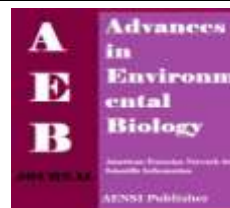




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## Conceptual Design of an Automated Green Technology Sorting Device for Mixed Household Waste

Zol Bahri Razali

Gunasegaran s/o Madasamy School of Mechatronic Engineering University Malaysia Perlis, Kampus Pauh Putra, 02600 Arau, Perlis, MALAYSIA

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### ABSTRACT

The purpose of this project was to design a conveyor belt and develop an efficient automated mechanical sorting system for mixed household waste especially paper and plastics that are left uncollected from domestic waste due to lack of efficient and economical waste sorting mechanism. This project is designed to segregate plastic and paper waste which would be the pioneer step for recycling. An intelligent system is developed using computer vision to recognize parts with features on the sorting production line (conveyor belt). Different paper and plastic objects with various shapes and sizes are used for the experimentation process. The proposed algorithm was experimental verified using a fabricated prototype paper and plastic system. Experimental results validate the proposed algorithm.

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## INTRODUCTION

In particular green technology sorting device, the project relates to segregate paper from plastic objects automatically by using conveyor. In this project, our system would be able to indentify plastic objects and paper objects which come in the conveyor. As the system is fully automatic and it is also an intelligent system, it should be able to identify which were not used in training. As for automatic, this system work without any human intervention. The efficiency of our system should be at least 80% of correct classification with an acceptable time taken from indentifying the category of the object.

Other than that, in order to distinguish plastic and paper objects from each other, complex spectral analyses and/or the use of the electromagnetic wavelengths outside the visible spectrum are required. The resulting apparatus and methods are too complex or expensive to implement in a typical recycling plant or waste sorting facility.

Generally, sorting and recycling of paper and plastic articles is a low margin activity, and the complex setups required for optical sorting arrangements have made them unattractive even for investigation with respect to sorting of paper and plastic articles. Other sorting techniques use laser infra red and infra red sensor to distinguish between paper and plastic, monochromatic source laser and a detector can measure the intensity of the light passing through the objects to differentiate between materials [10]. In contrast, the proposed method can be implemented with a minimum of equipment, and used in typical sorting or recycling facility of the type that currently uses manual labor to separate paper from plastic articles [9]. In this paper we propose a vision system which can identify the different type of recyclable objects present in solid domestic waste [1].

A conveyor belt consists of two or more pulleys, with a continuous loop of material – the conveyor belt – that rotates about them. One or both of the pulleys are powered, moving the belt and the material on the belt forward. The powered pulley is called the drive pulley while the unpowered pulley is called the idler. There are two main industrial classes of belt conveyors. Those in general material handling such as those moving boxes along inside a factory and bulk material handling such as those used to transport industrial and agricultural material, such as grain, coal, ores, etc. generally in outdoor locations. Generally companies providing general material handling type conveyors do not provide the conveyors for bulk material handling. In addition there are a number of commercial applications of belt conveyors such as those in grocery stores [2].

**Corresponding Author:** Zol Bahri Razali, Gunasegaran s/o Madasamy School of Mechatronic Engineering University Malaysia Perlis, Kampus Pauh Putra, 02600 Arau, Perlis, MALAYSIA  
E-mail: zolbahri@unimap.edu.my

The belt consists of one or more layers of material they can be out of rubber. Many belts in general material handling have two layers. An under layer of material to provide linear strength and shape called a carcass and an over layer called the cover. The carcass is often a cotton or plastic web or mesh. The cover is often various rubber or plastic compounds specified by use of the belt. Covers can be made from more exotic materials for unusual applications such as silicone for heat or gum rubber when traction is essential [2].



**Fig. 1:** Conveyor Belt

The belt consists of one or more layers of material they can be out of rubber. Many belts in general material handling have two layers. An under layer of material to provide linear strength and shape called a carcass and an over layer called the cover. The carcass is often a cotton or plastic web or mesh. The cover is often various rubber or plastic compounds specified by use of the belt. Covers can be made from more exotic materials for unusual applications such as silicone for heat or gum rubber when traction is essential.

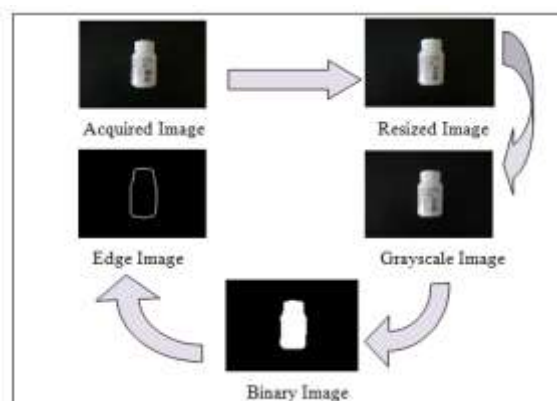
Material flowing over the belt may be weighed in transit using a beltweigher. Belts with regularly spaced partitions, known as elevator belts, are used for transporting loose materials up steep inclines. Belt conveyors are used in self-unloading bulk freighters and in live bottom trucks. Conveyor technology is also used in conveyor transport such as moving sidewalks or escalators, as well as on many manufacturing assembly lines. Stores often have conveyor belts at the check-out counter to move shopping items. A wide variety of related conveying machines are available, different as regards principle of operation, means and direction of conveyance, including screw conveyors, vibrating conveyors, pneumatic conveyors, the moving floor system, which uses reciprocating slats to move cargo, and roller conveyor system, which uses a series of powered rollers to convey boxes pallets [2].

*Methodology:*

*Vision System:*

In this project we are using vision system to capture image and process it. In vision part, we will be discussing about the image processing and what feature extraction is used.

*Image Processing:*



**Fig. 2:** Flow diagram of image processing

Image is acquired with the use of digital camera. When capture the objects we should switch off camera flash because to avoid shadow of object and to maintain source of light. The image captured size will be 3264 by 2448. The acquired image will be resized into ratio 100:140. This is done to reduce the size of the image. Smaller size will give us less computational time which is an important aspect in industrial application. Resized image will be filtered by median filter. Filtering process is to remove unwanted noises and information(s) which

can affect our image when doing other processes. In Median filter, each output pixel is set to an average of the pixel values in the neighbourhood of the corresponding input pixel. The size of the neighbourhood used for filtering is 3-by-3. We are using median filter because it removes outliers without reducing the sharpness of the image. After filtering process, the image will be converted into grayscale. Conversion to grayscale is because again for the shorter process time reason. Color image will take longer time to process compare to grayscale image. This because in grayscale image only 2 colors will exist. One is black and one more is white. The grayscale image will later be converted into binary image. In binary image, it will be either black or white only. In previous image, that is grayscale image, there will be a gray color which is mix of white and black in binary image, it will be only either black or white. In this project, I am using with 'X' threshold value I will be getting a image which retains its edge only. Image that is converted into binary will be changed into edge image. Edge image will have only lines. In this process I am using Canny edge detector. I am using Canny edge detector because Canny preserves all the important lines. Any weak lines that are connected with important lines will be retained. This preserves most of the details in the image. Other than that, Canny also smoothen my image. Edging process is done, again for the purpose of making the process time faster and straight make the system to be more efficiency [9].

#### *Feature Extraction:*

Feature extraction from my added image is an important process in the estimation of object category. There are various types of feature that we can extract from the images such as Area, SVD, Fourier, Moments and so on. Feature extraction is done to feed the data to our Neural Network for classification purpose. We are sending feature extracted data because all images will have their own feature and this will be easy for the Neural Network to do classification. In this project we using Singular Value Decomposition (SVD) as our feature extractor. Below is the description of SVD.

The SVD command computes the matrix singular value decomposition.

$s = \text{svd}(X)$  returns a vector of singular values.

$[U,S,V] = \text{svd}(X)$  produces a diagonal matrix  $S$  of the same dimension as  $X$ , with non-negative diagonal elements in decreasing order, and unitary matrices  $U$  and  $V$  so that  $X = U*S*V$ .

$[U,S,V] = \text{svd}(X,0)$  produces the "economy size" decomposition. If  $X$  is  $m$ -by- $n$  with  $m > n$ , then  $\text{svd}$  computes only the first  $n$  columns of  $U$  and  $S$  is  $n$ -by- $n$ . A neural network can be trained with feature data as input and object distance as output. Once the network is trained, it can compute the distance of similar object images accurately with only the input data.

#### *Neural Network:*

The Neural Network architecture consists of three layers such as the input layer, hidden layer and output layer [3]. Figure 3 shows the architecture of the neural network used in this study. 300 singular values are fed to the network for training the neural network.

The hidden layer is chosen to have 6 neurons and the output consists of 2 neurons which show the category or type of the material. The hidden and input neurons have a bias value of 1.0. Hidden neurons are activated by binary sigmoid activation function and the output neurons are activated by pure linear function.

The choice of initial weight will influence whether the net reaches a global minimum of the error and so how quickly it converges. It is important that the initial weights must not be too large. Otherwise the initial input signals to each hidden or output unit will be likely to fall in the saturation region. On the other hand if the initial weights are too small, the net input to a hidden layer or output layer will be close to zero which can cause extremely slow learning. [4]. The NN is trained with 120 samples and tested with 80 samples. The NN is trained using the Levenberg-Marquardt back propagation algorithm [5]. After completed the neural network portion, we are using the tested neural network data for the implementation.

Here we choose one captured image. Then we create another programme which consists of image processing algorithm which will be from image acquisition until edge image of the captured image.

After the image processing, the programme will continue to extract the SVD from the added image. Here the SVD is processed in the neural network and the extracted output (the category) for the SVD will be chosen. The output of the neural network will show either one result from all the 2 output.

## **RESULT AND DISCUSSION**

#### *Feed Forward Neural Network:*

The network training results are tabulated when the number of hidden neuron is 6 in Table 1. From the table 4.1, it was observed that the Neural Network is able to classify 84.44% of samples correctly when 60% of samples used for training. But the Neural Network is able to classify only 84.17% of samples correctly when 40% of samples used for training. The network training results are tabulated when the number of hidden neuron 9 is in Table 2. From Table 3, it was observed that the Neural Network is able to classify 84.44% of samples

correctly when 60% of samples used for training. But the Neural Network is able to classify only 84.17% of samples correctly when 40% of samples used for training. It showing that accuracy for both hidden neuron 6 and 9 are same.

**Table 1:** Result for 6 hidden neuron

Number of input neurons: 300, Number of Hidden Neurons: 6, Number of output neuron:2		
Activation Function: Logsig, Purelin		
Learning Rate: 0.01		
Training Tolerance: 0.01		
Testing Tolerance: 0.07		
Number of samples used for training: 120		
No. samples used for testing: 80		
Classification Rate (%)		
	40% of samples	60% of samples
Maximum	84.17	84.44
Average	84.17	84.44

**Table 2:** Result for 9hidden neuron

Number of input neurons: 300, Number of Hidden Neurons: 6, Number of output neuron:2		
Activation Function: Logsig, Purelin		
Learning Rate: 0.01		
Training Tolerance: 0.01		
Testing Tolerance: 0.07		
Number of samples used for training: 120		
No. samples used for testing: 80		
Classification Rate (%)		
	40% of samples	60% of samples
Maximum	84.17	84.44
Average	84.17	84.44

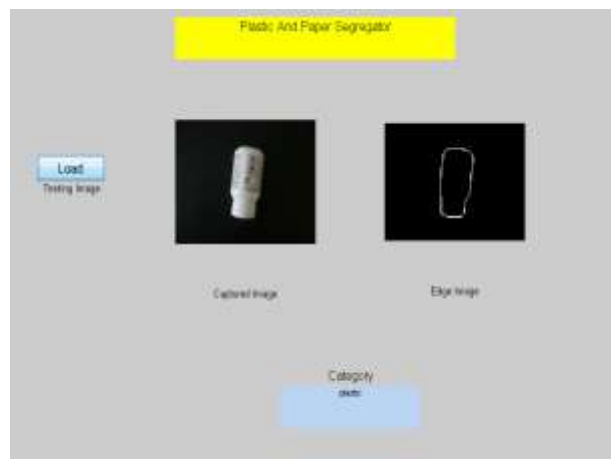
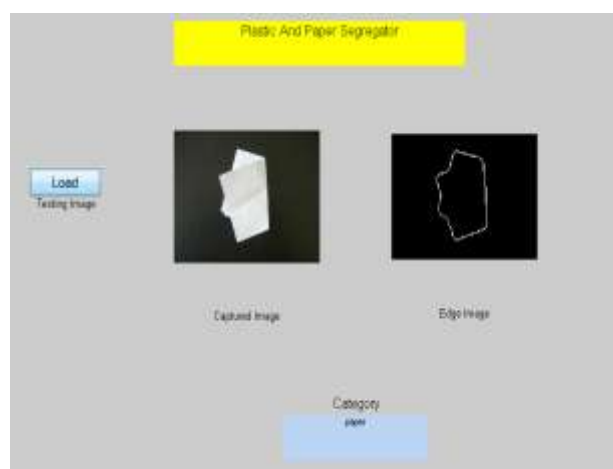
### *Different Sigmoid Function:*

**Table 3:** Result with Logsig and Logsig:

Number of input neurons: 300, Number of output neuron:2				
Activation Function: Logsig, Logsig				
Learning Rate: 0.01				
Training Tolerance: 0.01				
Testing Tolerance: 0.07				
Number of samples used for training: 120				
No. samples used for testing: 80				
Classification Rate (%)				
	40 % Data		60% Data	
Number of hidden Neuron	6	9	6	9
Max Perc	0.8417	0.8417	0.8444	0.8444
Average Perc	0.8234	0.8234	0.8336	0.8336

**Table 4:** Result with logsig and purelin

Number of input neurons: 300, Number of output neuron: 2				
Activation Function: Logsig, Purelin				
Learning Rate: 0.01				
Training Tolerance: 0.01				
Testing Tolerance: 0.07				
Number of samples used for training: 120				
No. samples used for testing: 80				
Classification Rate (%)				
	40 % Data		60% Data	
Number of hidden Neuron	6	9	6	9
Max Perc	0.8417	0.8417	0.8444	0.8444
Average Perc	0.8234	0.8234	0.8336	0.8336

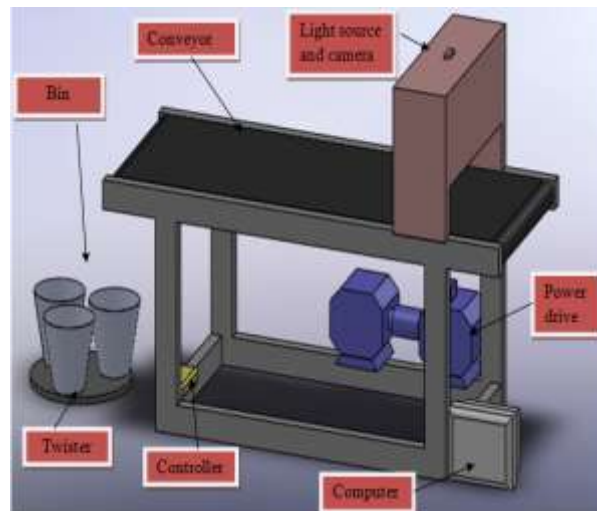
*Graphical User Interface:***Fig. 3:** GUI result for plastic object (original image and edge image)**Fig. 4:** GUI result for paper object (original image and edge image)

This GUI is done by loading the image which was used for testing or newly captured. The images will be processed and the data from Neural Network will be used to determine the category of the object. The user has

to press the load picture button to load the required picture. After that, the picture will be processed and displayed on 2 axes which shows captured image and edge image. There is one box in the GUI where the category of the waste appears. To clear the image, the user has to type clear while to exit, the user has to just click the close window button.

There is one load button to choose the object which is already captured and saved in folder. Once we choose the file of the object it will display captured image, edge image and the category of the object either plastic or paper.

#### *Design and System of Conveyor Belt:*



**Fig. 5:** Design and system of conveyor belt

The first step is the object will be passing a sensor. The sensor detects the presence of the object. If there any object detected by the sensor, the conveyor will be stopped right directly under the sensor. After passing the sensor, the object move again on the conveyor until it will pass another sensor. This sensor is to detect the presence of the object and stops the conveyor once the object is under the camera. Once the object is under the camera, data will be sent serially to Matlab to start capturing the image of the object and do the image processing and Neural Network in Matlab. Once processed, the data will be sent to controller serially from Matlab and controller will make decision about the category of the object. Once decision is made, the decision or signal will be sent to the twister to move the correct bin under the conveyor so that the object will fall into respective bin. The categories of the objects are paper, plastic and unknown. Sometimes, we would get error in our analyses and unidentified objects by the sensor will be sent to unknown bin. The category and other details of the analyses will display on computer.

#### *Belt Tension:*

In order to calculate the maximum belt tension and hence the strength of belt that is required, it is first necessary to calculate the effective tension. This is the force required to move the conveyor and the load it is conveying at constant speed. Since the calculation of effective tension is based on a constant speed conveyor, the forces required to move the conveyor and material are only those to overcome frictional resistance and gravitational force.

#### *Mass of Moving Parts:*

For the sake of simplicity the conveyor is considered to be made up of interconnected unit length components all of equal mass. The mass of each of these units is called the mass of the moving parts and is calculated by adding the total mass of the belting, the rotating mass of all the carrying and return idlers and the rotating mass all pulleys. This total is divided by the horizontal length of the conveyor to get the mean mass of all the components. At the outset the belt idlers and pulleys have not been selected and hence no mass for these components can be determined.

#### *Mass of the Load Per Unit Length:*

As in the case with components the load is conveyed is considered to be evenly distributed along the length of the conveyor. Given the peak capacity in ton per hour the mass of the load per unit length is given by:

$$Q = 0.278T/S \quad (1)$$

The effective tension is made up of 4 components

- The tension to move the empty belt  $T_x$
- The tension to move the load horizontally  $T_y$
- The tension to raise or lower the load  $T_z$
- The tension to overcome the resistance of accessories  $T_u$

The effective tension is the sum of these four components

$$T_e = T_x + T_y + T_z + T_u \quad (2)$$

$$T_x = 9.8G \times f_x \times L_c \quad (3)$$

$$T_z = 9.8Q \times H \quad (4)$$

Various conveyor accessories that add resistance to belt movement are standards on most conveyors. The most common are skirtboards at the loading point and belt scrapers. Other accessories include moveable trippers and belt plows.

Tension required overcoming the resistance of skirtboards  $T_{us}$

$$T_{us} = (9.8f_s \times Q \times L_s) / (S \times b^2) \quad (5)$$

Tension to overcome the resistance of scrapers  $T_{uc}$

$$T_{uc} = A \times \rho \times f_c \quad (6)$$

*Corrected Length:*

Short conveyors require relative more force to overcome frictional resistance than longer conveyors and therefore an adjustment is made to the length of the conveyor used in determining the effective tension. The adjusted length is always greater than the actual horizontal length.

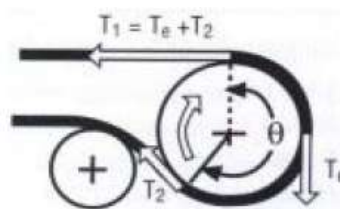
$$L_c = L + 70 \quad (7)$$

The length correction factor

$$C = L_c / L \quad (8)$$

All conveyors require an additional tension in the belt to enable the drive pulley to transmit the effective tension into the belt without slipping. This tension, termed the slack side tension  $T_2$ , is induced by the take up system. In the case of a simple horizontal conveyor the maximum belt tension  $T_1$  is the sum of the effective tension  $T_e$  and the slack side tension  $T_2$ .

$$T_1 = T_e + T_2 \quad (9)$$



**Fig. 6:** Maximum belt tension

$T_1$  is the tight side tension and  $T_2$  is the slack side tension

For a more complex conveyor profile that is inclined, additional tensions are induced due to the mass of the belt on the slope. This tension is termed the slope tension  $T_h$  and increases the total tension.

$$T_1 = T_e + T_2 + T_h \quad (10)$$

The slack side tension is determined by consideration of two conditions that must be met in any conveyor. The first condition is that there must be sufficient tension on the slack side to prevent belt slip on the drive. The second condition is that there must be sufficient tension to prevent excessive sag between the carrying idlers.

Minimum tension to prevent slips  $T_m$

$$T_1 / T_2 = e^{\mu\theta} \quad (11)$$

Since  $T_1 = T_2 + T_e$

$$T_2 = [1 / (e^{\mu\theta} - 1)] T_e \quad (12)$$

The expression  $1 / e^{\mu\theta} - 1$ :

is called drive factor  $k$  and the value of  $T_2$  that will just prevent slip is referred to as the minimum to prevent slip  $T_m$  and therefore

$$T_m = k \times T_e \quad (13)$$

Minimum tension to limit belt sag  $T_s$

$$T_s = 9.8S_f \times (B + Q) \times l_d \quad (14)$$

The tension required to limit sag is dependent on the combined mass of belt and load, the spacing of the carry idlers and the amount of sag that is permissible. The value of the slack side tension must ensure that both conditions are met and therefore  $T_2$  must be the larger of  $T_m$  or  $T_s$ .

Slope tension  $T_h$

$$T_h = 9.8B \times H \quad (15)$$

The slope tension is the product of the belt weight and the vertical lift and has its maximum value at the highest point of the conveyor.

Unit tension

$$T = T_1 / W \quad (16)$$

The maximum belt tension  $T_1$  has as its reference width the full width of the belt. Usually this is converted to the tension per unit of belt width as this is the reference dimension for belt strengths.

Absorbed power

$$P = T_e \times S \quad (17)$$

The amount of power required by the conveyor is by definition of power equal to the product of the force applied and the speed at which the conveyor belt travels.

#### Summary:

In this project, Feed Forward Neural Network was chosen. Feed Forward Neural Network gave us maximum 84.44% of classification for 60% of data. For the 40% of data, it gives the classification accuracy of 84.17%. For the image processing, the threshold value used was 0.15, 0.25 and 0.35 because that was the value which gave us the best edge image. Epoch is the number of times the network trained the whole data sent to input. For example, 20 epoch. It means the network trained the database provided to it for about 20 times. We used either Logsig or Log Sigmoid function because our value is a binary value. For the background we had chosen black color background because it gave us a good image with very less noise. It I noticed that a darker background absorbs the lights fall on the object. On white background, with the same lighting condition, the Lux intensity was 32 while for black background it was only 22. For graphical user interface, we received 2 images which will be the original image and also the edge image. The type of the category is also shown in the GUI.

#### Conclusion:

It was hoped to gain an excellent understanding of neural networks. Developing a neural network framework from scratch turned out to be an interesting experience that helped in acquiring the understanding of neural networks that was paramount for this project. With the help of the gained knowledge, it was possible to



find appropriate network configurations and training data to conduct the various experiments. Bigger networks, especially networks with two hidden layers, might have produced a different behavior, because of the added complexity. However, bigger networks were not used in the experiments because of the heavily increased runtime of the training process due to their complexity. The work done in this project has shown that neural networks are very well capable of acting as a visual system. The model was very simple. The input images were reduced to black and white. The set aims were all reached, although more work is still to be done. A great understanding in neural networks was achieved, not least because of the strategies that neural networks employ was also gained. In this project we only managed to sort out paper and plastic because of time constraint.

## REFERENCES

- [1] Nicholas, P., Ph.D Cheremisinoff, *Handbook of Solid Waste Management and Waste Minimization Technologies*, Imprint of Elsevier Science.
- [2] wikipedia(2000)[http://wiki.answers.com/Conveyor\\_belt](http://wiki.answers.com/Conveyor_belt), 10 January 2011
- [3] Richard, O., Duda, Peter E. Hart, and David G. Stork, 2000. *Pattern Classification*. Wiley-Interscience.
- [4] Sivanandam, N. and M. Paulraj, 2003. *Introduction to Artificial Neural Network*, Vikas Publishing House, India.
- [5] Sastry, P.S., G. Santharam and K.P. Unnikrishnan, 1994 "Memory neuron networks for identification and control of dynamic systems," *IEEE Transactions on Neural Networks*, 5: 306-319.
- [6] *Belt Conveyors for Bulk Materials*, 2007. 6th edition 2nd printing, Conveyor Equipment Manufacturers, Association, Naples Florida pdf
- [7] [http://www.ckit.co.za/Secure/Conveyor/Troughed/belt\\_tension/Dunlop/Belting%20B.24/05/2004](http://www.ckit.co.za/Secure/Conveyor/Troughed/belt_tension/Dunlop/Belting%20B.24/05/2004)
- [8] [http://www.apexfenner.com.au/pdf/Conveyor\\_Handbook.pdf](http://www.apexfenner.com.au/pdf/Conveyor_Handbook.pdf), update June 2009
- [9] Razali, Z.B. & G. Madasamy, 2013. *Automated Mechanical Sorting Device for Mixed Household Wastes: Integration Sorting Conveyor with Neural Network*. LAP Lambert Academic Publishing, Germany. 67 pages. ISBN 978-3-659-33579-2
- [10] Razali, Z.B. & N.A. Mat Nawi, 2013. *Automated Segregating Device for Reuse and Recycle Waste: Application on size based, friendly recycling designed*. LAP Lambert Academic Publishing, Germany. 73 pages. ISBN 978-3-659-34178-6.