Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 14 (13): 1391-1396, 2014
ISSN 1812-5654 / DOI: 10.3923/jas.2014.1391.1396

Particle Mixing Analysis Using Digital Image Processing Technique

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Abstract: Digital Image Processing (DIP) techniques have shown great potential in the field of particle mixing and in this paper, colour histogram was implemented to analyse particle mixing in a fluidized bed. The proposed method serves as a proof of concept that particle mixing alters the colour distribution in the image, thus can be used to analyse the quality of the mixing process. The results indicate that particle mixing indeed alters the histogram of images taken at various durations. Therefore it presents an interesting avenue for research in an automated particle mixing technique based on image processing. From the study, the histogram for colours distribution of red, green and blue gave the same pattern starting at 90 sec which indicate that the particle is well mixed. Hence, DIP has high potential to be used for studying performance of particles mixing process in a fluidized bed.

Key words: Image processing, mixing, fluidized bed, non-invasive method, webcam

INTRODUCTION

Particle mixing is an important and widely used process in many industries such as chemical, pharmaceutical, food, mining and agriculture (Kaye, 1997). Mixing is defined as a process to combine two or more materials to form one substance or mass. In order to increase the homogeneity of the mixture, external forces such as mechanical agitator and gas blower are used (Howard, 1983).

This study focuses on the mixture of coloured particles. There are three mixing mechanisms, namely convective, diffusive and shear (Charles, 2005). In free-flowing powders, diffusive and shear mixing give rise to size segregation (Susana and Santomaso, 2011). Therefore for such powders, convection is the major mixing mechanism. In most applications, uniform mixing and blending of the different types of particles is desired. This is because a segregated non-uniform mixture can severely degrade the quality of the final product and in many situations, have serious safety implications (Allen, 1981). For example, in the pharmaceutical industry, it is essential that the same amount of active ingredients to be present in each individual tablet or capsule (Allen, 1981). That mean, the quality of particles mixing process must be thoroughly analysed to produce a good product.

The quality of mixing can be determined by using either invasive or non-invasive methods. Invasive methods involve continuous sampling and evaluation of the mixture to determine its mixing quality. It has a tendency to produce unreliable data as many manual processes are involved (Venables and Wells, 2001). For non-invasive methods, manual sampling is not required, therefore are more preferable. The methods used are usually advanced and expensive techniques such as Positron Emission Particle Tracking (PEPT) (Rafiee *et al*., 2011), Discrete Element Model (DEM) Simulation (Gui and Fan, 2011) and Magnetic Resonance Imaging (MRI) (Porion *et al*., 2004).

Alternative method to this expensive technique is digital image processing which is cheap to implement. This method is used with the intention to develop such a system using web cameras to acquire the images at specified intervals and monitor the mixing process based on acquired images. To perform this, the images acquired during the mixing process are analysed. It has been found that the colours in the image indeed changes during the mixing process.

Digital Image Processing (DIP) is a form of signal processing that produces a digital image or a set of characteristics or parameters related to the image as its output. Interest in digital image processing methods stems from two principal application areas, namely: (1) improvement of pictorial information for human interpretation and (2) processing of image data storage, transmission and representation for autonomous machine perception (Kim and Kim., 2011).

In DIP, an image is represented as pixels. The pixels carry information regarding its colour. The representation can either be single-dimensional grayscale (0 to 255 representing different levels of grey) or three-dimensional colour information (representing different levels of red, green and blue). These numerical values can be interpreted and processed by the computer.

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This study presents a non-invasive DIP-based method for quality evaluation of a fluidized bed mixing setup. In this study, red and white coloured sago pellets were used. Mixing was performed and images were taken at specified time intervals. Histograms of these images were then analysed to reveal important characteristics of the mixing process.

In the beginning of the mixing process, the colour distribution is expected to be approximately similar. This is because the particles are arranged at the top and bottom layers. As mixing progresses, particles below would start to rise to the top of the mixture resulting in the change in colour distribution. These changes would continue until a homogeneous mixture is achieved where the colour distribution is not expected to change very much, thus indicating that the mixing process is completed.

MATERIALS AND METHODS

The mixing process was performed by using a fluidized bed as shown in Fig. 1. In order to prevent segregation, the particles must be uniform in particle size, density and shape. The particle also must be non-cohesive to avoid stationary state in the fluidized bed. Free flowing sago pellets with similar size, density and shapes have been used. However, the sago pellets were distinguished with different colours (red and white) to facilitate the mixing analysis.

Figure 2 shows the schematic diagram of the fluidized bed. The fluidization process occurred when the fluid is passed upwards through a bed of particles and the particles flowed upward caused by the upward drag force exerted by the fluid. They were fluidized at the minimum fluidization velocity. In the experiment, similar amounts of different dyed sago pellets were used, with a weight ratio of 50:50. Breakage of sago is assumed to be negligible since low velocity was used. Both sago pellets were sieved using a vibrated sieve to obtain similar particle sizes.

A Logitech web camera was used for image acquisition process. The camera has a resolution of 640×480 pixels with 24 bit Red, Green and Blue (RGB) representation. The camera acquisition rate is 30 images per second. To acquire the images, the web camera was connected to the computer which was placed on top of the fluidized bed. Sequences of images were captured in 30 sec intervals using a software trigger. MATLAB version r2011a was used for image analysis. The histogram image processing function utilized were from the MATLAB Image Processing Toolbox.

RESULTS AND DISCUSSION

Histograms for red, green and blue channels were plotted. In the histogram, the y-axis represents frequency and x-axis represents colour (which ranges from 0 to 255). A higher frequency value indicates that the image have more of that colour. For example, an image which has redder colour will have a more intense distribution in its histogram compared to others.

Fig. 1: A fluidized bed

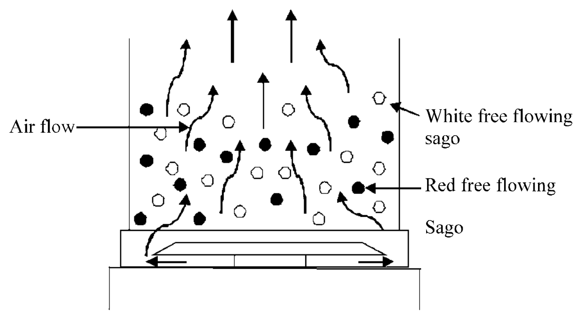

Fig. 2: Schematic diagram of a fluidized bed

Figure 3 show the initial mixing image and colour distribution. The particles were static as the fluidization process has not started yet. From top view where the web cam was placed, only white sago pellets were visible as it was placed at the upper part of the fluidized bed while the red sago pellets were distributed at the bottom. The white colour is a combination of same amount of three colours which are red, green and blue. From the histogram of colours distribution as shown in Fig. 3, it is observed that the histogram for each colour was the same. The highest peak for each colour distribution was approximately 130. The tapering in the histogram was because of shadows present in the pellet image.

From Fig. 4 and 5, it was observed that the frequency of green and blue components decreased during

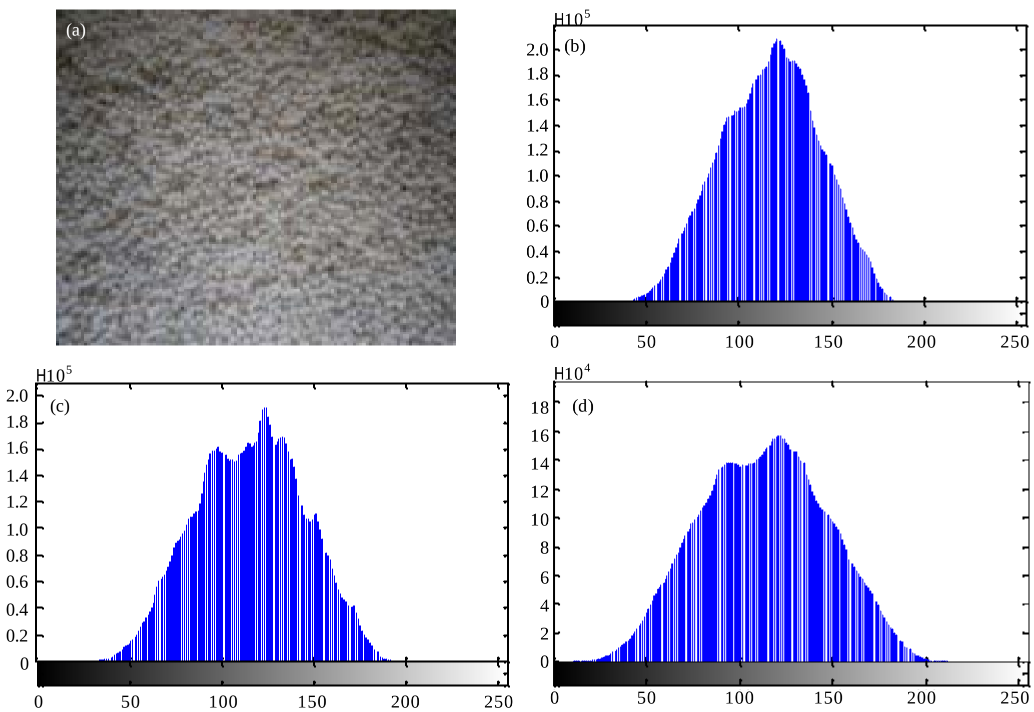

Fig. 3(a-d): Colours distribution at 0 sec, (a) Image, while graphical distribution of, (b) Red, (c) Green and (d) Blue color

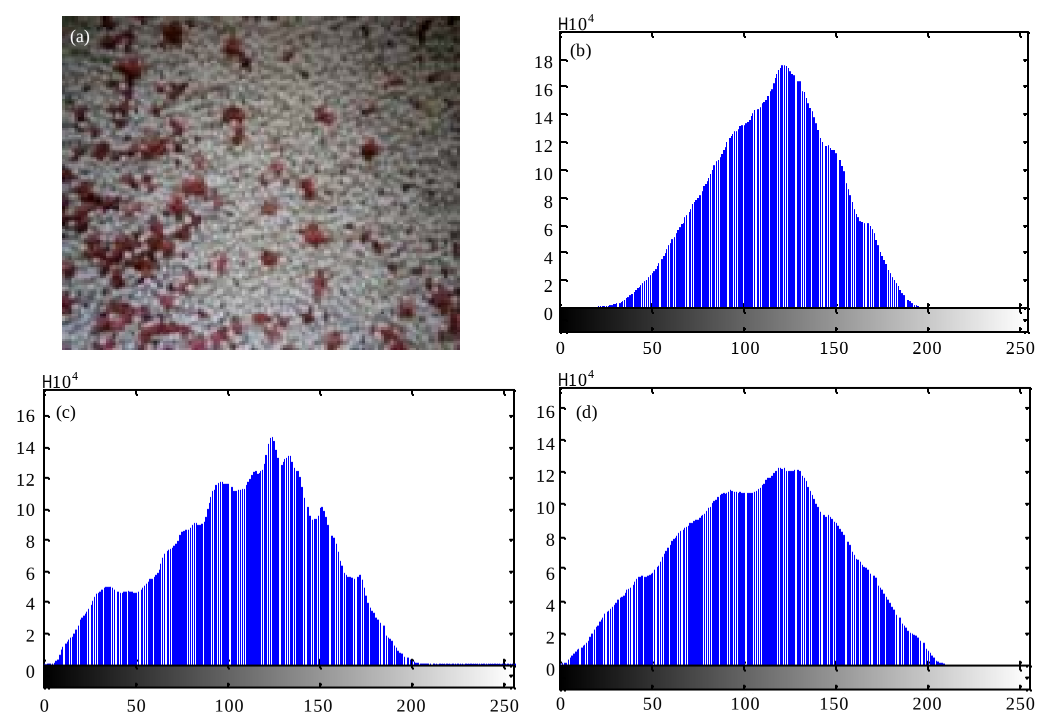

Fig. 4(a-d): Colours distribution at 30 sec, (a) Image, while graphical distribution of, (b) Red, (c) Green and (d) Blue color

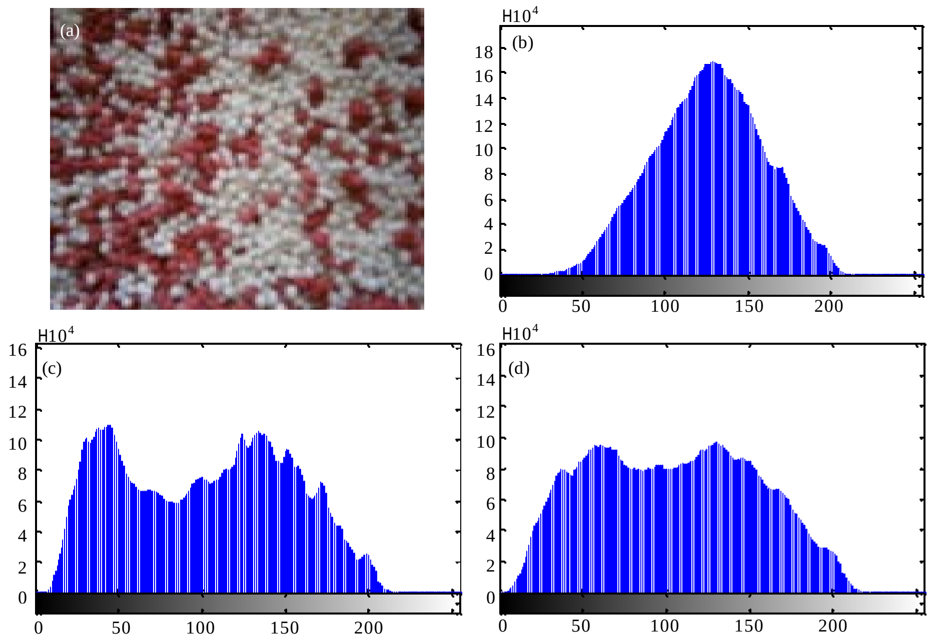

Fig. 5(a-d): Colours distribution at 60 sec, (a) Image, while graphical distribution of, (b) Red, (c) Green and (d) Blue color

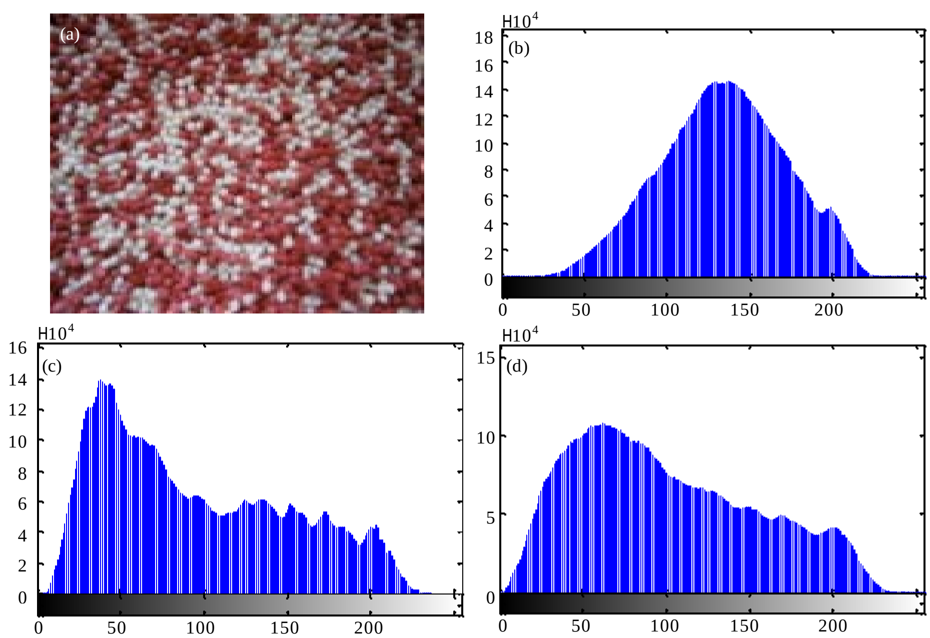

Fig. 6(a-d): Colours distribution at 90 sec, (a) Image, while graphical distribution of, (b) Red, (c) Green and (d) Blue color

30 to 60 sec. This is because the white pellets on the surface were gradually decreased and replaced by red ones. Since the value of white sago particles was decreased, the colour distribution for green and blue was also decreased. Red particles started to present themselves in the mixing image at 30 sec and its value increased in mixing image at 60 sec.

As the mixing time was further increased, the mixing quality increased. Figure 6, 7 shows the histogram of images taken at 90 and 120 sec. The histogram pattern for

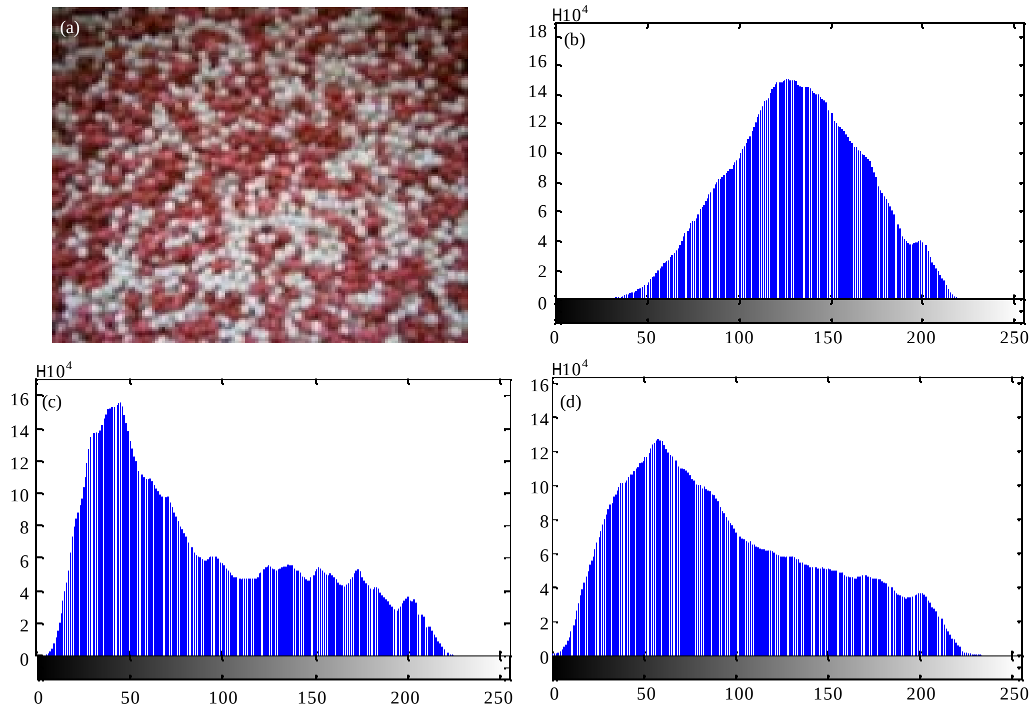

Fig. 7(a-d): Colours distribution at 120 sec, (a) Image, while graphical distribution of, (b) Red, (c) Green and (d) Blue color

red, green and blue components was relatively similar. This indicates that the colour distribution of the two images were almost similar. This observation indicates that particles have been distributed well in the fluidized bed. Therefore, it was concluded that the mixture was sufficiently homogeneous at the point where the histogram distribution start to become constant.

CONCLUSION

A histogram analysis of particles mixing process in a fluidized bed was performed. A low-cost web camera was used as the image acquisition device. Histogram analysis performed on the images at different intervals indeed indicates that the colour distribution is affected by the mixing process. Furthermore, the histograms showed similar patterns when the mixing process was completed, showing that it can be used as an indicator for the homogeneity of the mixture. The findings of this paper may be used as a proof of concept for development of digital image processing technique to analyse the quality of particle mixing by using a web camera.

The histograms for each of the colour component were constant for image at 90 and 120 sec. From this result, the particles were assumed as well mixed at 90 sec because the colour distribution was constant. It can be concluded that the image processing technique has a potential to be used for analyzing the particle mixing in fluidized bed.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support from Ministry of Science and Technology and Innovation (MOSTI) grant No: 03-01-01-SF0031, Excellent Fund Grant No: 600-RMI/DANA 5/3/RIF (90/2012), Research Management Institute, UiTM and Faculty of Chemical Engineering, UiTM.

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