# A Brief Survey on Agricultural Robots

Mohammad Behmanesh[1], Tang Sai Hong[1], Muhamad Saufi Mohd Kassim[2], Arsalan Azim[1], and Zahra Dashtizadeh[3]
[1]Department of Mechanical Engineering, Faculty of Engineering, University Putra Malaysia
[2]Department of Biological and Agricultural Engineering, Faculty of Engineering, University Putra Malaysia
[3]Institute of Tropical Forestry and Forest Products, University Putra Malaysia
Email: {mohammadbehmanesh, Dr.s.h.tang, Arsalan.azim, zdashtizadeh}@gmail.com, saufi@upm.edu.my

***Abstract*—Agriculture has always been one of the most important issues for humankind. During past decades while robotics technologies have been introduced to many industries, agricultural scientists also made advantages of it and improved agricultural methods and products. In this paper the main advantages of the robotics in agriculture by far is presented. The robots that have been used in agricultural researches can be categorized in 4 main types; path navigators, harvesting robots, crop disease detectors and weed detectors which are studied in this paper.**

***Index Terms*—agricultural robotics, agribots, robotic harvesting, robotic plantation**

## I. Introduction

Agriculture is for sure the most important industry because it produces food. Unfortunately, it requires huge human work with considerably low speed. Agricultural robotic aims to minimize the labor work as well as increasing the speed and accuracy of the agricultural tasks. This would lead in less dependency of human livelihood on human labor work that would increase the efficiency of the procedure. Many agricultural robots have been introduced by far, however they are not applied in industrial scales. In this paper, some of the latest applications of agricultural robots have been reviewed.

## II. Agricultural Robots for Path Navigation

Implementation of robots in plantation fields requires a reliable navigation system for the robotic design. Fortunately, many researchers have studied this issue to determine that the simulation designs are in line with the experimental results. In a novel study, a vision based system that used a camera to navigate the path was studied. After taking the picture by camera, the robot checks whether the green color of plant is captured and can be recognized or not, after this segmentation, the robot can find its path through the plants, however it requires a map as well. This system was tested in real environment and the results determine the capabilities of this robot for path navigation in plantation fields. Fig. 1 below demonstrates the robotic system in real environment [1].

Figure 1. The robotic system for path navigation “Yeti” [1]

Vision based systems for navigating in the fields are well studied and mostly are consisted of some proper types of camera and a computer to process the data and gives the feedback to the robot for either following the path or stopping the movement. In a study from acquired data of the continuous pictures from the camera, and using Hough Transform the robot is capable of path tracking [2]. A framework based on near to far perception was proposed for conditional random fields (CRFNFP), which results determine significant improvement on path navigation compared to local map navigation system [3]. Their flowchart of navigation software is illustrated in Fig. 2 [3].

A simulation of path navigation based on sub-region shows that according to their algorithm the robot is able to track the path through the field. They simulated the real environment with rectangles. However, since the real environment is complex this method needs a significant improvement for real experimental application [4]. Rather than implementing sub-region for path navigation, a predictable path tracking system was introduced for this aim which showed a great reliability and accuracy according to experimental results [5].

Kalman filter simulation is another method that is studied for path navigation of wheeled robot based on sigma-point, however they did not implement their results on experiment [6]. In addition, an ultrasonic system was defined as a controller to track between the rows in the agricultural fields [7], also based on robot vision, offset and heading angels were calculated to guide the robot through the rows [8].

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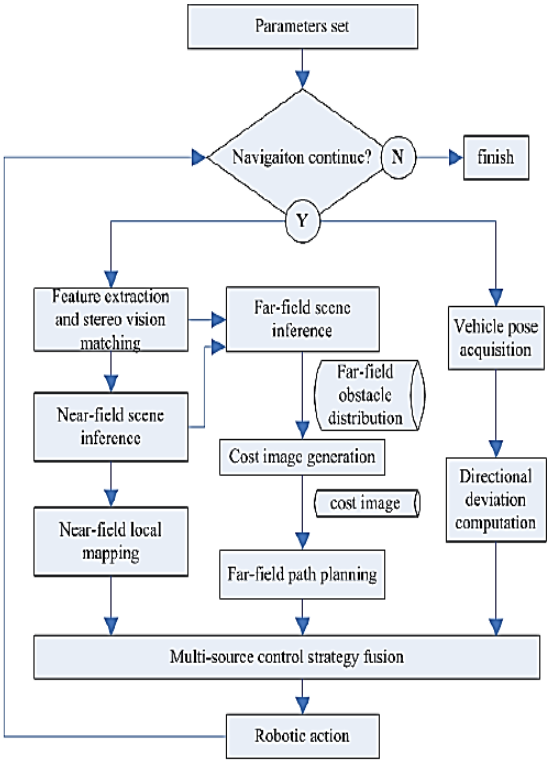


Figure 2. Flowchart for CRFNFP navigation system [3]

Another novel and reliable system that was defined and implemented for path tracking in the agricultural fields, is fuzzy controller. The benefit of this method is that it is automatic [9] and on line. Changing the steering angle and also controlling the speed of the robot are other advantages of using fuzzy logic system as controller [10]. In addition, fuzzy behavior has been implemented to simplify arbitrary behavior of the robot as a feasible method to control and navigate the robot in the field, Fig. 3 shows the simple behavior of fuzzy arbitrary method [11]. Line detection for harvesting robot was developed with Hough Transform and camera to detect the harvesting line [12]. A comparison between support vector machine and artificial neural network system for identifying steering angle determined that support vector machine gives better results in both steering angle finding and training time for this purpose [13].

| | | OBSTACLE | | |
|---|---|---|---|---|
| | | FAR | MEDIUM | CLOSE |
| PATH | FAR | STRAIGHT | AVOID | AVOID |
| | MEDIUM | STRAIGHT | AVOID | AVOID |
| | CLOSE | FOLLOW | FOLLOW | AVOID |

Figure 3. Fuzzy arbitrary behavior [11]

Figure 4. Robot obstacle avoidance [14]

In path tracking it is important that the robot could recognize and avoid the obstacles. A combination of GPS, ultrasonic sensors, infrared sensors and etc. were used for obstacle avoidance. Fuzzy logic was also used to navigate the path. Fig. 4 shows how the system is successful and the robot is capable of detecting and avoiding the obstacle [14].

In the forests or agricultural fields, trees could be either obstacles or the target on which harvesting should be carried out, therefore recognizing of the trees trunk or branches is significantly important [15]. A system was developed by Hough Transform function of L*A*B* color representation. The experimental results agree with the simulations [16].

## III. Harvesting Robotics

It has been a while since robots were introduced as harvester in the agricultural fields, many products such as apple, grapes, watermelon, tomatoes and so on were studied for robotic harvesting system. Most of the harvesting robots use some kind of visual hardware to visualize the agricultural product and then via software they do the required process to decide whether to harvest the product or leave it.

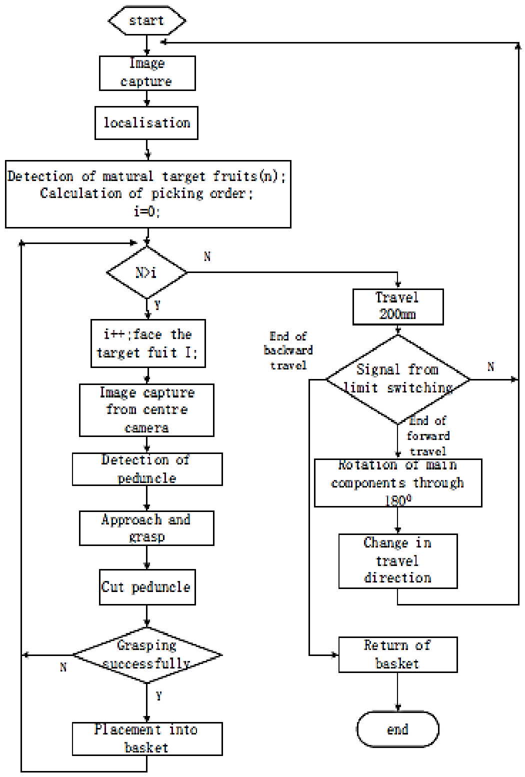


Figure 5. Tomato harvesting program flowchart [20]

For a vision system of apple harvesting robot Video for Windows (VFW) method was used and the results indicate that this system could effectively recognize the apples [17]. To improve the apple harvesting system, ant colony algorithm was studied and determined optimal results for picking path plans [18]. In addition, for better cutting process, 30 W power stem cutting laser diode was implemented which works efficiently [19].

In another study a 4 DOF robot was designed with vision based system to harvest tomatoes, the flowchart of harvesting program for this system is illustrated in the Fig. 5 [20].

Other tomato harvesting robot with color segmentation to improve the quality of harvesting worked successfully which picture of in site experimenting is shown in Fig. 6 [21]. Kinematics and workspace of tomato harvesting robot was studied by MATLAB to study the joint variables, then the problem with robot joint was solved by implementing the arithmetic application of numerical solution [22]. A hand arm coordination system with self-designed end effectors was developed for tomato harvesting, the results indicate that the harvesting in this system is successful by the rate of over 70% [23].

Figure 6. Tomato harvesting robot [21]

Not only big fruits such as apple and tomatoes that have quite big round shape were studied for robotic harvesting system but also grapes that are very sensitive fruits were examined to be used for robotic harvesting system. In the grape harvesting robotic system by using different end effector, different tasks were done such as grape harvesting, thinning, spraying and bagging [24]. Strawberry harvesting robot was also developed and well-studied. This system also was a multifunctional robot which was capable of harvesting, spraying and grading the strawberries [25]. In addition, asparagus harvesting robotic system was designed and experimented. This system used a 3-D visual system for a better recognition of the product. Then after recognition, the arm of the robot grasps the asparagus then cuts it [26].

In harvesting, most of the time there are heavy loads, such as heavy fruits or heavy baskets full of vegetables or fruits, which needs to be carried out. In order to reduce labor work, robots were applied to carry heavy loads in agricultural fields. Watermelon harvesting requires a robotic system which is capable of carrying the heavy fruit. Watermelon harvesting system was developed with high speed control system that in experiment determined its great efficiency [27]. An experiment for watermelon harvesting based on the combination of vision based control system and the configuration was performed in concern of initial cost problem, they defined a new variable and robust control system which makes a reduction in initial cost [28]-[30].

## IV. Crop Disease Detections

Due to economic and environmental issues it is very important to detect the crop diseases fast to increase the sustainability. Fig. 7 shows different types of crop disease detections [31].

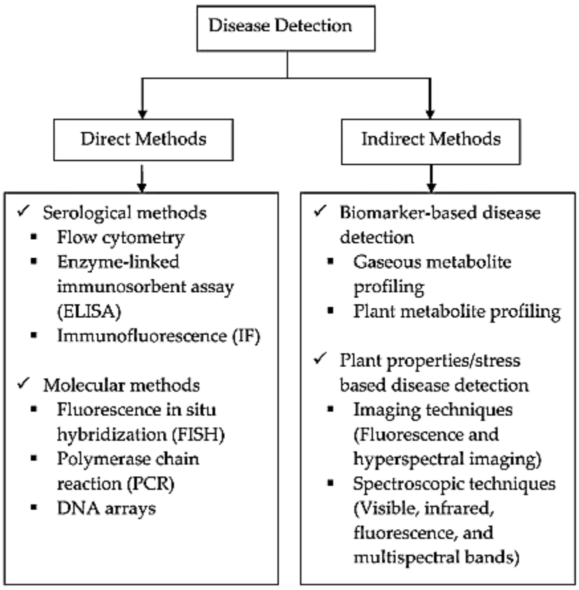


Figure 7. Different types of crop disease detection [31]

With the aid of image processing system, a robot for detection the crop disease at early stage was designed. This study provided a robot which is capable of moving along the rows in agricultural fields, detecting the diseases and spraying pesticides to treat the disease. The experimental results in cotton field showed a great agreement with the simulation design [32].

## V. Weed Detections

Weeds are one of the problems in agricultural fields which take lots of time and labor work to be removed. In order to make it easier and faster, robotic weeding was introduced. With using a structural design method, a weeding vehicle was designed with diesel engine, hydraulic transmission, four wheels which can steer 360°. This vehicle was shown to be capable of weeding in the actual agricultural field [33]. Due to environmental issues, the fuel consumption of the weeding robotic vehicles was reduced by gear and throttle positions adjustment. Also it was indicated that the control system plays important role in fuel consumption [34].

a. Labor work required for weeding    b. weeding with co-robot system

Figure 8. Weeding improvement with co-robot system [35]

In weed control system a challenge is inter- row weeding. Because it might damage the crop rows. A co-robot system was designed for this aim. It works with odometry sensing pneumatic hoe action in real situation. Co-robot means robot with human help that is using robots as assistance to human work to result in more accurate work with less labor effort as it is shown in Fig. 8 [35].

Crop row detection for weeding plays a significant role, which was studied and developed based on Otsu's method. Its algorithm is shown in Fig. 9. This method can successfully detect the crop rows (Fig. 10). [36].

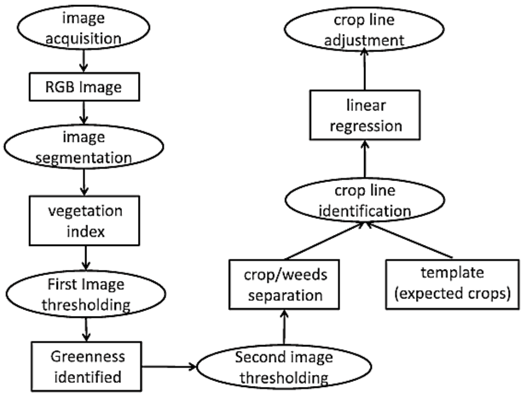


Figure 9. Algorithm of Otsu's method for crop row detection [36]

Figure 10. Crop row detection based on Otsu's method [36]

A review on robotic weeding system indicates that there are four aspects of this matter such as guidance, detection and identification, precision in-row weed control and mapping, which detection and identification is the main issue. Automatic weeding is in need of more investigation to fully develop [37].

## VI. Conclusions

Based on different applications of robotics in agricultural industry, 4 different categories have been considered. All applications are highly depended on vision system of the robots. Vision system plays the very important role, because according to its accuracy the results change in the implied task.

Still, there is a huge gap of knowledge and experiment in application of robots for agricultural use with more accurate robots and more defined applications.

## Reerences


[1] J. M. Ortiz and M. Olivares, "A Vision Based Navigation System for an Agricultural Field Robot," in *Proc. IEEE 3rd Latin American Robotics Symposium*, Oct. 26-27, 2006, pp. 106-114.

[2] C. J. Zhao and G. Q. Jiang, "Baseline detection and matching to vision-based navigation of agricultural robot," in *Proc. International Conference on Wavelet Analysis and Pattern Recognition*, July 11-14, 2010, pp. 44-48

[3] M. Wang, X. Wang, X. Yi, and J. Tu, "Experimental study on long-range navigation behavior of agricultural robots," in *Proc. International Conference on Computing, Measurement, Control and Sensor Network*, July 7-9, 2012, pp. 409-412.

[4] G. Zuo, P. Zhang, and J. Qiao, "Path planning algorithm based on sub-region for agricultural robot," in *Proc. 2nd International Asia Conference on Informatics in Control, Automation and Robotics*, March 6-7, 2010, pp. 197-200.

[5] C. Gao, Y. Su, and H. Ma, "Agricultural robot path tracking based on predictable path," in *Proc. 2nd International Conference on Networking and Digital Society*, May 30-31, 2010, pp. 519-521.

[6] Y. Zhang, F. Gao, and L. Tian, "INS/GPS integrated navigation for wheeled agricultural robot based on sigma-point Kalman Filter," in *Proc. 7th International Conference on System Simulation and Scientific Computing, Asia Simulation Conference*, Oct. 10-12, 2008, pp. 1425-1431.

[7] N. M. Thamrin, N. H. M. Arshad, R. Adnan, R. Sam, N. A. Razak, M. F. Misnan, and S. F. Mahmud, "Tree detection profile using a single non-intrusive ultrasonic sensor for inter-row tracking application in agriculture field," in *Proc. IEEE 9th International Colloquium on Signal Processing and its Applications*, March 8-10, 2013, pp. 310-313.

[8] J. Xue and L. Xu, "Autonomous Agricultural Robot and its Row Guidance," in *Proc. International Conference on Measuring Technology and Mechatronics Automation*, March 13-14, 2010, pp. 725-729.

[9] J. Zhou, M. Zhang, G. Liu, and S. Li, "Fuzzy control for automatic steering and line tracking of agricultural robot," in *Proc. International Conference on Computer Science and Software Engineering*, Dec. 12-14, 2008, pp.1094-1097.

[10] K. Prema, N. S. Kumar, S. S. Dash, and S. Chowdary, "Online control of remote operated agricultural Robot using fuzzy controller and virtual instrumentation," in *Proc. International Conference on Advances in Engineering, Science and Management*, March 30-31, 2012, pp. 196-201.

[11] R. V. de Sousa, W. C. Lopes, R. R. D. Pereira, R. Y. Inamasu, and A. J. V. Porto, "A methodology for composing and coordinating primitive fuzzy behaviors to guide mobile agricultural robots," in *Proc. 9th IEEE International Conference on Control and Automation*, Dec. 19-21, 2011, pp. 280-285.

[12] G. Wu, Y. Tan, Y. Zheng, and S. Wang, "Walking goal line detection based on machine vision on harvesting robot," in *Proc. Third Pacific-Asia Conference on Circuits, Communications and System*, July 17-18, 2011, pp. 1-4.

[13] D. S. Jodas, N. Marranghello, A. S. Pereira, and R. C. Guido, "Comparing support vector machines and artificial neural networks in the recognition of steering angle for driving of mobile robots through paths in plantations," *Procedia Computer Science*, vol. 18, pp. 240-249, 2013.

[14] P. Liu, S. Bi, G. Zang, W. Wang, Y. Gao, and Z. Deng, "Obstacle avoidance system for agricultural robots based on multi-sensor information fusion," in *Proc. International Conference on Computer Science and Network Technology*, Dec. 24-26, 2011, pp. 1181-1185.

[15] J. Lv, D. A. Zhao, W. Ji, Y. Chen, and Y. Zhang, "Research on trunk and branch recognition method of apple harvesting robot," in *Proc. International Conference on Measurement, Information and Control*, May 18-20, 2012, pp. 474-478.

[16] L. Shao, X. Chen, B. Milne, and P. Guo, "A novel tree trunk recognition approach for forestry harvesting robot," in *Proc. IEEE 9th Conference on Industrial Electronics and Applications*, June 9-11, 2014, pp. 862-866.

[17] J. Lv, D. A. Zhao, W. Ji, Y. Chen, and H. Shen, "Design and research on vision system of apple harvesting robot," in *Proc. International Conference on Intelligent Human-Machine Systems and Cybernetics*, Aug. 26-27, 2011, pp. 177-180.

[18] Y. Yuan, X. Zhang, and H. Zhao, "Apple harvesting robot picking path planning and simulation," in *Proc. International Conference on Information Engineering and Computer Science*, Dec. 19-20, 2009, pp. 1-4.

[19] J. Liu, Z. Li, P. Li, and H. Mao, "Design of a laser stem-cutting device for harvesting robot," in *Proc. IEEE International Conference on Automation and Logistics*, Sept. 1-3, 2008, pp. 2370-2374.

[20] J. Wang, Z. Zhou, and X. Du, "Design and co-simulation for tomato harvesting robots," in *Proc. 31st Chinese Control Conference*, July 25-27, 2012, pp. 5105-5108.

[21] Q. Feng, X. Wang, G. Wang, and Z. Li, "Design and test of tomatoes harvesting robot," in *Proc. IEEE International Conference on Information and Automation*, Aug. 8-10, 2015, pp. 949-952.

[22] Z. Li, J. Liu, P. Li, and W. Li, "Analysis of workspace and kinematics for a tomato harvesting robot," in *Proc. International Conference on Intelligent Computation Technology and Automation*, Oct. 20-22, 2008, pp. 823-827.

[23] J. Liu, Z. Li, F. Wang, P. Li, and N. Xi, "Hand-arm coordination for a tomato harvesting robot based on commercial manipulator," in *Proc. IEEE International Conference on Robotics and Biomimetics*, Dec. 12-14, 2013, pp. 2715-2720.

[24] M. Monta, N. Kondo, and Y. Shibano, "Agricultural robot in grape production system," in *Proc. IEEE International Conference on Robotics and Automation*, May 21-27, 1995, pp. 2504-2509.

[25] S. Arima, S. Shibusawa, N. Kondo, and J. Yamashita, "Traceability based on multi-operation robot; information from spraying, harvesting and grading operation robot," in *Proc. IEEE/ASME International Conference on Advanced Intelligent Mechatronics*, 20-24 July 2003, pp. 1204-1209.

[26] N. Irie, N. Taguchi, T. Horie, and T. Ishimatsu, "Asparagus harvesting robot coordinated with 3-D vision sensor," in *Proc. IEEE International Conference on Industrial Technology*, Feb. 10-13, 2009, pp. 1-6.

[27] S. Sakai, K. Osuka, H. Fukushima, M. Iida, "Watermelon harvesting experiment of a heavy material handling agricultural robot with LQ control," in *Proc. IEEE/RSJ International Conference on Intelligent Robots and Systems*, 2002, pp. 769-774.

[28] S. Sakai, K. Osuka, T. Maekawa, and M. Umeda, "Active vision of a heavy material handling agricultural robot using robust control: a case study for initial cost problem," in *Proc. IEEE/RSJ International Conference on Intelligent Robots and Systems*, Aug. 2-6, 2005, pp. 572-578.

[29] S. Sakai, K. Osuka, T. Maekawa, and M. Umeda, "Robust control systems of a heavy material handling agricultural robot: A case study for initial cost problem," *IEEE Transactions on Control Systems Technology*, vol. 15, no. 6, pp. 1038-1048, Nov. 2007

[30] S. Sakai, M. Iida, and M. Umeda, "Heavy material handling manipulator for agricultural robot," in *Proc. IEEE International Conference on Robotics and Automation*, 2002, pp. 1062-1068.

[31] S. Sankaran, A. Mishra, R. Ehsani, and C. Davis, "A review of advanced techniques for detecting plant diseases," *Computers and Electronics in Agriculture*, vol. 72, no. 1, pp. 1-13, June 2010.

[32] S. K. Pilli and S. J. George, "eAGROBOT - A robot for early crop disease detection using image processing," in *Proc. International Conference on Electronics and Communication Systems*, Feb. 13-14, 2014, pp. 1-6.

[33] T. Bakker, K. A. van, J. Bontsema, J. Müller, and G. S. van, "Systematic design of an autonomous platform for robotic weeding," *Journal of Terramechanics*, vol. 47, no. 2, pp. 63-73, April 2010.

[34] M. Gonzalez-de-Soto, L. Emmi, I. Garcia, and P. Gonzalez-de-Santos, "Reducing fuel consumption in weed and pest control using robotic tractors," *Computers and Electronics in Agriculture*, vol. 114, pp. 96-113, June 2015.

[35] M. Pérez-Ruíz, D. C. Slaughter, F. A. Fathallah, C. J. Gliever, and B. J. Miller, "Co-robotic intra-row weed control system," *Biosystems Engineering*, vol. 126, pp. 45-55, October 2014.

[36] M. Montalvo, G. Pajares, J. M. Guerrero, J. Romeo, *et al*., "Automatic detection of crop rows in maize fields with high weeds pressure," *Expert Systems with Applications*, vol. 39, no. 15, pp. 11889-11897, November 1 2012.

[37] D. C. Slaughter, D. K. Giles, and D. Downey, "Autonomous robotic weed control systems: A review," *Computers and Electronics in Agriculture*, vol. 61, no. 1, pp. 63-78, April 2008.


**Mohammad Behmanesh** (Iran,1985) has done research onvarious control systems. Currently, he is working on a hexapod robot used for seed plantation for his master degree in mechanical engineering. He has worked part time for Nectar Consortium.co as design project engineer. He is expert in instrumentation as well as industrial troubleshooting. In addition, he is lecturing PLC, TA portal of Sieme.

**Tang Sai Hong** is an associate professor at the department of mechanical and manufacturing engineering, university Putra Malaysia, he is very expert at mechanical and system engineering, operation research and robotics.

**Muhamad Saufi Mohd Kassim** is a senior lecturer at the department of bological and agricultural engineering, faculty of engineering, university Putra Malaysia. His research is mostly on agrciultural robotic, agricultural mechanization and automation.

**Arsalan Azim** (Iran,1991) graduated from UCSI university in mechatronic engineering. He has done research on various artificial intelligent system. Currently, he is working on network communication and design controller for agricultural robots

**Zahra Dashtizadeh** (Iran,1984) is a Ph.D. candidate in University Putra Malaysia in biocomposite technology. She has graduated from Ferdowsi universtity of Mashhad,Iran in mechanical engineering,then continues her master degree in the same field at university Putra Malaysia(UPM). She has done research on biocomposites and her main research field is material characterization.