E-Wastes – A Valuable Source of Components for Sustainable Designs in Engineering Education

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Abstract

The growing technology craze among the population is generating more waste from electronic devices in Mauritius. Many of these electronic components cannot be easily disposed of in landfills and special recycling plants are usually required to process the electronic waste (e-waste) and recuperate materials which can harm the environment or even human health. Sustainable engineering aims at inculcating good practice in young engineers to allow them to design or select equipment that will mitigate the negative impacts on the future generation. One strategy is to consider using e-waste to design and manufacture low cost tailor made equipment for the manufacturing sector. The small and medium enterprises can benefit from this strategy but unfortunately they are usually reluctant to changes and are also not ready to share information about their businesses. Proper collaboration between all stakeholders in small island developing states will provide the necessary platform to allow the youngsters to design and implement low cost tailor made equipment that will help the industry. The main benefits of using e-wastes are reduction in e-waste to landfills, development of low cost equipment, inculcating sustainable design and developing the troubleshooting skills in the young engineers.

Keywords: *Sustainable Design, University-Industry Collaboration, Mechatronics.*

1. Introduction

Universities in small island development states (SIDS) are striving to provide adequate training to local population to support the economic growth of the countries. In this spirit, the University of Mauritius launched the B. Eng (Hons.) in Mechatronics programme in the late 90's. The students of this 4 year full time programme have to complete a major project related to their field of study in the final year. The projects usually consist in the design and implementation of autonomous or automated systems at an average cost US $400 per project (lab based project). Lack of fund usually limits the inclusion of many advanced features in the prototype but the students are forced to consider alternative components and/or designs to achieve the desired functions in the equipment.

Many reports have highlighted the issues and dangers related to waste electronic and electrical equipment (WEEE) in various parts of the world [1] [2] and many recognise that businesses dealing with scrap materials are very lucrative. Legal and illegal transnational shipment of WEEE [3] [4] is increasing in the world transferring the problems to poverty stricken areas. The e-waste ends up in countries in Africa and Asia where the control is less strict or quasi inexistent. [5] The WEEE are being processed and valuable metals are extracted from the waste in small workshops without appropriate health and safety measures. [4] [6] The toxic by-products from the WEEE are then randomly discarded without considering the environmental threat. The low cost of electronic components have prompted the population to be large consumers of the latest high technology equipment. Some representatives of international brands provide after sales services and spares for the strict minimum period forcing customers to purchase new models. Citizens must be sensitised [7] to the environmental and health problems associated with e-waste and that there are solutions that can be adopted to mitigate the effects of these problems. They must be taught that there are possibilities of using e-waste for the manufacture of low cost custom designed equipment for the local industry, SMEs or even low income families. In many developing countries, the population is not able to differentiate between e-waste and domestic wastes and everything are dumped together. The collection and disposal of electronic waste (e-waste) is considered to be the sole responsibility of the central government which transfer everything to a refuse transfer station where they may be sorted into various categories.

Reports [1]-[7] have dealt mostly with recuperating the metals and polymers from the WEEE for re-use or re-cycle but very often many components in the machine are still in good working condition. Many of these components can still be used to manufacture prototypes at much lower costs. The design process is much more tedious than purchasing components off the shelf as very often the specifications of the individual components in an assembly or machine are not provided by the manufacturers.

Reports have stressed on the fact that sustainability and sustainable engineering must form an integral part of engineering education [8]-[11]. A change in the design methodology is required according to L. Mingrone et al. [12] where the waste should be considered as resources for the same or other systems and also the necessity to design customized product for a specific country. Sustainability oriented approach assumes that resources are scarce and should continuously be re-used. [13] One report [14] proposed that the components should be designed for ease of disassembly which is a good initiative as this will also ensure that the components are not damaged in the process. Some design strategies have been proposed by A. Crabbe [15] whereby a proper collaboration between developed and developing world may be established to help entrepreneurs and communities in developing world to manufacture their own equipment. This can be further extended to support the local entrepreneurs to use the WEEE available locally and not as a means to dump the wastes from developed countries to the developing countries. The definition of SME's vary from country to country but in any case the SMEs cannot afford to take any commitment to sustainable engineering due to the complexities involved and lack of expertise. [16] In developing countries the SME's cannot afford to invest in high technology equipment due to financial constraints as well as a restricted market. If given the appropriate support, local expertise can be used to design and manufacture tailor made equipment which performs the same basic operations as the high technology equipment.

The Mauritian government has come up with the "Sustainable Mauritius" concept as one of the strategy to cater for the ever increasing environmental hazards. The estimated amount of e-wastes generated in Mauritius was 6600 tons in 2008 [17] while only 1600 tons was disposed of at the transfer stations before proceeding to landfills. The estimated amount of e-waste generated in 2011 was 7600 tons and expected to increase further. The WEEE is representing a serious threat to the environment but the amount is not sufficient to consider the setting up of recycling plants in Mauritius. Given the difficulty to discard e-waste in Mauritius, it is very common to see large WEEE on the roadside. This may explain the small amount of e-waste actually collected at the transfer stations. Many electrical appliances are scrapped if a major component failure occurs but many of the remaining components in the faulty machines are still in good working condition. These components (e-wastes) can be recuperated and used as spares for other machines or help in the manufacture of custom designed machines for the local companies.

Manufacturing companies in Mauritius are rarely involved in research and development but rather produce for international brands. The companies are more focused in attracting the international customers and often do not concentrate on the enhancing their production facility because of financial constraints. Studies have shown [18]-[21] that local companies can benefit from collaboration with the university in developing tailor made equipment/system but the main hurdle is funding. There is a scope for proper collaboration between universities, especially in small island developing countries, and local companies to develop new or enhance existing machines at lower cost using e- wastes.

2. Project overview

This paper describes the design and implementation an autonomous guided vehicle (AGV) for automated storage and retrieval of parcels or parts using the maximum amount of waste. The functions of the proposed AGV will not be constrained by the availability of e-waste and it be fitted with all safety features. The components obtained from waste will be blended together with the new components to manufacture the system. A specific company was selected and the design was based on its requirements. The AGV has been scaled down as the funds required for the re-engineering of the facility was not available.

After evaluation of different concepts, the major components/requirements of the AGV have been determined as follows:

- Motors to drive the chassis using differential steering configuration
- Gears and transmission belt to couple the wheels to the motor.
- Telescopic arm to pick up parcel/part.
- A load cell to determine the weight of the parcel lifted; thereafter the control system can allocate a maximum acceleration, deceleration (braking rate) and maximum constant velocity at which the AGV is allowed to move.
- Machine vision to locate the positions of the shelves.
- Sensors for safety and to avoid obstacles
- A fuzzy control system and neural network to monitor the weight and velocity ratio.
- Appropriate processor to monitor and control all the interfaces used and provide wireless connection from remote computer.
- Verbal feedback from AGV on its status.

The AGV will be constrained to move on a synchronous track over long distances and it will be able to leave the synchronous track at specific location to fetch the parcel.

3. Design

The initial requirements of the system were determined and were used to design the AGV. All procedures were followed to have a reliable engineering design. The proposed AGV was modeled in Solidworks® and the design was modified and optimised (Figure 1) to reduce weight of the machine. The simulation also highlighted functional problems and the designs were modified accordingly. The components were then sized and manufactured based on the results obtained from the data collection and simulation.

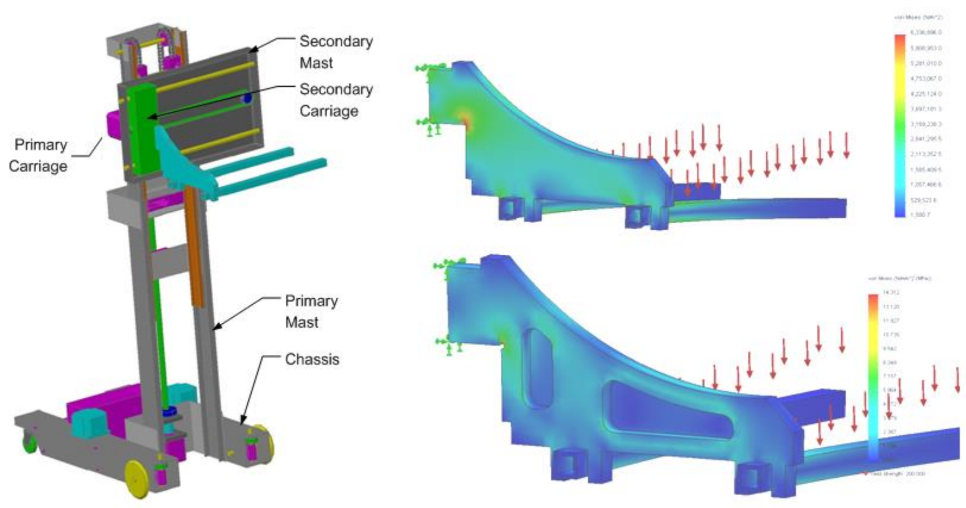

Figure 1. (left) 3D model of proposed forklift, (right) Optimization of components.

The design process adopted when using e-wastes is slightly more complex than when using new components. The components obtained from e-wastes very often do not exactly match the requirement of the system. The system will, therefore, have to be modified and re engineered to include the components without compromising the performance of the machine. Figure 2 summarises the design process to integrate the components from e-waste.

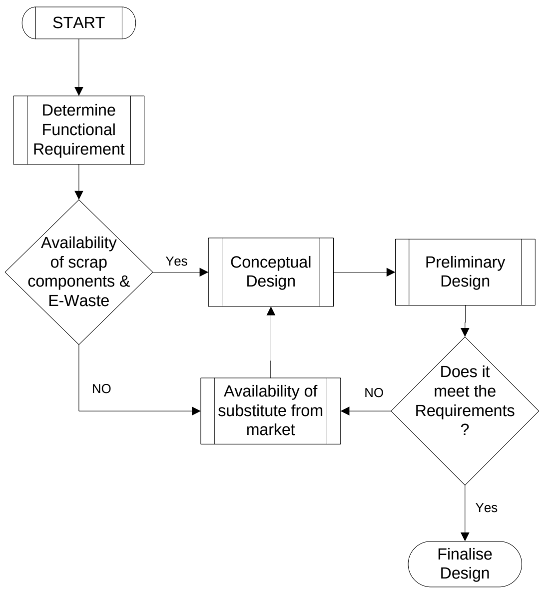

Figure 2. Design strategy.

4. E-Wastes – Collection, Testing & Troubleshooting

Many stores and companies were visited and old machines and components were gathered. This was a very successful task as discarding of electrical wastes is not easy in Mauritius. There is no proper system and regulations for the collection, dismantling and recycling of e-waste. Equipment obtained were printers, computers, fans, electronic balance and many others. As far as possible, the machines were dismantled and usable parts were removed on company's site but in certain cases the equipment had to be transferred to the university compound where they were stripped down of all useful components.

The individual components had to be tested to make sure that they are still in working condition. There were some components which were faulty and they were repaired, wherever possible, after troubleshooting. The unavailability of datasheets of batch made components made troubleshooting more difficult and one should rely entirely on skills and experience.

Moreover, other mechanical components have also been obtained from the waste such as belts, leadscrew, gears and pulleys. The materials used for the construction of the structural members were also waste materials collected from companies or structural components obtained from the e-wastes.

5. Prototype

The system implemented is shown in Figure 3. An Omni-directional wheel was designed and implemented in the system to allow the system to move in a straight line which was not possible with the castor wheels. The motors and other components were assembled in modules and tested individually. All the sub systems were then integrated together and the prototype was tested. The Vortex86DX® which is an advanced technology OS based processor has been selected for the control of the AGV to ensure optimum performance and upgradeability. The system can easily be interfaced to vision system as well as audio system. The control of the AGV can be done via wifi from a desktop or laptop computer or even a mobile phone. The graphical user interface (GUI) was designed in Visual Basic 6. It allows both autonomous and manual operations, and through initialisation the AGV is able to self troubleshoot. Figure 4 shows the GUI to control the AGV through wifi.

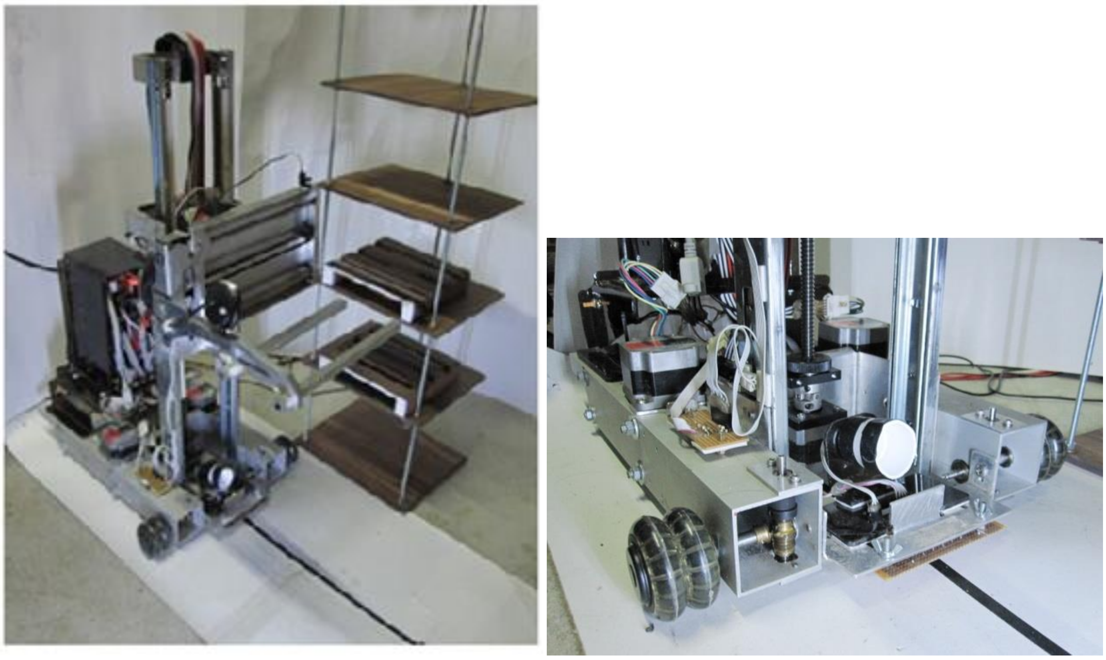

Figure 3. The prototype: (left) overall view, (right) close-up on the base.

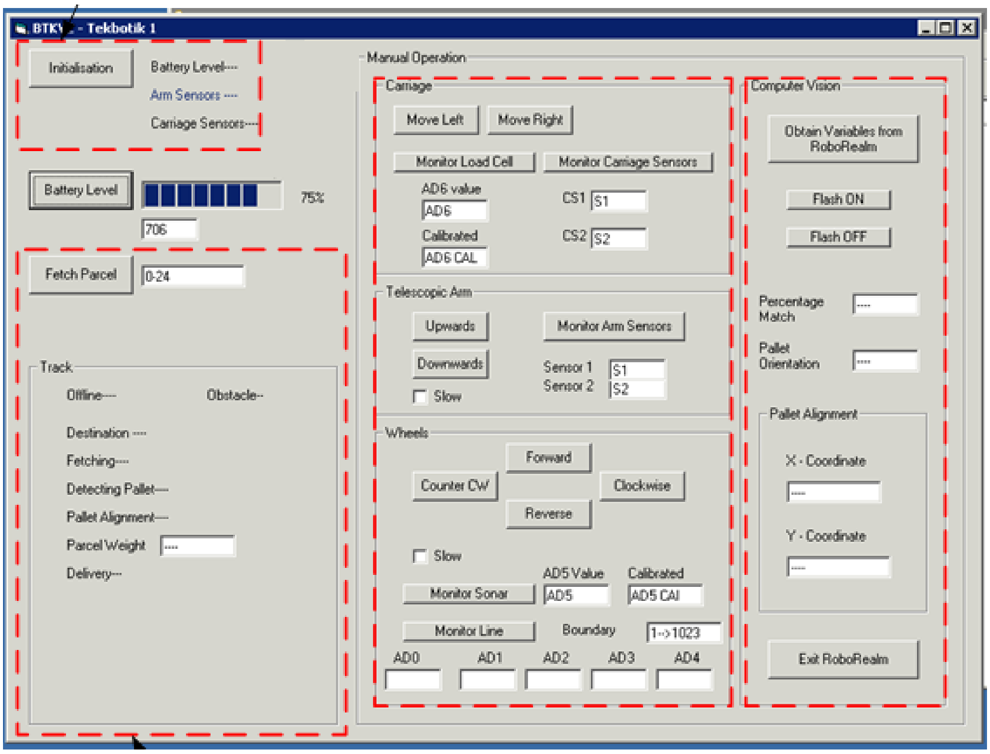

Figure 4. Graphical user interface to control AGV through wifi.

RoboRealm® has been used to provide computer vision to the AGV. An application programming interface (API) was created on Visual Basic to access the run functions (modules) in RoboRealm®. The AGV can provide verbal feedback on its status and an API module was also created to access the module in-built in windows which is known as “Text To Speech”.

Video of the system including the design process and manufacturing of the AGV is available at http://www.youtube.com/watch?v=qWN08pPaOlg and http://www.youtube.com/watch?v= 11NHGEm5ACg

6. Costing

The detailed costing of the AGV is given in Table 1 and the cost of equipment using components that have been recuperated from scrap machines is approximately 1/3 the cost of the system manufactured using new components only. The cost of design, research and development and testing has not been included but this is taken as the contribution of the tertiary institution.

Table 1. Cost comparison: using e-waste versus new components only.

Component/s	Cost of Re-Engineered Modules Using E-Waste & Processors / USD	Actual Market Value of Existing Modules / USD
Dual Stepper Motor Driver	16.5	170.
Power Supply / DC-DC Convertor	5.	60.
Input Output Interface	10.	25.
External Modules	3.5	8.
Motors	0.00	240.
Mechanical / Structural	20.	660.
Processor & Wifi Module	470.	470.
Others	50.	105.
Total (USD)	575.	1738.

7. Finding & Discussion

7.1 Sustainable Design in Engineering Education

Use of available electronic components that may not necessarily meet the required specifications of the equipment will force the students to think critically. This will usually lead to modifying the designs to suit the available components instead of buying components off the shelf. The process of turning scrap into high tech equipment will create a new type of engineers who will think of re-using first and then consider recycling or buying new components. The system that has been designed is working perfectly and shows that electronic wastes can be blended with new components and technologies to give reliable machines. If the system is designed locally, a component can be changed easily and the system re-designed to work correctly with minimum downtime.

7.2 Problems with E-Waste

The useful electronic components represent a small fraction of the total volume of the electrical appliances but very often they contain the largest amount of toxic materials. The companies are ready to discard the large equipment but these become a problem to universities. With the setting up of a proper collaboration stakeholders, a unit can be created that will be responsible for the collection, dismantling and testing of the components. The useful components will then be tested, classified and stored for future use. The remaining parts of the equipment can then be re-cycled.

7.3 Collaboration between UoM and the Private Sector and SMEs

The universities in small island developing states can help the countries' economy by developing low cost machines and automated manufacturing system. Many of the new machines available on the market are manufactured by the developed countries for the developed countries. They are loaded with lots of features and options not necessarily required by companies in developing countries. There is a need, therefore, for low cost custom made machines to meet the needs and budget of the companies in the developing countries.

7.4 Funding and After Sales Service

The SMEs are reluctant to invest in the re-engineered machines as they have doubts on the reliability of such second hand machines. There is a need for a proper collaboration between the central and local government, funding institutions and universities to ensure that the support is not ephemeral but last in time. The after sales service will still be provided by the universities and the machines will be repaired using other available e-wastes or simply replaced by new components in case of breakdown. The system can be easily be modified to accept other available components, given that the expertise is readily available.

7.5 Specifications of Components

Many suppliers do not include the specifications of small electronic components in the manual and troubleshooting becomes complex. Tests have to be performed to determine the ratings of these components and sometimes equipment for the testing is not available. It is proposed that all manufacturers include the specifications of all small components on a CD together with the machine to support the sustainable engineering strategy.

8. Conclusion and Future Recommendation

Recycling of components will make the young generation more environment conscious and consider sustainable development as a serious means to reduce environmental pollution. The best method to inculcate sustainability in the youngsters is to allow them to indulge in the process of turning waste into productive equipment that will help the country as well as protecting the environment. This will be possible by proper collaboration between the SMEs, universities, private companies and funding institution to design and manufacture custom engineered equipment for the local industry. Universities can provide maintenance and necessary support to companies after the equipment have been installed at minimal cost. This collaboration will provide numerous advantages:

- Creates the awareness towards sustainable engineering and development – re-use first
- Protection of the eco system by reducing illegal dumping.
- Re-using electronic components that are still in good working conditions
- Provide appropriate troubleshooting skills and training to engineering students
- Support the SMEs by lowering the investment cost in new equipment
- Reduce the cost of production and increase the competitiveness of the SMEs
- Enhances the collaboration between local universities and the industry.

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