Automated Sorting of Closed-Shell Pistachio Nuts Using Machine Vision System

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Abstract: Pistachio nut is one of the most important commodities of Iran. The quality of market pistachio nuts is an important factor for consumer's acceptance. Sorting of pistachio nuts is a post-harvesting process which is currently performed using a mechanical device called "pin-picker". Replacement of pin-picker with other appropriate systems due to the possibility of damage the kernel of open shell pistachio nuts is necessary. In this paper, an intelligent low cost system is proposed, designed and developed for pistachio sorting using computer vision. The system uses a combination of two flat mirrors and one low cost CCD camera to obtain suitable 3 dimensional images which are processed to detect closed-shell nuts. The programming section of proposed system consists of two steps. First, the system should be trained using particle swarm optimization which is introduced by Eberhart and Kennedy. Then, the trained system can sort the mixed pistachios. The experimental results for three varieties of pistachios nuts shows 90.2%, 83.3% and 86.6% closed-shell pistachio nuts removal accuracy, respectively for Akbari, Ohadi and Kalle-Ghuchi pistachio nuts varieties.

Key words: Pistachio · Closed shell · Sorting · Computer vision · PSO

INTRODUCTION

The Pistachio nuts (*Pistacia vera* L.) is one of the popular tree nuts cultivated in Middle East, United states and Mediterranean countries. Based on FAO statistics, Iran as a first producer of pistachio nuts produced about 192269 Mt of pistachio nuts in 2008, which represents approximately 35% of the world's pistachio production [1]. The post-harvest process of pistachio nuts includes several stages. When pistachios arrive at the processing plant, the following procedures are conducted: (a) dehulling, to separate the soft hull from nuts; (b) trash and blank separation, to remove blank pistachios and trashes such as small branches, remaining shells and leaves; (c) unpeeled pistachios separation, to remove unpeeled and unripe nuts; (d) washing, which involves spraying water at high pressures on the pistachios to clean the nuts; (e) drying, to decrease moisture content of pistachios from 30-40% to the appropriate level; (f) split nuts separation, to separate split nuts from non-split ones; (g) salting; (h) roasting; and (i) packaging [2].

Post-harvest processing of open (split) and closed (unsplit) shells pistachio nuts is different. Open-shell pistachios are principally served as roasted nuts and they are usually marketed for snack food. Unsplit pistachios are undesirable because they are difficult to open and they may contain immature kernels. Therefore, sorting of open and closed shell pistachio nuts is an important part of the post-harvesting operations. Closed shell nuts are currently separated from open shell product by mechanical devices called "Pin-picker". Although they have high capacity, they may damage the kernel of open shell nuts by inserting a needle into the kernel meat. The hole created by the needle can give the appearance of an insect tunnel and lead to rejection by the consumer [3].

Diverse techniques including mechanical, optical, electrical and acoustical have been used for classification and/or sorting of pistachio nuts. Machine vision was recommended for detection of stained and early split pistachio nuts by Pearson [4] Ghazanfari *et al.* employed Fourier descriptors and gray level histogram features of two-dimensional images to classify pistachio nuts into

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one of three USDA size grades or as having closed shells [5, 6]. Fourier descriptors are very time-consuming and they are not suitable for real-time applications. Pearson's system exhibits that pistachios with either split or unsplit shells can be distinguished by means of gray scale images [7]. Later, an automated machine vision system developed to recognize and remove pistachio nuts with closed shells from processing streams. The system includes a feeding system to feed nuts through three high speed line-scan cameras without tumbling. The camera output signals are input to digital signal processing boards which educe image features characteristic of closed and open shell pistachios. The sorting accuracy of this machine vision system for separating open shell from closed shell nuts in two passes is approximately 95% [3]. Even though the system has a throughput maximum rate of 40 nuts per second, its cost is costly for many producers in Iran.

As an alternative for vision systems, impact acoustic emission was used as the basis for a device that separates pistachio nuts with closed-shells from those with split-shells [8-10]. The proposed algorithm used a small number of features and achieved a classification accuracy of 91.5% on the validation dataset. Later, an intelligent pistachio nut sorting system combined with acoustic emissions analysis, Principal Component Analysis (PCA) and Multilayer Feed forward Neural Network (MFNN) classi?er was developed and tested [11, 12, 8]. This system is less expensive than Pearson's vision system barring that it is very slower.

In this study a high performance low-cost computer vision system for automated sorting of closed pistachio nuts is designed and developed. The system tested for three important varieties of Pistachio nuts in Iran namely Akbari, Ohadi and Kalle-Ghuchi.

In this system, intelligent learning process is used and tuned by Particle Swarm Optimization (PSO) algorithm. PSO as a core of learning system is used for selecting of appropriate values for separation. PSO is a population-based stochastic optimization algorithm modeled after the simulation of the social behavior of bird flocks. PSO is easy to apply and has been effectively applied to solve a wide range of optimization problems. Thus, due to its simplicity and efficiency in navigating large search spaces for optimal solutions, PSOs are used in this research to develop efficient, robust and flexible algorithms to solve a selective set of difficult problems in the field of image processing.

MARERIALS AND METHODS

Acquire a suitable image from pistachio nut is one of the major problems in the classification of pistachio nuts using computer vision. Due to the spherical shape of pistachio nuts, the axial rotation of pistachio nuts cannot be mechanically constrained as they are conveyed. To provide for whole surface inspection, three line-scan cameras have been used before to take several linear images from all directions of pistachio during free fall [4].

This method of taking images is very expensive. To overcome this shortcoming, three cameras were replaced by one camera and two flat mirrors. This allows the system to view every side of the nut which eliminates system sensitivity to pistachio orientation. The arrangement of these components and sample taken image can be seen in Fig. 1. As it can be seen in the figure, using this method, cleavage of an open area of pistachio nuts in any orientation can be detected by only one camera.
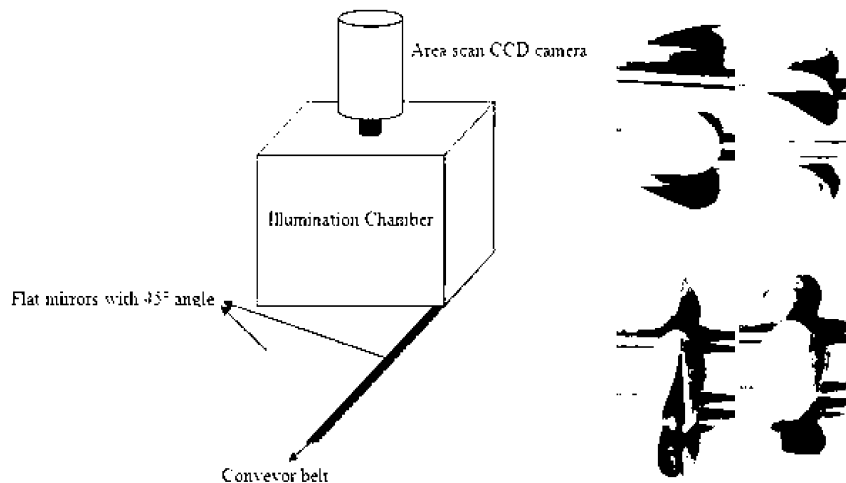

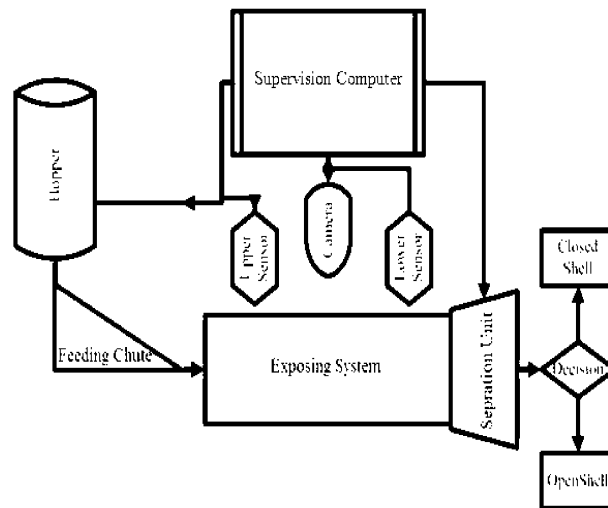Fig. 1: Methods of image acquisition and sample of taken image

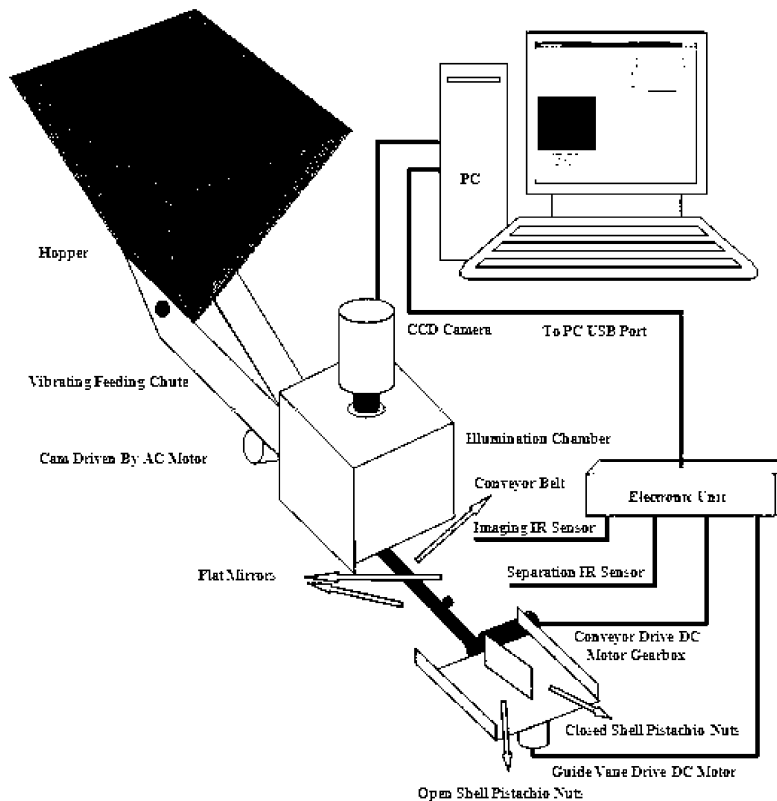Fig. 2: Block-diagram of the developed sorting system

Fig. 3: Schematic shape of designed sorting system

To achieve appropriate processing the Sorter system should be fully automatic and have a discrete controller while it has discrete events such as pistachio arrival in the imaging area or separation area. The general configuration of the designed system is shown in Fig. 2.

Proposed system has several subsystems includes: Feeding subsystem, exposing subsystem, imaging subsystem, electronic subsystem and separation subsystem. The schematic shape of designed sorting system shows in Fig. 3.

Sequence of System Application: Following the system start and when a pistachio crosses the ray of imaging IR sensor, the camera takes an image from pistachio nut and
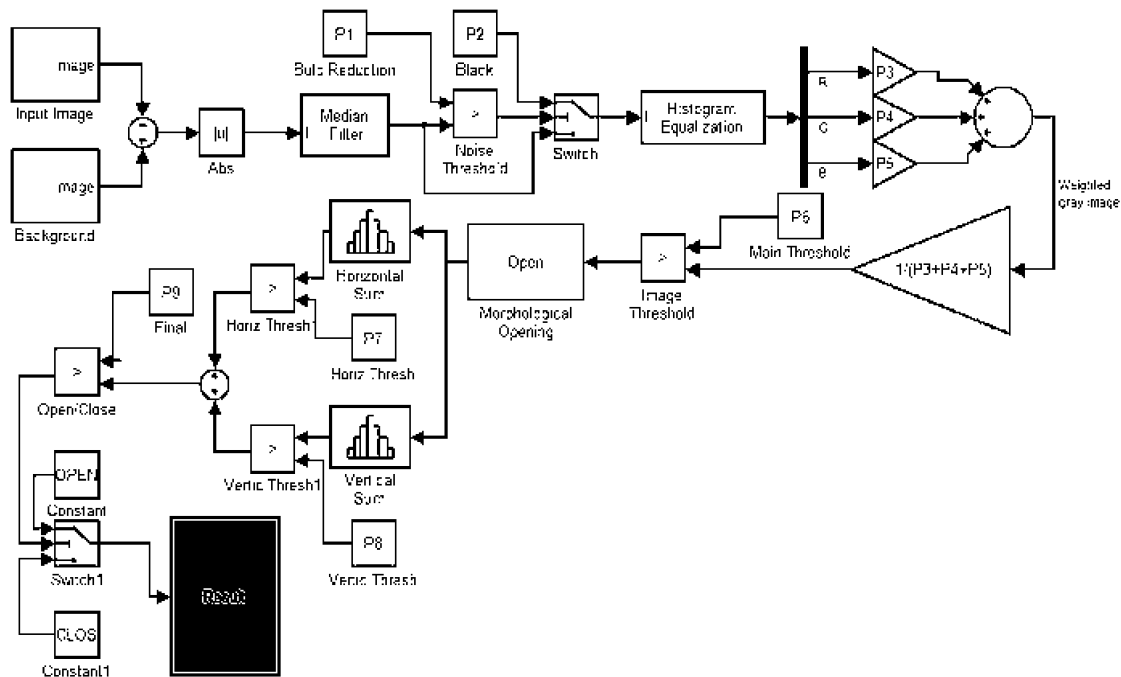
Fig. 4: Classifying of the input pistachio image as open or closed shell

after a short delay from background. This image becomes rapidly checked for open or closed status and then the result is appended to result queue. In the splitting excitation the splitter picks a first saved result from the sorting queue and splitter changes its sorting group to read position.

Learning and Image Processing Algorithm: In the real-time many limitations is appeared and application of many methods such as Fourier methods, Spectral methods, Active contours and all that are difficult to utilize and cost-consuming. Therefore the simple methods should be completely analyzed and optimized in off-line step of procedure.

Thresholding and morphological applications are subset of high speed methods in the real-time applications. In this study these dealings are optimized and implemented for pistachio sorting system. To best of our knowledge, few works are published in implementation of pistachio sorting system using low cost and simple systems. Very low-priced camera is employed and therefore high noisy and low resolution image is in right to use. Moreover, the frame rate of the camera is confined and this restriction becomes many hard problems for segmentation and evaluation of image for closed or open shell pistachio nuts. The high performance system of judgment is presented in figure 4.

Table 1: The unknown parameter of image processing algorithm

P1	Thresholding level for noise reduction
P2	Dark color
P3	Red channel weight
P4	Green channel weight
P5	Blue channel weight
P6	Major Threshold level
P7	Horizontal sensitivity threshold
P8	Vertical sensitivity threshold
P9	Detection final threshold

Image processing algorithm is programmed in real-time and high performance Delphi programming environment. The unknown parameter of image processing algorithm is according to table 1.

The unknown parameters are tuned with PSO algorithm. Particle Swarm Optimization (PSO)developed by Kennedy and Eberhart [13, 14], is one of the most well-known evolutionary optimization techniques. PSO idea is based on social interaction such as bird flocking and fish schooling. The algorithm of PSO is demonstrated as follows.

- Initialization. Randomly spread a population of the potential solutions, called "particles" and each particle is allocated a randomized velocity.

- Velocity Update. The particles thus "fly" through search hyperspace while updating their own velocity, which is accomplished by considering its own past flight and those of its companions.

The particle's velocity and position are dynamically updated by the following equations:

$$x_{id}^{NEW} = w_i \; x_{id}^{NEW} = x_{id}^{OLD} + v_{id}^{NEW} \qquad (1)$$

$$v_{id}^{NEW} \; w_i \cdot x_{id}^{OLD} + C_1 \cdot r_1 \cdot \left(x_{pd} - x_{id}^{OLD} \right) + C_2 \cdot r_2 \cdot \left(x_{gd} - x_{id}^{OLD} \right) \qquad (2)$$

Where the acceleration coefficients C_1 and C_2 are two positive constants; w_i is an inertia weight and r_1, r_2 is a uniformly generated random number from the range [0, 1] which is generated in each iteration consistently. Equation (1) shows that, when calculating the new velocity for a particle, the previous velocity of the particle (v_{id}), their own best location that the particles have discovered previously (x_{id}) and the global best location (x_{gd}) all contribute some influence on the outcome of velocity update. The global best location (x_{gd}) is identified, based on its fitness, as the best particle among the population. All particles are then accelerated towards the global best particle as well as in the directions of their own best solutions that have been visited previously. While forthcoming the current best particle from different directions in the search space, all particles may run into unexpectedly even better particles en route and the global best solution will finally appear. Equation (2) shows how each particle's position (x_{id}) is updated in the search of solution space.

Fitness function of the learning process is based on train dataset which fulfilled by N open and closed shell images. Fitness function assessment is shown in equation (3). Therefore the error of classifying is appropriate to consider in optimization process as training process.
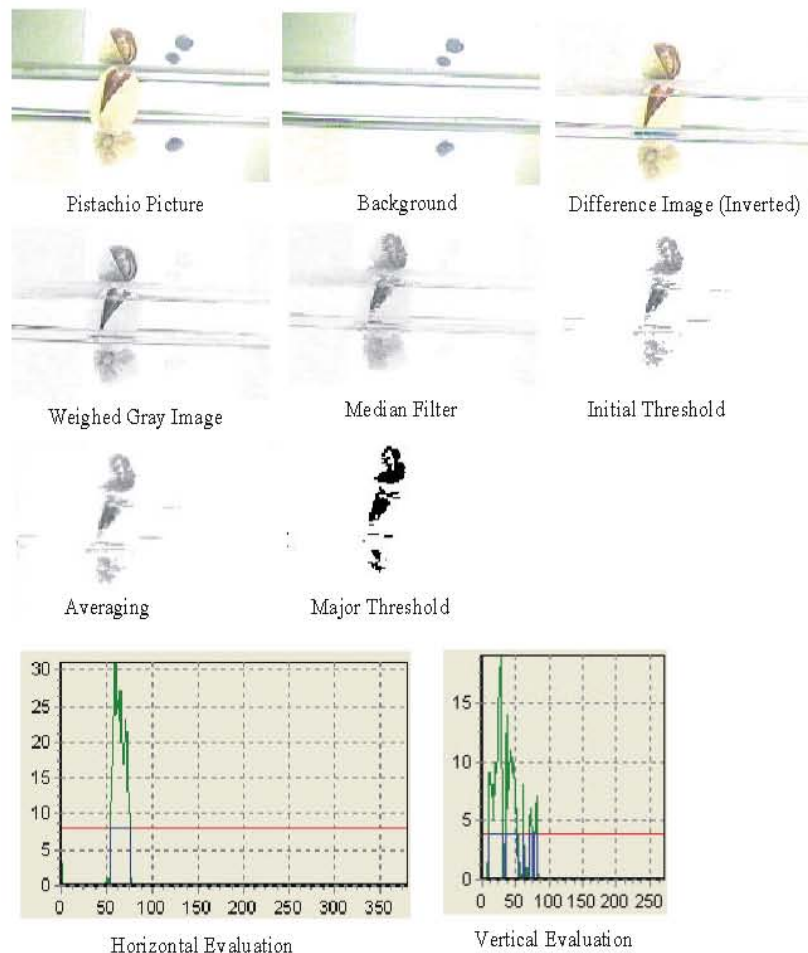

Fig. 5: Sample online images of open and close pistachio

$$\text{Fitness} = \varepsilon \sum_{i=1}^{N_{open}} err_i + (1-\varepsilon) \sum_{i=1}^{N_{colse}} err_i \qquad (3)$$

Where ε is weighing function between important of open or close dispersion. If $\varepsilon > 0$ all of open shells detected as closed and thus the purity of the box of open shells becomes high. Also, if $\varepsilon > 1$ all of closed shells detected as open shell and thus closed shell box turn into pure. Sample images of camera are also presented in figure 5.

Training and Testing Experiments: Samples of open shell and closed shell pistachio nuts from the 2010 harvested crops in three different varieties namely Akbari, Ohadi and Kalle-Ghuchi, were provided by a Rafsanjan pistachio processor. Classification of each split type was performed by the processor's quality control staff. The 200 pistachio nuts from each variety are randomly selected for training. These 200 nuts are contained by 100 open shell and 100 closed shell pistachio. The nuts used for training pistachio are passed through the sorting system to acquire and save training images. Training images for each variety included 400 pictures from pistachio nuts and 200 pictures from the background. Thereafter, the unknown parameters of the system are tuned by PSO algorithm. The sorting system is programmed in the Delphi environment where this program is fully adopted to real-time events of the system. Then the unknown parameters, tuned by PSO, were sent to sorting program. Results of training and testing are presented in table 2.

Discussion and Cost Analyze: The capacity of the system is defined as number of pistachio which is sorted per second. The comparison of proposed systems and Pearson's system should be done by the cost in the same capacity. The cost of proposed system is expressed as follow

$$\text{Cost} = (C_1 + C_2)n + C_3 \left(\left\lfloor \frac{n-1}{n_d} \right\rfloor + 1 \right) C_4 \qquad (4)$$

Where C_1 denotes camera cost, C_2 denotes apparatus cost, C_3 denotes capture card, C_4 denotes computer cost, n denotes as number of lines for the sorter system and finally n_d denotes the number of input channel for capture card. The amount of parameters for proposed system showed in table 3.

The capacity of the proposed system is computed as 5 pistachios per second while the capacity of Pearson's system is 40 pistachios per second. Therefore 8 line of the proposed system is required (n=8). The total cost of the system becomes as: Cost = $200 \times 8 + 2 + 500 = 2200\$$

Table 2: Results of experiments

Variety	Training Percent	Testing Percent	
		Open Shell	Closed Shell
Akbari	94%	91%	90.2%
Ohadi	91.5%	94%	83.3%
Kalle-Ghuchi	97%	93.1%	86.6%

Table 3: Amount of cost parameter of proposed system

Parameter	Value (unit)
C_1	50$
C_2	150$
C_3	50$
C_4	500$
n_d	4

This cost is less than 15000$ of Pearson's system. Although that cost is reported in 2000 and it may has fewer due to development of new technologies in the vision system. Anyhow, high speed camera has a high cost yet. This cost analyze does not contain the service and operational costs.

CONCLUSION

A low cost system for sorting of unsplit pistachio nuts is designed and implemented. Evaluation of the system in training and testing stages indicates that the system is very flexible for different varieties. The capacity of the system in initial tests is approximately 5 pistachios per second. Pearson's system is reportedly able to sort 40 pistachios per second. A simple analysis of proposed system indicated that the fabrication cost of the proposed system is approximately 2200$ for capacity of 40 pistachio nuts per second and Pearson's systems 15000$, thus the amount of primary enterprise in this system is better than Pearson's system.

Future works in this field can be fulfilled by improving of the whole subsystems such as feeder, exposing, separator subsystem, illumination and camera and of course optimization and image processing algorithm. Multi-line systems can also be considered to increase the system capacity.

REFERENCES

1. http://faostat.fao.org.
2. Nakhaeinejad, M., 1998. Pistachio hulling and processing in Iran. Kerman, Iran: Momtazan Industrial. Co.,

3. Pearson, T. and N. Toyofuko, 2000. Automated sorting of pistachio nuts with closed shell. Applied Engineering in Agric., 16(1): 91-94.

4. Pearson, T., 1995. Machine vision system for automated detection of stained pistachio nuts. Lebensm Wiss, U. Technol., 29: 203-209.

5. Ghazanfari, A., D. Wulfsohn and J. Irudayaraj, 1998. Machine vision grading of pistachio nuts using gray-level histogram. Canadian Agriculture Engineering. 40(1): 61-66.

6. Ghazanfari, A., J. Irudayaraj and M. Romaniuk, 1997. Machine vision grading of pistachio nuts using Fourier descriptors. J. Agriculture Engineering Res., 68(3): 247-252.

7. Pearson, T.C. and D.C. Slaughter, 1996. Machine vision detection of early spilt pistachio nuts. Transactions of ASAE., 39(3): 1203-1207.

8. Cetin, A.E., T.C. Pearson. and A.H. Tewfik, 2004. Classification of closed and open shell pistachio nuts using voice recognition technology. Transactions of the ASAE. 47(2): 659-664.

9. Pearson, T.C., 2001. Detection of pistachio nuts with closed shells using impact acoustics. Applied Engineering in Agric., 17(2): 249-253.

10. Pearson, T.C., 2003. Accoustical apparatus and method for sorting, United States Patent. Patent., 6, 541,725 B2.

11. Mahmoudi, A., M. Omid, A. Aghagolzadeh and A.M. Borghayee, 2006. Grading of Iranian's export pistachio nuts based on artificial neural network. International J. Agriculture and Biol., 1560-8530/2006/08-3-371-376.

12. Omid, M., A. Mahmoudi and M.H. Omid, 2009. An intelligent system for sorting pistachio nut vareties. Expert Systems with Applications, 36: 11528-11535.

13. Kennedy, J. and R. Eberhart, 1995. Particle Swarm Optimization. Proceedings of the IEEE International Conference on Neural Networks, Perth, Australia, pp: 1942-1945.

14. Kennedy, J. and R. Eberhart, 2001. Swarm Intelligence. Academic Press, 1st ed. San Diego, C.A.,