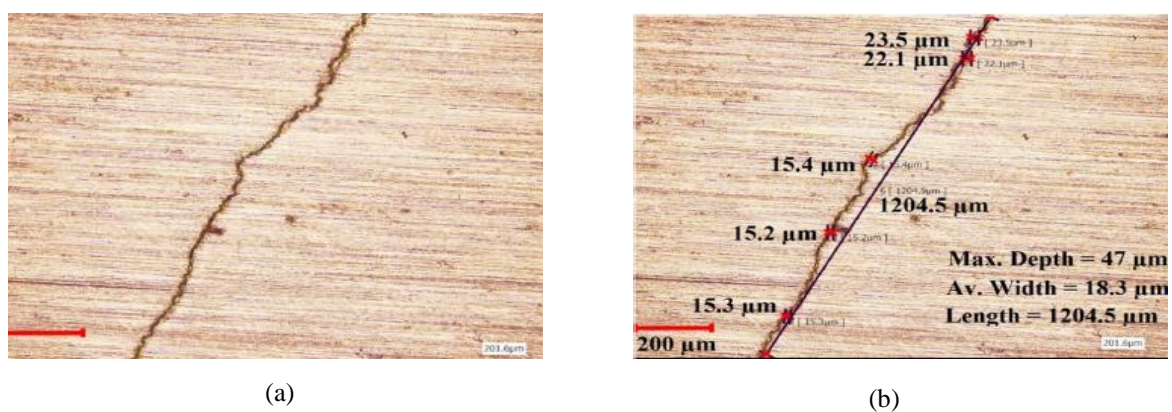

| (a) | (b) |

Fig 5. (a) Acquired image through image processing;(b) density analysis of the formed crack [6].

3.2.Image processing in fluid flow applications

The exclusive pattern of the supersonic jet structure formation, propagating into a stationary gas at an ambient temperature, is shown in figure 6 [12]. The pattern is obtained from a supersonic jet, impacted on an ambient material and accelerated through a bow shaped obstacle, whereas, the outflow decelerates in a Mach disk or jet shock. Image processing is carried out with the radiation obtained from a point x-ray backlighting source, which develops a point-projection shadow of the developed experimental setup on an x-ray film. This type of technique only gives jet flow pattern images of short scale lengths. By using an electron beam, fluorescent images can be produced to characterize and analyze the propagation of hypersonic jets at a long scale [13]. Mach number, jet velocity and jet-to-ambient density ratio, was considered as the main output parameters to study the fluid flow pattern. To analyze the developed output parameters, an image based algorithm as shown in Figure 7 is adopted to indicate the way the curvature looks of the developed head [14].
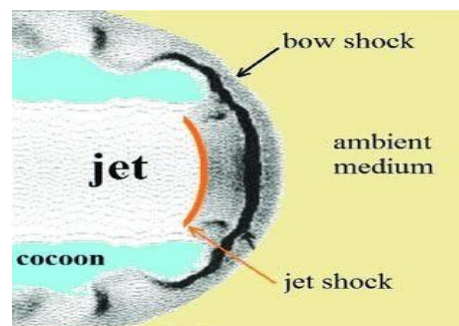

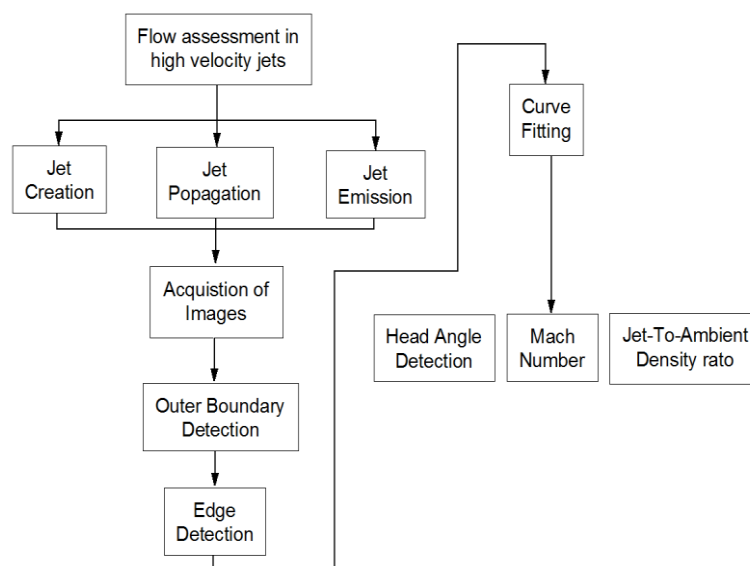Fig 6. Structure of a jet head [14].

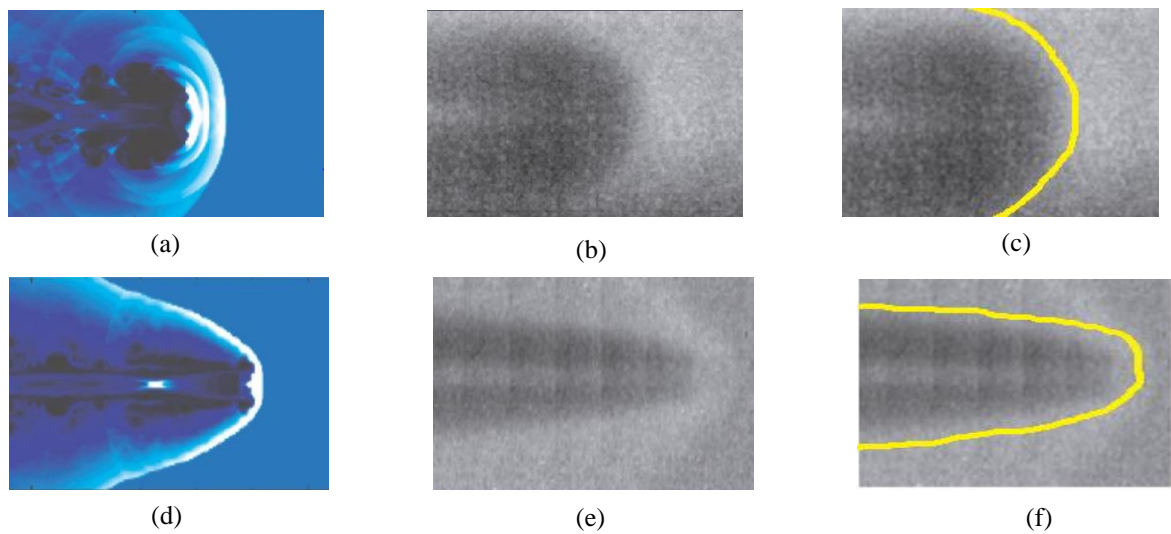Fig 7. Algorithm used for image processing in fluid flow.

Fig 8. (a) Original image of jet initiation;(b) processed image of jet initiation;(c) image with curve fitting;(d) original image of jet propagation;(e) processed image of jet propagation;(f) image with curve fitting [15].

3.3. Image processing in thermal applications

A thermal imaging inspection in a refractory can even stop catastrophic failure leading loss in production and safety related problems. Thermal images can be also used for analyzing vehicle category in night time traffic. Thermal imaging cameras are most suitable in regions, where conventional cameras or image scanners could not be applied due to lack of illumination. Due to advancement in thermal imaging, application is also extended to border surveillance and security (cooled and uncooled cameras), considering their ability to detect sized targets in absolute darkness at extreme weather conditions. Application of thermal imaging are food industry, medicine, building diagnostics, tool condition monitoring, solar panels, volcanology, weather forecasting, Study of prototypes, by using thermal imaging cameras, may help the researchers and engineers to examine and determine the flaws in the prototypes and parts. Infrared technology can be applied for better and long lasting parts [16]. The flow chart given in Figure 9, clearly depicts the thermal imaging procedure that is mostly adopted.
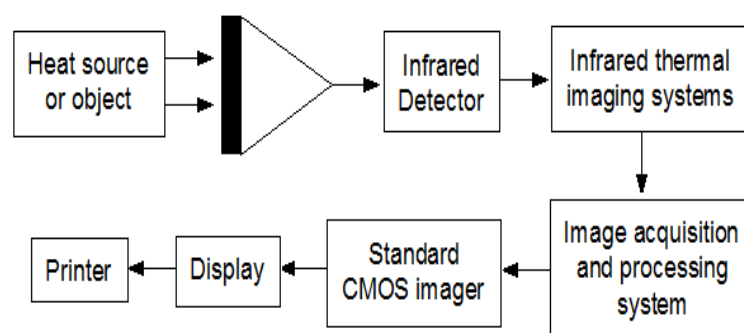

Fig 9. Steps of image processing used in thermal applications.

By the application of Kantorvich (S-K) algorithm, thermo-graphic images were reconstructed and their resolution has been enhanced.

### 3.4. Image processing in medical applications

Brain MRI can be used to diagnose glioma, HIV and cancer metastasis, in the similar way mammograms are used to detect breast cancer and CT scans are employed to detect cardiovascular diseases. Even the skin disorders like eczema, acne, melanoma, mycosis, etc., can also be recognized by microscopic images. The RGB scale of the images are taken into consideration to analyze the diseases. Different color shades using hue saturation value (HSV) and YCbCr like blackish, reddish, bluish, whitish and grayish are used to distinguish the region of interest. The contrast of the image can be adjusted more precisely by mapping the Region of Interests (ROI) with normalization of the gray image intensity. The whole MR and MRI images obtained can be stretched within the gray level region (0,255) and the noise in the images can be removed by normalizing the RGB within 0 to 1 using the following equations, where $g', R', G' and B'$ are the new values of gray level and RGB at the pixel i, j..

$$g'_{i,j} = \left[\left(g_{i,j} - mn \right) \frac{255}{mx - mn} \right] \quad (1)$$

$$R' = \frac{R}{R+G+B}, G' = \frac{G}{R+G+B}, B' = \frac{B}{R+G+B} \quad (2)$$
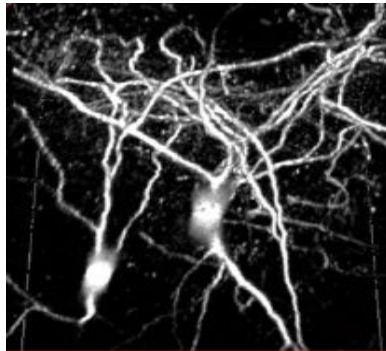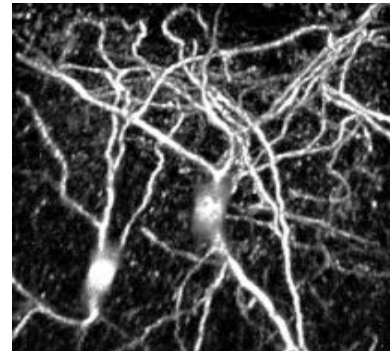
(a)   (b)

Fig 10. (a) the original image of tissues;(b) the normalized image with full gray level (0,255)

This kind of process in medical field can be implemented even to study the skin disorders by normalizing the average skin color to gray intensity level so that the digitization errors can be minimized [17].

3.5. Image processing in material processing

From the previous studies of image processing in medical applications it is known that lot of re-constructional algorithms for 2D images into 3D images have been used [19,20]. Similar way, those relations are extended in the material processing. The relationship between the local 2D coordinate point (u,v) and the global 3D coordinate point P(x,y,z), using the camera coordinate system can be represented by

$$\lambda p = A[R][T]P \quad (3)$$

where λ is the scale parameter, p is the local coordinate point, A is the camera matrix which includes the focal length (fu,fv) and the mid-point of the image (u0,v0), and P is the global coordinate point. The R and T matrices are the rotational and transformation matrixes respectively.
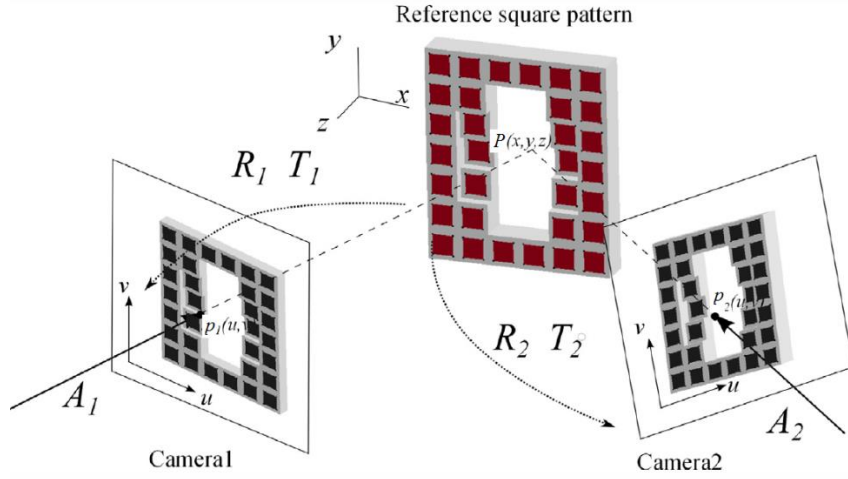

Fig 11. Comparison of rotation and translation of deformed pattern with reference pattern [18].

The A, R and T matrices are given by

$$A = \begin{bmatrix} f_u & s & u_o \\ 0 & f_v & v_0 \\ 0 & 0 & 1 \end{bmatrix}, R = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix}, \text{and } T = \begin{bmatrix} T_x \\ T_y \\ T_z \end{bmatrix} \quad (4)$$

The part of A[R][T] can be condensed into a 3x4 matrix M.

$$M = \begin{bmatrix} M_{11} & M_{12} & M_{13} & M14 \\ M_{21} & M_{22} & M_{23} & M_{24} \\ M_{31} & M_{32} & M_{33} & M_{34} \end{bmatrix} \quad (5)$$

Once the rotation and the transformation of the etched pattern is known, then the position and the scaled image can be calculated, thus the strain developed on the sample can be obtained by the equation

$$\lambda \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} M_{11} & M_{12} & M_{13} & M14 \\ M_{21} & M_{22} & M_{23} & M_{24} \\ M_{31} & M_{32} & M_{33} & M_{34} \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} \quad (6)$$

Curve fitting method can be used to determine the dimensions of the developed strain on the sample where the patterns are made. By measuring the major and minor dimension of the deformed circle grids, and comparing with the original ones, the developed strain can be measured.

(a)   (b)   (c)

(d)   (e)   (f)
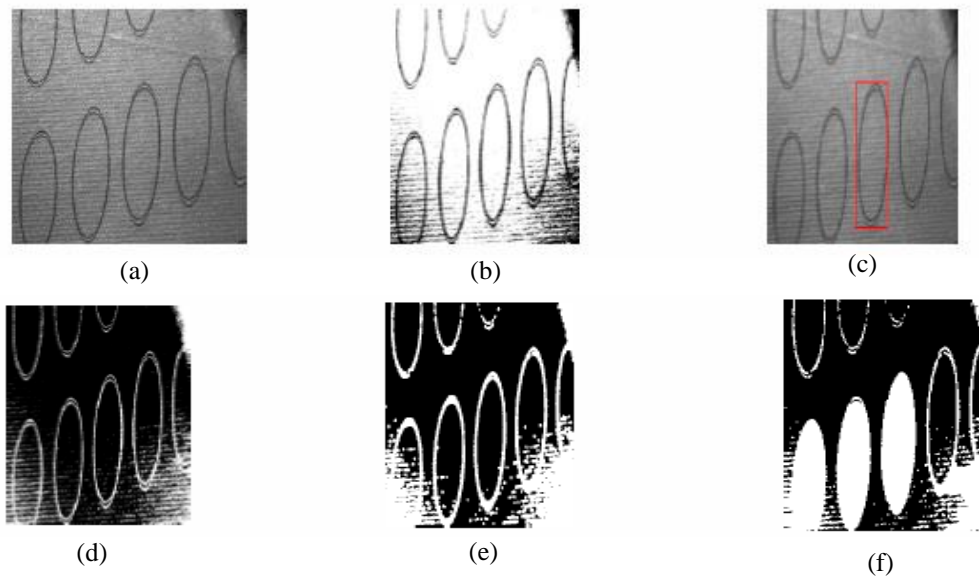
Fig 12. (a) Acquired image; (b) Gray scale to binary conversion; (c) Morphological element identification arbitrary shapes; (d) Complement of b/w image; (e) Two Dimensional Averaging filter and dilation and erosion to remove noises; (f) Flood fill.

To picking up the region of interest, the developed algorithm displays the major and minor axis dimensions. Using these dimensions, the developed strain can be calculated using the appropriate equations like,

Fig 13. Measurement of image region major and minor axis dimension [22].

The major and minor strain is given by

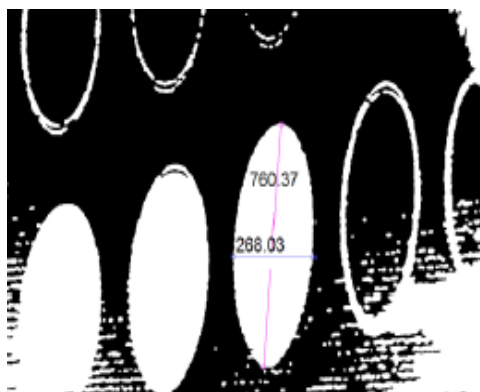$$\varepsilon_{major} = \ln\left(\frac{a}{d}\right) \text{ and } \varepsilon_{minor} = \ln\left(\frac{b}{d}\right) \quad (7)$$

where a and b denote the major and minor axis of the ellipse respectively, and d denotes the original diameter of the circle grid.

3.6. Image processing in food industries

Image processing is intended to use for food safety and standards. Moreover, this is a contemporary technique used to ensure consumer satisfaction mostly in a range of food-related fields. Mainly focusses on the detection of adulteration, ensures virgin fruits, vegetables and meat to customers. Even image processing is used to sever products and check & evaluate food-producing tools. This all eventually intense to meet quality in life-saving products, especially in foods.

Consider the fruit Orange which has infected regions in a different color in nature may be brown Figure 14 (a). By distinguishing these colors by Image processing the go or no go status of fruits will be decided. The pixels near the different colors or pixels which are a mixer of both (orange and brown) colors are identified and it is spotted and bounded by multicolor [23]. This multi-color represents the boundary to be detect called the region of interest (ROI).

(a)   (b)

Fig 14. Edge detection with gray intensity (a) level 100; (b) level 255.

Same as all other processes food industry also follows image capturing, image segmentation, object measurement or feature extraction, and classification. This method is pervasive to maintain a good quality of food. Fuzzy logic has also considered brightening the boundary. By adjusting the threshold value the RGB [25, 26] image can be converted to grayscale figure 15.

Fig 15. Normalized image with different thresholds of RGB.

Actually, the conversion of RGB to grayscale or black & white is to increase the processing time and reduce the computational time. Even color intensity will not have any influence over the results.

4. Conclusion

Computer aided Image processing techniques is pervasive in all the field and also a contemporary field of research. Several applications of image processing like construction, fluid flow, medical treatment, material screening, medical and food processing were studied in this review. Most of these applications adapt the same procedures like filtering the initial input image, segmentation and separation of the region of interest, area extraction and classification based on these required features. Although each area required special treatment, there are few common methods like edge detection, edge sharpening, noise detection and smoothening, and conversion to gray scale image for identification. All these are done through normalizing the RGB and gray values by adopting few algorithms like neural networks, fuzzy clustering, decision trees, random forests, etc. Eventually Potential for doing research in computer aided image processing techniques are substantial and challenges to be solved and yet to find in each field are boundless. The concept and methodology to implement these techniques is almost similar in all fields which can infer to the new researchers with wide opportunities. Eventually it is proven that substantial innovations and researches are in progress in and around the computer aided digital image processing and this going to lead the future unanimously.

References

[1]   PrateekPrasanna, Kristin J Dana, NenadGuncunski, Basily B Basily and Hung M La 2014 Automated Crack Detection on concrete bridges, *IEEE Transactions on Automation Science and Engineering,* Vol. **13 (2)**, pp. 1-9.

[2]   Valenca J, Puente I, Julio E, Gonzalez Jorge H and Arias Sanchez P 2017 Assessment of cracks on concrete bridges using image processing,*Laser scanning survey, Construction and Building Materials,* Vol. **146**, pp. 668-678.

[3]   Jingsi Yang and Jesse Zhu 2015Cluster identification using image processing, *Particulogy*, Vol. **23**, pp. 16-24.

[4]   Jin- Young Park, Jung-Ho Chung, Jung-Seok Lee, Hee-Jim Kim, Seong-Ho Chol and Ul-Won Jung 2017 Comparison of the diagnostics accuracies of optical coherence tomography, micro computed tomography, and histology in periodontal disease: an ex vivo study, *Journal of Periodontal and Implant Science*, Vol. **47(1)**, pp. 30-40.

[5]   Jeong Choi, Yun Lee, Yun Yong Kim and Bang Yeon Lee 2017Image processing technique to detect carbonation regions of concrete sprayed with phenolphthalein solution, *Construction and Building Materials,* Vol. **145**, pp. 451-461.

[6]   Hesham M Shehata, Yasser S Mohammed, Mohammed Abdellatif and Taher H Awad 2018 Depth estimation of steel cracks using laser and image processing techniques, *Alexandria Engineering Journal,* Vol. **57** (4), pp. 2713-2718.

[7]   Maheswari Subramanian and ReebaKorah 2018 A framework of secured embedding scheme using vector discrete wavelet transformation and lagrange interpolation, *Journal of computer networks and communications,* Vol **20**, pp. 1-9.

[8]   ChristoperSkea, AlirezaRezagholilou, Pouria Behnoud Far, RaoofGholami and Mohammed Sarmadivleh 2018An approach for wellbore failure analysis using rock carvings and image processing, *Journal of Rock Mechanics and Geotechnical Engineering,* Vol. **10 (5)**, pp. 865-878.

[9]   Tomoyuki Yamaguchi, Shingo Nakamura, Ryo Saegusa and Shuji Hashimito 2008 Image based crack detection for real concrete surfaces, *IEE Journal on Transactions on Electrical and Electronics Engineering,* Vol. **3(1)**, pp. 128-135.

[10]   Carnedente V 2013 Experimental and numerical simulation, by an arcjet facility, of hypersonic flow in Titan's atmosphere, *Experimental Thermal and Fluid Science,* Vol. **48**, pp. 97-101.

[11]   KedarBharadwaj, AzadehSheidaei, ArashAfshar and JavadBaqersad 2019 Full field strain prediction using mode shapes measured with digital image correlation, *Measurement,*Vol. **139**, pp. 326-333.

[12]   Blondin J M 1989 Herbig-Haro objects as the heads of radiative jets, *The Astrophysical Journal*, Vol. **37**, pp. 37-40.

[13]   Belan M 2014 Hypersonic jets in astrophysical conditions: focus on spreading and asymmetric stability properties, *New Journal of Physics,* Vol. **16**, pp. 679-698.

[14]   Mirazaei M, and Khodabakshi Rafsanjani H 2017 An automatic algorithm for determination of the nanoparticles from TEM images using circular hough transform, *Micron,* Vol. **96**, pp. 86-95.

[15]   Mohsen Mirzaei, and Hossein Khodabakshi Rafsanjani 2018 Assessment of image processing methods to characterize the precise shape of the jet head in the hypersonic jet flows, *Flow Measurement and Instrumentation,* Vol. **64**, pp. 142-154.

[16]   Xiaona Li, Ruolan Li, Mengyu Wang, Yaru Liu, Baohua Zhang and Jun Zhou 2017 Hyperspectral Imaging and Their Applications in the Nondestructive Quality Assessment of Fruits and Vegetables,*hyperspectral-imaging-in-agriculture-food-and-environment(Intech Open).*

[17]   Soma Datta and NabenduChaki 2015 Person identification technique using RGB based on dental images, *14th Computer Information Systems and Industrial Management (CISIM)* Warsaw, Poland, pp.**169-180**,

[18]   Kentaro Sato, Qiang Yu, Jiro Hiramoto, Toshiaki Urabe and Akihide Yoshitake 2015 A method to investigate strain rate effects on necking and fracture behaviors of advanced high strength steels using digital imaging strain analysis, *International Journal of Impact Engineering,* Vol. **75**, 2015, pp. 11-26.

[19]   PadmajaGrandhe, Sreenivas Reddy Erra and VasumathiDevara 2018 Adaptive analysis and reconstruction of 3D DICOM images using enhancement based SBIR algorithm over MRI, *Biomedical Research,* Vol. **29(4)**, pp. 644-653.

[20]   Sato J 2006 Recovering multiple view geometry from mutual projections of multiple cameras, *International Journal of Computer Vision,* Vol. **66**, pp. 123-140.

[21]   Kenji Takada, Kentaro Sato and Ninshu Ma 2015 Fracture prediction for automotive bodies using a ductile fracture criterion and a strain dependent anisotropy model, *SAE International,* Vol **1,** pp. 1-10.

[22]   Mugendiran V, AGnanavelbabu 2017 Comparison of plastic strains on AA5052 by single point incremental forming process using digital image processing, *Journal of Mechanical Science and Technology,* Vol. **31 (6)**, pp. 3943-2949.

[23]   Nikos Petrellis 2018 A review of image processing techniques common in human and plant disease diagnosis, *Symmetry,* Vol. **10(7)**, pp. 1-34.

[24]   Deepak P Hujare ,Nitesh R Girase and Madhuri G Karnik 2016 Crack detection in Shaft by Finite Element Analysis and Experimental Modal Analysis, *European Journal of Advances in Engineering and Technology,*Vol**3(10)**: 18-24.

[25]   Muthukrishnan R 2011 Edge detection techniques for image segmentation, *International Journal of Computer Science and Information Technoology,* Vol. **3,** pp. 259-267.

[26] JissKuruvilla, Dhanya Sukumaran, Anjali Sankar and Siji P Joy 2016 A review on image processing and image segmentation, *International Conference on Data Mining and Advanced Computing (SAPIENCE).*