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Capacity Enhancement of Micro Hydro Power Plant at Demodara Tea Estate for Net Metering

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Abstract–*In Sri Lanka, 30% of the total electrical energy requirement is supplied from hydro power generation, where 3.5% is met by non-dispatchable mini hydro and micro hydro (<10 MW) power plants. This research study is carried out for the existing run-of-river type micro hydro power plant installed at Demodara tea-estate with maximum generating capacity approximately about 66 kW. The introduction of net metering system to the tea factory demand is the main part of this study while looking at the possibility of enhancing the existing capacity.*

In net metering study, the total energy consumption of the tea factory is compared with the expected generation from the maximum possible enhanced plant capacity of 250 kW computed at 2 m^3s^{-1} flow rate. It is identified that most of the energy generated by the enhanced plant capacity, imported to the national grid owned by the Ceylon Electricity Board (CEB) is much higher than that of the factory energy requirement. Subsequently, the optimum plant capacity is found at 1.7 m^3s^{-1} flow rate and 200 kW is selected as the feasible capacity satisfying net metering concept. Finally, the paper discusses the techno-economic feasibility of the whole process.

***Keywords**: Micro hydro power plant, Non-dispatchable, Capacity enhancement, Net metering, Run-of - river*

Nomenclature

η_t - Turbine efficiency
η_g - Generator efficiency
Q - Flow rate (m^3/s)
ρ - Density of water (kg/m^3)
PLC - Programmable Logic Controller

1 INTRODUCTION

Hydro power is attractive because of its renewable, non-pollution and environmental friendly nature. Hydro electricity generation plays a major role in power generation in Sri Lanka and around 30% of country's electricity requirement is supplied from hydro power industry out of which 3.5% of demand is being supplied by non-dispatchable mini hydro and micro hydro power plants (<10 MW) owned by the private sector(www.ceb.lk, 2016). This research is based on existing run of river type micro hydro power plant installed at

Demodara in Badulla district which is more than 75 years of age and its maximum generation capacity is around 66 kW, operated and maintained by the tea factory in Demodara Tea Estate.

The objective of this research study is to introduce net metering system for capacity-enhanced power plant to the tea factory and to propose an optimum feasible plant capacity for net metering system.

At the beginning of the study, enhanced power plant capacity is used to simulate net metering study with the stochastic behaviour of the load at the tea factory. Subsequently, feasible and optimum hydro power plant capacity for net metering is investigated.

Finally, a comprehensive techno-economic feasibility study is carried out and the payback period is calculated.

2 SELECTION OF DESIGN FLOW RATE FOR THE CAPACITY ENHANCED PLANT

In this study, drawbacks of the existing micro hydro power plant are observed. Insufficient fore-bay capacity during rainy seasons, water leaks in the channel, unable to handle plant under flood conditions and in-sufficient water for turbine during dry seasons are some of the problems that are identified in and around the power plant.

In order to address these issues, hydrological study is carried out to identify the possibility of capacity enhancement. It is observed that most of the time, stream flow of the river is greater than the channel inflow and existing power plant capacity is underrated. Therefore, there exist a high potential to enhance the capacity of existing micro hydro power plant.

To enhance the capacity of the micro hydro power plant, selection of flow rate is very essential. Hydrological analysis is carried out based on the past ten years stream flow data measured at Demodara gauging station obtained from Irrigation Department. In addition, location of existing micro hydro power plant is studied by using topographical map. Subsequently the design flow rate is selected using flow duration curve.

2.1 Selection of catchment area

In order to select design flow rate for the computation of new plant capacity, both topographical study and hydrological study are carried out, based on the plant location. Plant is located on upstream of the Badulu Oya which has 36.13 km^2 of catchment area at the point of channel intake, obtained from topographical map. In this study, the catchment area ratio is used to calculate flow rate at the channel intake since flow rate data at the stream diversion point (channel intake) is not available in the Irrigation Department. Topographical map is used to select relevant catchment areas at the gauging point and at the channel intake. Relevant catchment areas are shown in Figure 1.

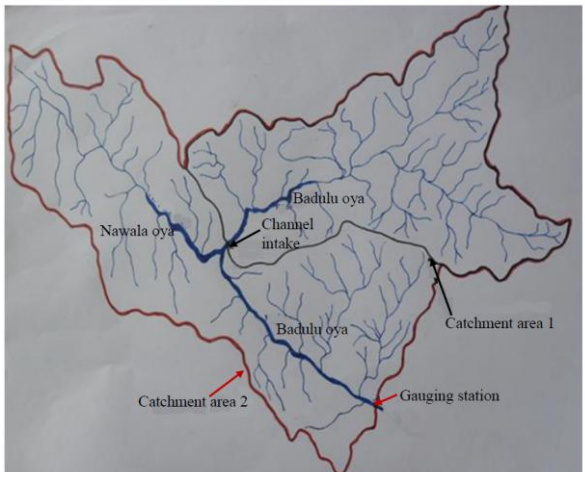


Figure 1: Catchment areas

Catchment area 1 is approximately about 36.13 km^2 and Catchment area 2 where stream flow is gauged by Irrigation Department, is selected from the map is about 82.2 km^2. Ratio of the catchment areas is obtained as 0.44 as follows.

$$Ratio = \frac{\text{Catchment area 1}}{\text{Catchment area 2}} = \frac{36.13\,\text{km}^2}{82.2\,\text{km}^2} = 0.44$$

Relevant stream flow data can be obtained by multiplying this ratio with data available at gauging station.

In hydrological study, stream flow data of Demodara gauging station are collected from Irrigation Department. Collected stream flow data is multiplied by the ratio established to obtain channel intake flow rates. Then the channel intake flow rate data is analysed to produce flow duration curve. Thereby suitable design flow rate is selected for enhanced hydro power plant by carefully examining the flow duration curve (Kunwor, 2012).

2.2 Flow duration curve and design flow rate

Flow duration curve is created using relevant stream flow data at the point of channel intake as shown in Figure 2. Maximum energy output can be taken through the selection of maximum flow rate. Therefore, design flow rate was selected as 2 m^3/s from the flow duration curve at 10% exceedance probability, which gives the maximum energy output throughout the year. Expected power produced from proposed plant can be calculated as follows (Penche, 1998).

$$P = 9.81\eta Q H (kW) \qquad \text{---------- Equation (1)}$$

Where;

P = electrical power produced, kW

ρ = density of water = 1000 kg/m^3

g = acceleration due to gravity= 9.81 m/s^2

H = elevation head of water= 15.3 m

Q = flow rate, m^3/s

η = overall efficiency ($\eta_t * \eta_g$)

Turbine Efficiency (η_t) = 0.85 (Selected turbine is Francis Type. Therefore, maximum turbine efficiency would be 0.85 and Generator Efficiency (η_g) = 0.9

Therefore, P =242 kW

The capacity of enhanced hydro power plant is taken as 250 kW. Since the capacity lies within the range of (100kW-1MW) capacity, this plant can be considered under the category of mini hydro power plant.

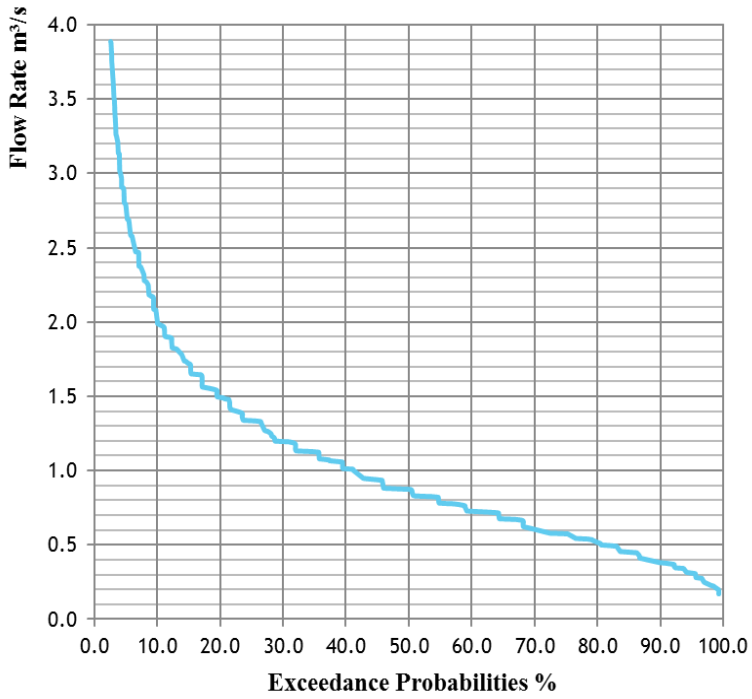


Figure 2: Flow duration curve for below 4 m³/s flow rate

3 NET METERING CONCEPT

The CEB consumer, who avails of this facility, energy meter needed to be replaced with an Import/Export meter. The electrical energy consumed from the grid is connected as import energy (energy debit) and the electrical energy generated and supplied to the grid is considered as export energy (energy credit). At the end of each billing period (typically one month), CEB will read the consumer's export energy meter and the import energy meter reading and the monthly electricity bill will be prepared charging the consumer for difference between the import and the export energy readings (NA, 2014).

If the export is more than the import in any billing period, the consumer will receive to carry forward export energy credit, and it will be credited towards his next month consumption. The key factor in this process is that there will be no payment made to the consumer for the excess energy exported by the consumer. All exports will be set off against consumer's own consumption, either in the current billing period or in future billing periods (NA, 2014).

Customer Category I-2 is the tariff plan of this tea factory and it is multi-tier tariff. If the tariff, applicable to the consumer/customer is multi-tier tariff, the energy credit is given only in the tier where credit is generated. This credit is carried forward to next billing period in the same tier. If the factory total energy consumption is less than the mini

hydropower generator maximum output, factory can export excess energy to CEB side and at the end of billing period it can settle with the same tier energy consumption.

3.1 Typical arrangement of net metering

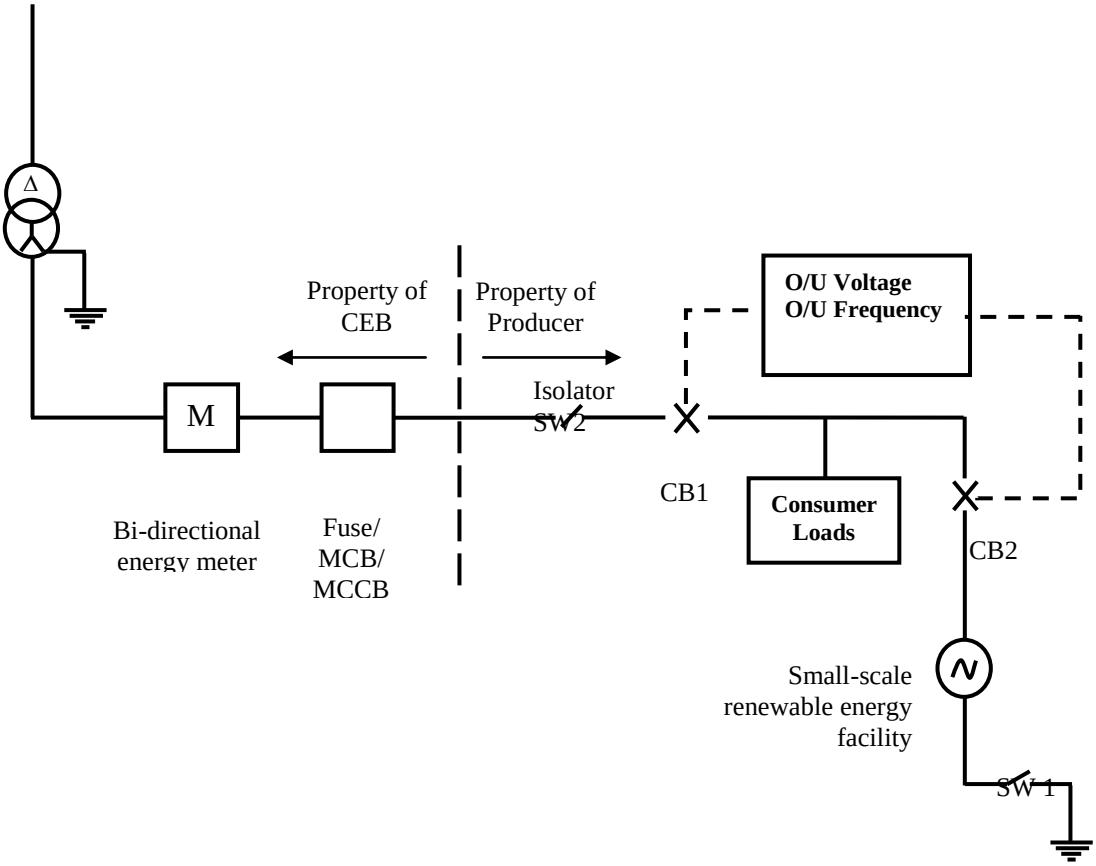


Figure 3: Net metering arrangement for parallel operation of small-scale renewable energy facility

Figure 3 shows only the required interconnection protection. Interconnection protection may operate either CB1 or CB2. SW2 isolator need to be kept at an easily accessible place to CEB and the switch should be locked and kept protected against unauthorized operation. SW1 should keep "Open" during all times of parallel operation with CEB system (NA, 2014).

3.2 Net metering study for enhanced power plant capacity

In net metering study, tea factory energy consumption is compared with the maximum possible capacity that could be harnessed from the entire flow duration. Correspondingly 2 m^3/s flow rate is being selected as the design flow rate. Maximum generation capacity of enhanced power plant is computed as 250 kW according to the said flow rate. Factory's real energy consumption data and the monthly expected energy generation at the flow rate of 2 m^3/s are used to simulate behavioral pattern of the net metering concept to the tea factory.

Net metering analyzing study is carried out by using factory real energy consumption data since 2008 January. In addition, it is assumed that 250 kW of

mini hydro power plant is available and operated since 2008 January 1st. CEB billing period is selected as 30 days (one month).
In this analysis, the electrical energy consumed from the grid is considered as import energy and the electrical energy generated and supplied to the grid is considered as export energy (NA, 2014). At the end of each billing period (typically one month) total export or import energy is considered. In the net metering concept in Sri Lanka, there is no payment for excess exported energy as mentioned earlier. The consumer will be received a carried-forward export energy credit, and it will be credited towards consumer's next month energy consumption.

4 ANALYSIS OF NET METERING

4.1 Net metering analysis for enhanced power plant capacity

Analysis of the net metering concept in 2008 is shown in Table 1.

Table 1: Analysis of net metering behavior at 2 m^3/s flow rate in 2008

Month	Factory's total energy consumption (kWh/Month)	Expected mini hydro power plant generation (kWh/month)	Import energy from CEB (kWh/month)	Export energy to CEB (kWh/month)
2008 January	49,935	56,677	-	6,742
2008 February	67,500	34,578	26,180	-
2008 March	100,130	93,496	6,634	-
2008 April	83,880	129,215	-	45,335
2008 May	100,832	100,458	-	44,961
2008 June	65,710	68,603	-	47,854
2008 July	46,890	42,499	-	43,463
2008 August	54,640	43,707	-	32,530
2008 September	95,434	57,269	5,635	-
2008 October	69,058	89,663	-	20,605
2008 November	69,784	58,227	-	9,048
2008 December	60,236	97,331	-	46,143
Total energy import from CEB end of year 2008			38,449	

As per the above analysis, toward the end of year 2008, the factory had to be paid for 38,449 kWh of energy and carried forward 46,143 kWh of export energy as a credit. Similarly, it had been analyzed net metering behavior of the factory since 2008 to 2012 and simulated results are shown in Table 2.

Table 2: Analysis of net metering behavior at 2 m³/s flow rate since 2008 to 2012

Year	Factory's total energy consumption (kWh/year)	Expected mini hydro power plant generation (kWh/year)	Import energy from CEB (kWh/year)	Export energy to CEB end of year (kWh)
2008	864,029	871,723	38,449	46,143
2009	693,761	541,870	189,922	84,174
2010	816,328	804,484	-	72,330
2011	678,328	863,770	-	257,772
2012 up to September	510,381	409,195	228,371	

According to Table 2, it is identified that the energy exported to CEB in each year is much higher than that of the factory requirement. Exporting that much of higher energy to CEB through net metering is not economical for mini hydro power plant since it will not gain any profit. Therefore, to take better advantage of net metering, an optimum flow rate is recognized to match with net metering system thus, feasible hydro power plant capacity for net metering is proposed.

Therefore, optimum and feasible plant capacity for net metering needed to be investigated. In hydro power plant capacity investigation study, import energy from Ceylon Electricity Board (CEB) within a specified time is considered as the key factor. Therefore, expected plant generation capacities at different flow rates were considered and simulated to find out feasible plant capacity for net metering.

4.2 Study results with the different flow rates using net metering concept

In this study, real energy consumption data has been used for past five years i.e., up to September 2012. The design flow rates of the plant is considered in between 0.9 m³/s and 2.0 m³/s. Annual import energy from CEB from January 2008 to September 2012 at different flow rates are also recorded and are shown in Table 3.

Table 3: Total expected import energy with different flow rates within past five years

Design flow rate (m³/s)	Total energy import from CEB(kWh) within past 5 years
0.9	549,074
1.0	445,974
1.1	375,466
1.2	375,525
1.3	286,842
1.4	329,340
1.5	267,690
1.6	145,341
1.7	144,950
1.8	145,915
1.9	158,123
2.0	228,371

According to the data shown in Table 3, it is observed that the minimum imported energy from the CEB occurs at a flow rate of 1.7 m^3/s. Therefore, 1.7 m^3/s flow rate is selected as the optimum flow rate under net metering concept [Appendix-1].
As such, and at this flow rate, optimum feasible generation capacity can be established as 200 kW by using equation (1). Therefore, plant capacity of 200 kW is selected as the most suitable hydro power plant design capacity for net metering system for Demodara tea estate.

5 TECHNO ECONOMICAL ANALYSIS

Once the optimum design capacity of the mini hydro power plant is established, a gross cost estimation can be tabulated as presented in Table 4. It can be observed that the main contributions are the construction cost of civil structures and the installation costs of electrical equipment's. In addition, it is expected to cover capital cost of the project through a bank loan with interest (Fraenkel, *et. al.*, 1999). Plant operation and maintenance costs are also considered when computing the payback period using discounted cash flow analysis.

Table 4: Estimation of gross capital cost of the project

Description	Cost (MLKR)
Civil Constructions – Weir ,intake ,channel, settling basin , fore-bay , spillway , power house, tailrace and penstock pipes supporters(including labour cost)	29.246
Electro mechanical equipment cost – Turbine, synchronous generator, butterfly valve, governor, Control panel, switchgears and installation cost.	15.500
Penstock Material -Mild steel, Thickness -13mm, Diameter - 1m, Length - 60m	2.758
Transmission line 4 Core, Line Length-1.5km, Conductor -Arial Bundle Conductor	2.321
Transportation cost Electro mechanical equipment brings from China to Demodara & material transport cost for civil works	1.500
Cost of consultation	6.480
Total cost	57.805
Contingency 10%	5.781
Total capital cost	63.586

In this net metering study, net-present value (NPV) is considered using discounted cash flow analysis. Result of the NPV analysis is shown in Table 5.

Table 5: Net Present Value calculation

Year	PV Value (MLKR)		Annual Bank Payment (MLKR)	Other Expenditures (MLKR)	Annual Income (MLKR)	Present Value of annual Income (MLKR)	Net Present Value (MLKR)
	Annual Saving (MLKR)	O & M Cost (MLKR)					
0						-63.586	-63.586
1	8.298	1.156	13.353	15.897	-22.108	-20.098	-83.684
2	15.842	2.208	13.353		0.281	0.233	-83.452
3	22.700	3.163	13.353		6.184	4.646	-78.806
4	28.935	4.032	13.353		11.549	7.888	-70.917
5	34.602	4.822	13.353		16.427	10.200	-60.717
6	39.755	5.540			34.215	19.313	-41.404
7	44.439	6.193			38.246	19.626	-21.777
8	48.697	6.786			41.911	19.552	-2.226
9	52.568	7.325			45.243	19.187	16.962
10	56.088	7.816			48.272	18.611	35.573

It can be observed from the NPV analysis from Table 5 that the simple payback period can be taken as nine years since the total benefits from the hydro power plant covers its investment cost during the period concerned.

6 CONCLUSION

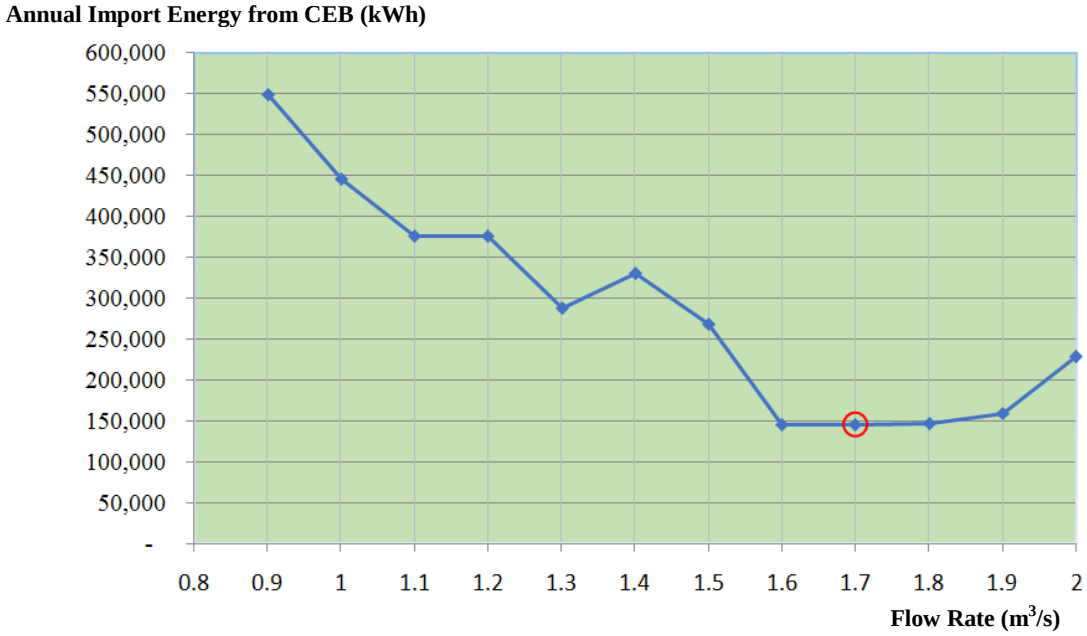
Most of the time, it can be seen that the water is spilling from the weir at existing micro hydro power plant. It is found that the existing micro hydro power plant capacity of 66 kW is underrated and can be upgraded to mini hydro plant (100 kW<capacity<10 MW)having capacity of 250 kW.

Initially a hydrological study was carried out and flow rate data are analyzed to obtain the channel intake flow rate. However, it is found that the hydrological head of the existing micro hydro power plant cannot be altered and only the flow rate can be regulated as per the geographical and practical limitations of the site. Therefore, to obtain maximum possible energy output, flow rate of 2.0 m^3/s is selected for the proposed power plant using flow duration curve. However, since the imported energy to CEB with the enhanced capacity is more than the requirement by the tea factory, the optimum plant capacity for the net metering requirement of the tea factory is established. Finally, 1.7 m^3/s flow rate is selected as the optimum design flow rate for the hydro power plant which gives the plant capacity of 200 kW.

Existing factory load installation consisting of main and sub-panel designs are considered as a secondary requirement of this study. Improvement for main panel and sub-panels with prevailing recommended standards are proposed. PLC program is developed for controlling the main panel to achieve most reliable and a stable electrical supply to the tea factory. Also, the flexibility is there at any moment to the factory maintenance crew to change PLC program as per the demand of the factory. Finally, the economic feasibility study is carried out to obtain the payback period for the net metering system. Discounted cash flow analysis using net present values showed that the simple payback period is about nine years.

7 APPENDIX

Appendix 1- Annual Expected Import Energy with Different Flow rates



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Development of Software Defined Radio (SDR) Receiver

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Abstract – *Purpose of this study is making digital signal processing blocks and connections in radio systems by software and making digital analog boundary for transmitting and receiving signals needed to connect with digital signal processing blocks.*

Aim of this research is analysis of how to create digital signal modulation and demodulation using free and open software tool kit named GNU Radio which is a type of software defined radio tool kit and analysis of how to make customized.

Telecommunication field is now continuously improving and different types of radio networks and technologies are evolving in the world. It is very essential to making devices with interoperable facilities between various networks and technologies. It is very difficult to implement these facilities by traditional making method of telecommunication devices which is by making hardware circuits. Software Defined radio important with this problem. Most functioning features, such as bandwidth, modulation, coding rate, can be modified during runtime according to software configuration.

***Keywords**: Software Defined Radio (SDR), Digital Signal Processing, FPGA, GNURadio*

1 INTRODUCTION

Today's voice, data and video transmission needs lots of flexible and reconfigurable radio systems for selecting various communication systems such as 3G, 4G and various modes such as video, audio. Multiple communication systems (3G,4G) or multiple functions (AM/FM) for a single system need computationally intensive signal processing algorithms and high data rates. Separate hardware resources for each of the function will increase the silicon area and complicate the design validation and compatibility (Gupta, 2010). Mobile communication services can be accessed by today's most of the mobile devices. But integrating various protocols and different IC chips into a small device is an important challenge in recent years (Chen, 2010).

With emerging digital signal processing (DSP) technologies, high speed micro controllers, microprocessors, computers and Field Programmable Gate Arrays (FPGA), SDR concept is becoming a new path to the telecommunication field. Analog transmitters and receivers can be converted to digital transmitters and receivers using SDR because most of the hardware components can be replaced with reconfigurable software.

Mitola's view of the SDR is radio is purely digital, except ADCs and DACs, (Bagheri, R. M., 2006). Highest degree of reconfigurability can be obtained by this concept.

Aim of the software defined radio is doing the entire signal processing functions digitally. All digital signal processing can be implemented by software. RF signals are analog and should be converted to digital levels for digital signal processing. For converting analog to digital and vice versa need ADCs and DACs. For entire digital signal processing, ADC and DAC should be at the antenna and everything else would be done by software (Tuutlebee, 2002). As technology progress, SDR is moving to Software Radio where the digitization can expanded to the (or close to the) antenna.

Ideal SDR block diagram is depicted in figure 1. SDR receiver gets signals from the antenna, amplifies using low noise amplifier, convert received analog signal to digital using ADC and send to the digital signal processor. Digital signal processor converts the signal to suitable format and send through DAC to get the required message.

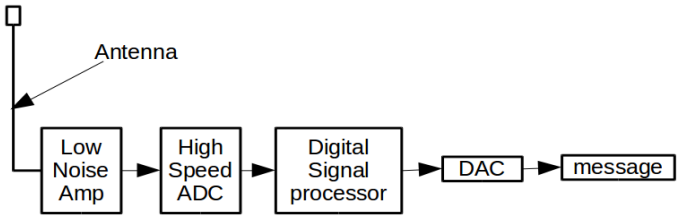

Figure 1: Ideal Software Defined Radio

ADC and DAC cannot be connected directly to DSP computers. Down conversion decimators after ADC and Up conversion interpolators before DAC must be implemented digitally between ADC/DAC and DSP computers. There must be a communication link between hardware and DSP computers. FPGA connected to ADC, DAC and serial communication link can be used for this purpose.

Aim of this research is developing open source analog digital hardware and driver for open source SDR software tool kit named GNURadio tool kit. ADC, FPGA and communication IC can be used for developing SDR analog digital boundary.

2 LITERATURE SURVEY

2.1 GNURadio tool kit

GNURadio is a world wide open source project which is published on the Internet through www.GNURadio.org web address. It is a free & open-source software development toolkit that provides signal processing blocks to implement software radios. GNURadio basically includes flow graphs and blocks. Sampled signals values pass through flow graphs. Flow graphs are graphs. Nodes of such a graph are called blocks, and the signal values pass along the edges of blocks (BLOSSOM).Signal blocks, edges and flow of signals are shown in figure 2.

GNURadio can be used to create flow graphs and digital signal processing blocks. Various signal processing block collection is already developed by GNURadio developer group. Graphical presentation GRC is easy to use and lots of simulations and real time experiments can be done. When you want to create your own signal processing modules, OOT gr_modtool can be used. When you become highly expert, your own modules

without gr_modtool can be created because these all are python and C++ programming.

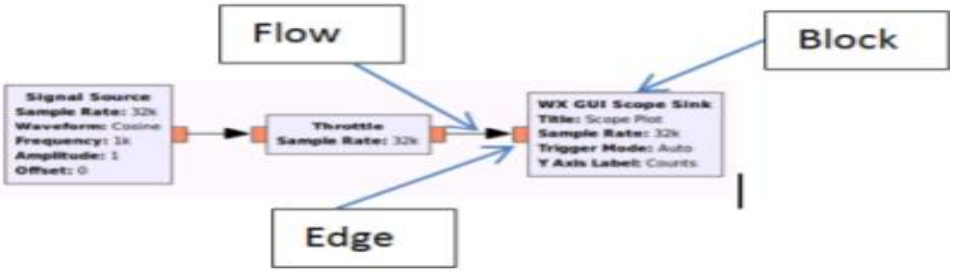

Figure 2: blocks, flow and edges of a GNURadio flow graph

GNURadio has following features

1. Graphical user interface called GNURadio Companion (GRC)
2. A mixed of C++ and python programming languages
3. Real time running
4. Changeable and able to create new signal processing blocks
5. Message passing facility

Message passing blocks are used for implementing feedback and non-synchronous signals. Message passing uses a common data type called Polymorphic Types (PMTs). Other data types such as int, float, char should be converted to PMT type when using message passing blocks.

2.2 Architecture of GNURadio

Figure 3 shows the architecture of GNU Radio. Flow graphs are written by python high level language. Signal processing blocks are written by lower level C++ blocks. Middle interface between python and C++ is Simplified Wrapper Interface Generator (SWIG).

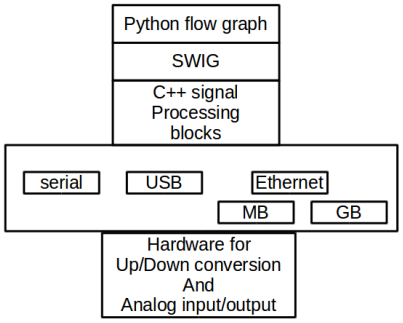

Figure 3: Architecture of GNURadio

GNURadio tool kit is an open source software but analog digital boundary hardware products available in the market are very expensive. Most hardware products available in the market have developed by using FPGAs. ADC is needed for converting analog signal to digital.

2.3 Analog digital boundary hardware for GNURadio

A separate hardware named Universal Software Radio Peripheral (USRP) is manufactured by Ettus Research team that can be used with specified DSP software including GNU Radio installed in personal computers. USRP Hardware Driver (UHD) in GNURadio tool kit is available for connecting hardware, developed by Ettus Research. The USRP devices can be connected to PC via serial, USB or Ethernet. Each USRP device has a separate device address that has to be entered in the UHD.

2.4 Field Programmable Gate Arrays (FPGA)

FPGA is programmable logic device that can be used for implementing large logic circuit. It has logic blocks for implementing required functions. It has 3 main resource types. Logic blocks, input output ports and wires and switches (Brown, 2007). Largest FPGA venders are Altera and Xilinx. More flexible and reconfigurable application specific DSP methods can be implemented than using microcontrollers (Bdti, 2007).

Altera is developing flexible soft processor called NIOS for implementing in Altera FPGA. User can modify NIOS processor with user specified features. i.e. bus width, number of general I/O port, connection modules called Intellectual Property (IP) cores to specific ports like Ethernet, USB, serial. Altera develop and sell 4 main categories of FPGA chips, Cyclone, MAX, Arria and Stratix. Application developer has to check specifications of FPGAs to check they are supported for their applications before buying. For example, 10GBit Ethernet and FIR II IP core is not support for cyclone ii devices (www.altera.com).

Software required to implement digital modules in Altera FPGA are Quartus II, Mage wizad plug in manager, QSYS, NIOS II Software Builder Tools (SBT) for Eclipse, programmer, QSYS is a fully automated GUI system for configuring processor features and generating hardware design in the FPGA. SBT for Eclipse is used as a GNU C/C++ programming tool for NIOS II processor (Altera, 2014).

NIOS II processor is a soft processor IP core designed for Altera FPGA as opposed to a fixed hardware processor. Therefore it has more flexible than other general purpose processor. It is a Reduced Instruction Set Computer (RISC) 32 bit processor, optional Memory Management Unit (MMU) and optional Memory Protection Unit (MPU) (Altera, 2014).

2.5 Pipelined Analog to Digital Converter

Figure 4 shows a block diagram of k bit pipelined ADC. Each stage contains a sample and hold (S/H) circuit, A/D sub converter and Digital to Analog (D/A) converter (Stephen, 1987).

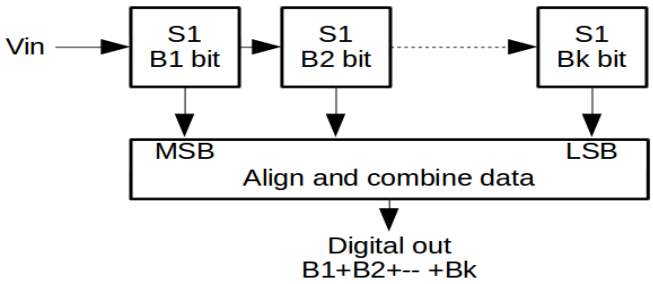

Figure 4: Pipelined Analog to Digital converter

2.6 Proposed analog digital boundary hardware and driver

Proposed analog digital boundary and driver is developing open source analog digital hardware and driver for the hardware. ADC, FPGA and communication IC can be used for developing SDR analog digital boundary. Serial communication can be implemented by using python serial communication and it can be connected to GNURadio by using message passing and message converting methods in GNURadio tool kit.

3 METHODOLOGY

The proposed system is shown in figure 5. FPGA board is depicted in figure 5.a. and CYCLONE II EP2C8Q208C8N altera FPGA is depicted in (a2) in figure 5. Serial USB conversion cable is depicted in figure 5.b. All the software needed to run SDR and driver is depicted in figure 5.c.

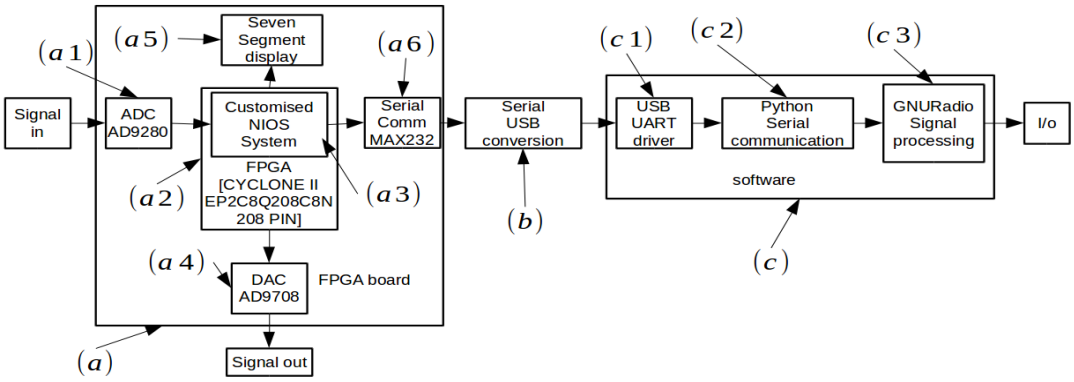

Figure 5: SDR hardware, GNURadio software and communication

Signals received to the ADC (a1) are converted to digital format and send to the serial communication port (a6) through NIOS system (a3). Digitized signal values can be displayed via seven segment display (a5). DAC (a4) can be used for transmitting purpose. Data send to computer is obtained by USB UART driver (libusb) (c1). Serial data obtained by USB UART can be sent to GNURadio by using python serial communication. (c3) indicates the GNURadio blocks and connection paths.

3.1 Equipment and software support for developing GNURadio receiver

1. Computer – Intel Core i3 CPU 2.3 GHz, Memory – 2GB, operating system- Ubuntu 14.04.

2. GNURadio tool kit and supporting software - Latest installed GNU Radio version is 3.7.6. Supported operating system is 64bit Ubuntu 14.04. Installing methods-Easy method "apt-get install GNURadio ".

3. FPGA board ordered for making open source hardware part to communicate with GNU Radio toolkit named as YG_V2.1. I assumed it is good for DSP purposes. This board has FPGA-ALTERA – CYCLONE II -EP2C8Q208C8N-208 PIN, Ethernet- ENC28J60, SERIAL CONTROLLER - MAX232, DAC- AD9708, pipelined multistage ADC- AD9280, USB - CH376, 8 seven segment displays, 9 keys for input. 5 LEDs and LCD display.

4. Windows base Altera Quartus II 32 bit Version 12.0 Web edition.

3.2 NIOS system implementation

Figure 6 shows custom based NIOS system for communication between computer and ADC through FPGA. Modules of this system are 32 bit NIOS II/e processor,32 bit On chip memory, 8 bit input port for ADC, 8 bit output port for display seven segment display, 8 bit UART for communication with computer through usb serial port. All components need clock signals. These modules are connected via Avalon memory mapped interface. Components in the "Altera QSys" can easily connect through Avalon memory mapped interface. It is an address based read-write interface with master-slave connections. Interface master side sends data to slave and vice versa.

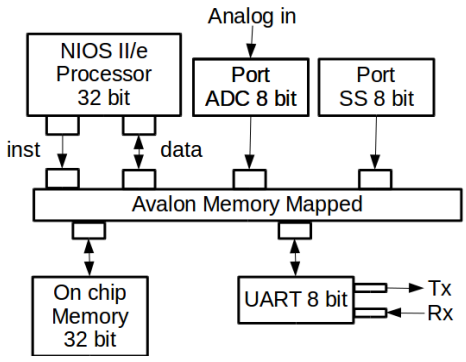

Figure 6: Customized NIOS II/e system

Experimental NIOS system designed for receiving from ADC to the computer through UART in QSYS is shown in figure 7. This system has 7 components- (1) Clock, (2) clock bridge, (3) memory, (4) cpu, (5) pin_adc, (6) pout_ss, (7) uart. These components are interconnected as necessary. Avalon memory mapped master slave interfaces are used to connect above components. Master is used to send data and slave is for receive data. Conduit endpoint interface is used to connect with external devices.

Figure 7: Receiving from ADC to the computer through UART in QSYS

3.3 Making communication through NIOS II software build tools for eclipse

NIOS II Software Build tools for Eclipse (SBT)

SBT is a GUI that runs NIOS II SBT utilities. User can create, edit, build, run, debug, and compile programs. User should have good hardware related knowledge of c programming. (Altera, 2014)

Program flow chart for the communication

Figure 8 shows the flow chart for sending data to the computer through uart port. First put the value of PORTADC to the variable "i" and it check whether the uart has received complete previous data to the uart. If previous data has sent to the uart next value is stored in the uart[1] i.e. for saving transmission data.

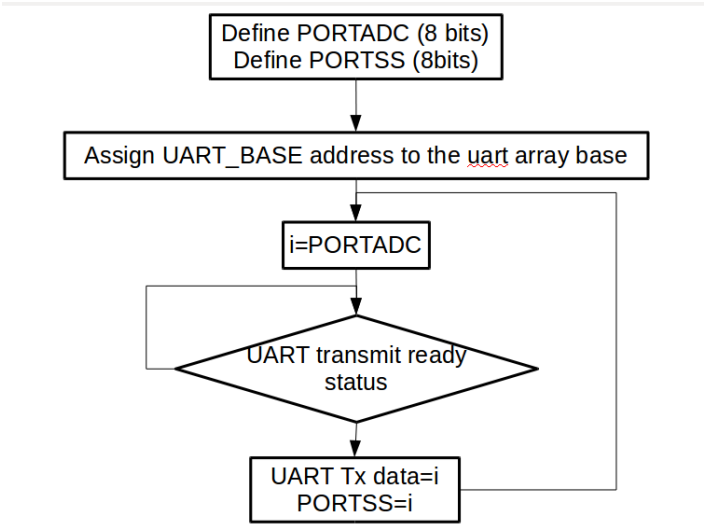

Figure 8: Sending data to the computer though UART port

3.4 Connecting serial port and GNURadio

To make connection between serial port and GNURadio, python serial access module (programmed by python language) called "serial. Serial" and message passing method of the GNU Radio tool kit are needed. Python serial module makes connection and read/writes operations between serial port and computer.

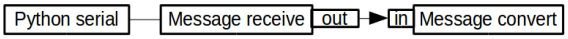

Figure 9: Python serial connection, message receiver and message convert blocks

Figure 9 shows python serial connection and 2 modules called Message_receiver and Message_convert. Python aided by special module belongs to the GNURadio is required to develop 2 modules called "PMT". These modules are imported to the python application program.

Message passing-Message passing method provides receiving and sending messages non synchronously. It uses common variable type called Polymorphic Types (PMTs). Originally only synchronous bit streams are used for sending data between signal processing blocks. There are no ways to communicate from upstream to downstream (feedback). Message passing method is used to connect external applications to GNU Radio.

Python serial connection-This is used for accessing serial port of the FPGA board trough usb port of the computer.

Message receiver block-Input side of the message receiver block is serial data and output side of the block is message port. Message passing blocks should write under the gr.basic_block. Streaming ports of the block must be null when making the message passing port. Therefore, both sides do not have streaming ports. Therefore, in_sig=[] and out_sig=[]. Output port is a message port.

Message converter block- Message converter block convert PMT data to the generic type. These data are not passing synchronously.

4 RESULTS AND DISCUSSION

There are 3 ways of communicating between FPGA and computer. I.e. USB, Ethernet and serial. USB has four transfer modes named "control, interrupt, bulk and isochronous". Best mode to transfer audio or video data is isochronous transfer mode because one way communication and no handshake controlling. USB connection of YG_V2.1 board is configured only for bulk transfer. USB controller in the board is CH376. It is not supported for isochronous transfer mode. MAX232 serial controller is used as serial port communication. Maximum baud rate for this IC is 112500. Serial communication is used to test communication for this research.

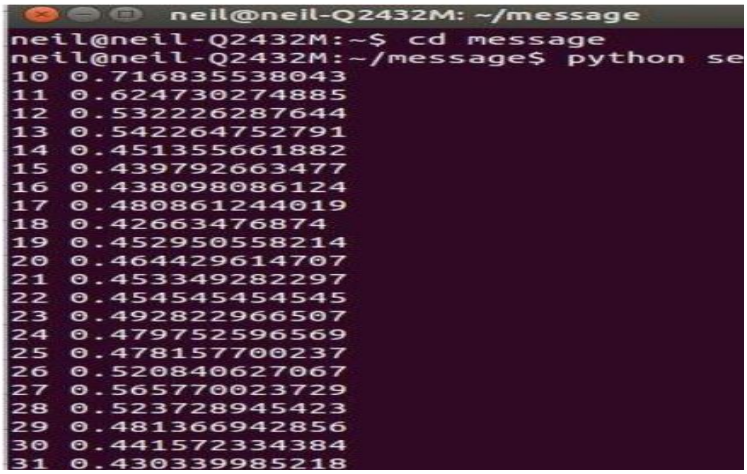

Figure 10: Serial communication output

10Hz sine wave output is shown in figure 10. There are 2 columns 1. Sample number, 2nd column is complex amplitude value of the signal.

GNURadio toolkit can be used to simulate, learn and testing digital signal processing in real time environment easily. With new high speed CPUs, high speed-high capacity FPGAs and continuously developing software modules in GNURadio, Software Defined Radio concept which is brining ADC/DAC closer to the antenna is becoming SDR from dream to reality.

5 CONCLUSION

Mobile communication world is changing from one device for one communication application to one device for all communication applications with Software defined Radio technology.

GNURadio (www.GNURadio.org) is a continuously developing free and open source toolkit for developing software defined radio. It is a large software project with many people in the world is joining through the Internet.

Making open source hardware part need to analyse how to make drivers for GNURadio, operating system based drivers like libusb (for USB connection) or serial port communication or Ethernet stack, selecting FPGA, selecting ADC, DAC, how to make digital up down conversion in FPGA, digital connection modules for USB, serial port, Ethernet and transmitting antenna.

Lots of theories of digital signal processing can be studied from beginning to expert level by simulating and can practice real time environments. Thus real results can be obtained. Users should have prior knowledge of C++, python, object oriented paradigm and Linux environment.

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Effect of bio-char on growth and yield of onion (*allium cepa*) and soil properties of Calcic Red Yellow Latasols in Jaffna District

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Abstract: *An experiment was conducted to study the effect of three different types of biochar applied to soil in combination with organic and inorganic fertilizers on growth and yield of Onion (Allium cepa) and on soil properties. The field research was carried out during the Yala season of 2016 at the Regional Agriculture Research Station, Thirunelvely. Randomized Complete Block design was used with three blocks and eight treatments. There were two fertilizer application treatments such as department recommended fertilizer (DRF) and farmers practice fertilizer(FPF) because farmers of study area usually applies 185% of the Department of Agriculture recommended fertilizer dosage. In addition there were three bio-char treatments namely coconut char (CC), Palmyra char (PC), and paddy husk char (PHC). Each fertilizer application treatment has a control treatment without the application of bio-char. Each biochar is applied with either department recommended fertilizer or farmers practice fertilizer. All the other cultural practices were same for all the treatments. Growth, yield and soil parameters were monitored continuously during the growing season. Significantly highest mean fresh weight of onions as yield (6750 kg/ha) was measured in treatment T7 (FPF+PHC). This contributes to 57% of fresh weight of yield compared to the control treatment T8 (FPF). Similarly significantly highest 51% increase in fresh weight of onions as yield was measured in treatment T3 (DRF +PHC) compared to the control treatment T4 (DRF). Statistically significant 60% dry weight of onions as yield increase was observed in both treatments T3 (DRF+PHC) and T7 (FPF +PHC) respectively compared to control treatment T4 (DRF) and T8 (FPF). Soil available phosphorus content has increased in all biochar applied treatments compared to the control treatments in both farmer practice fertilizer (FPF) and department recommended fertilizer (DRF). Significantly highest soil available potassium was obtained in paddy husk char with farmer practice fertilizer treatment. Soil available potassium is increased in all biochar applied treatments compared to the control treatments in both farmer practice fertilizer (FPF) and department recommended fertilizer (DRF). Soil organic carbon content has increased in all biochar applied treatments compared to the control treatments in both farmer practice fertilizer (FPF) and department recommended fertilizer (DRF). Therefore paddy husk char has increased the yield of onion significantly irrespective of the fertilizer application treatments compared to other biochar namely coconut char and palmyrah char. Therefore paddy husk char performs best when applied with farmer practice fertilizer or department recommended fertilizer application. However, coconut char and palm char has the potential to increase yield and improve soil properties with both DRF and FPF.*

Key words: *Bio char, soil properties, growth, yield, Onion*

1 INTRODUCTION

Increasing in population results in greater proportions of land needing to be cropped under cultivation and there is an urgent need to use of fertilizer to increase the crop yield by enhancing the soil productivity. However the rates of fertilizer applied by farmers concern about profit are usually much higher than the quantity recommended by the Department of Agriculture (DOA). Farmers apply nitrogen fertilizers when crop shows reduction in greenness of leaf caused by reduced crop response. Therefore it stimulates farmers to apply higher amount of urea (nitrogen fertilizer) which is cheap (Wijewardena, 1996; Wijewardena, 2001). Therefore loss of nutrient elements from fertilizers into the environment increases the environmental pollution.

Soils in Sri Lanka are low in organic matter (Panabokke and Nagarajah, 1964; Wijewardena, 1995; Wickramasinghe and Wijewardena, 2003). Cation Exchange Capacity (CEC) levels in majority of the soils are lower than 10 cmo1/kg, lead to poor retention of plant nutrients (Panabokke, 1966; Wijewardena 1993; 2000). Agricultural lands diminish in crop production potential or suitability for crop production through various types of land degradation in Sri Lanka (Nayakekorale, 1998). National average yields of paddy and several other food crops have been stagnating over the last decade (Wickramasinghe and Wijewardena, 2003) due to the degradation of overall soil fertility in cultivated lands in Sri Lanka. Being an agricultural country, Sri Lanka has to place much attention on soil degradation problem in consideration of the low per capita land availability at present. Soil fertility decline in Sri Lanka is mainly due to depletion of soil organic matter as well as loss of plant nutrients etc. Soil analytical studies conducted in various parts of the country revealed that low plant nutrient content is a major threat to crop production in Sri Lanka (Wijewardena, 1995; Nayakekorale and Prasantha, 1996). The depletion of soil nutrient due to leaching and run off could be considered as major course of fertility decline. Thus, many agricultural farming systems are becoming non-profitable to farmers.

Due to rigorous cultivation, greater amounts of CO_2 could be released to the atmosphere from biomass and soil. A reduction of this substantial CO_2 release could be achieved through bio-char (it is the carbon-rich product through heating of biomass under limited oxygen conditions) as a soil management system. Carbon sequestrations in the environment can off-set unavoidable greenhouse gas emissions. The application of bio-char to soil is proposed as an approach to establish a significant, long term, sink for atmospheric carbon dioxide in terrestrial ecosystems. Apart from positive effects in both reducing emissions and increasing the sequestration of greenhouse gases, the application of bio-char to soil will deliver immediate benefits through improved soil fertility and increased crop production.

Bio-char can be formed from a wide range of organic feed stocks under different pyrolysis conditions and at a range of scales. Many different materials have been proposed as biomass feed stocks for bio-char. The suitability of each biomass type for such an application is dependent on a number of chemical, physical, environmental, as well as economic and logistical factors. Application of bio-char varies with cultivation techniques. The application strategy used to apply bio-char to soils is an important factor to consider when evaluating the effects of bio-char on soil properties and processes. The placement of the bio-char directly into the rhizosphere is thought to be more beneficial for crop growth and less susceptible to erosion. Bio-char appears to improve a soils ability to retain and use fertilizers, reducing the amount lost to leaching and increasing soil water retention. If fully documented, this capability could be tied to water quality

improvement as less phosphorous and nitrates are lost from agricultural lands into waters.

In Jaffna neck of land, soil has low organic matter content and less CEC hence farmers use inorganic fertilizers at very higher rates than the DOA recommended rates (per.comm, 2016). This is leading to soil salinity, soil fertility decline and environmental pollution specially ground water (Mikunthan and De Silva, 2008). Bio-char has the ability to overcome these problems through improve the physical, chemical and biological properties of soil. In this background a field experiment was planned using the test crop as Onion (*Allium cepa*) with different charred biomass namely coconut char (CC), Palmyrah char (PC) and paddy husk char (PHC) in combination of inorganic and organic materials commonly used by Jaffna farmers. The field trial was conducted with the objectives of study the effect of different types of charred biomass in combination with department recommended fertilizer (DRF) and farmer practice fertilizer (FPF) on growth and yield of Onion (*Allium cepa*)and to study the effect of such treatments on important soil properties.

2 MATERIALS AND METHODS

The research was conducted at Regional Agricultural Research Station, Thirunelvely during the *yala* season of 2016. Two fertilizer treatments were used in this study because farmers in the study area usually use 185% of the Department of Agriculture recommended fertilizer dosage as shown in Table 1.Agriculture department recommended fertilizer (DRF) and Farmers practice fertilizer (FPF) were applied each with three types of charred biomass namely coconut char, palm char and paddy husk char and without any char. Coconut char, palm char and paddy husk char were produced through pit method. Eight treatments (Table 2) were tested in the field using as Onion (*Allium cepa)* test crop.

Table: 1 Rates of fertilizers

Fertilizers			Rate
DRF	Basal	Urea	50Kg/ha
		TSP	100Kg/ha
		MOP	50Kg/ha
		Cow dung	10 Ton/ha
	TD	Urea	100Kg/ha
		MOP	25Kg/ha
FPF	Basal	Urea	92.5Kg/ha
		TSP	185Kg/ha
		MOP	92.5Kg/ha
		Cow dung	10 Ton/ha
	TD	Urea	185Kg/ha
		MOP	46.25Kg/ha

Table 2: Treatments

Treatment	Char and fertilizer (for onion) combinations
T1	DRF+CC
T2	DRF+PC
T3	DRF+PHC
T4	DRF
T5	FPF+CC
T6	FPF+PC
T7	FPF+PHC
T8	FPF

The field was layout with blocking which was done perpendicular to the slope of the land. Three blocks were made and each block was further divided into eight plots with the plot size of 2m X 1.5m to each treatment (Figure 1). The soil layer up to the depth of 10 cm was removed and heaped in the each corner of the plot and basal fertilizer and cow dung were mixed with the heaped soil. Six years ago char was put in the plot as layer of five mm to ten mm below 10 cm from the soil surface. Then fertilizer and cow dung mixed soil was placed above the char layer and leveled. This the way the farmers were applying bio char in the study area. Therefore the same practice in done for this research too. These eight treatments were arranged using randomized complete block design with three replications. Before planting, the field was thoroughly irrigated. Onion bulbs were cleaned and 300 onion bulbs were allocated to each plot and weight of those onions were measured by balance. After 6 gram Captan was mixed into 10 l liter water and onion bulbs were soaked into that water before planted to field by hand with the spacing of 10 cm X 10 cm. As mentioned in the Table 1 fertilizers were applied to related treatments. All three types of char were applied at the rate of 20 tones/ha.

Figure 1: Onion trial field

Top dressing was done 2nd week after planting for treatments T1, T2, T3 and T4. For treatments T5 (FPF +CC), T6 (FPF + PC), T7 (FPF + PHC) and T8 (FPF) top dressing was done 2nd week after transplanting to farmer practice. Water was applied to the plots using hosepipe directly up to the field capacity level of the soil moisture and prevent the

mixing of soil between the plots. At early stage of planting field was irrigated at two days interval then four days interval. Hand weeding was done whenever weeds emerged. Weedicide (Goal) was applied at recommended rate to control the weeds.

Plant height was taken randomly selected five plants per plot. Plant height was determined in cm from the ground to the highest point of plant by using measuring tape at 2nd , 4th and 6th week after planting.

Each plot fresh weight of the yield onions were weighted by using balance immediately after the harvest. And dry weights of onion yield of each plot were weighted by using balance after one week from the harvest. Numbers of cluster, Numbers of cluster with leaves. Numbers of cluster without leaves were taken from five randomly selected plants in all treatments.

After the harvest soil from each plot in the field was collected by core sampler at the depth of 15 cm from the soil surface. Then collected samples were prepared by air drying, crushing and sieving to pass through 2mm sieve and important basic properties were determined. Soil pH and EC were measured preparing soil solutions using pH and electrical conductivity meter. Soil available potassium extraction was done using 1M neutral Ammonium acetate and exchangeable K was measured by flame photo meter (Knudsen et al., 1982). Soil's P content was measured by Olsen and Sommers (1982) method using 0.5M $NaHCO_3$ to extract. Moreover Available P in the extract was measured colourimetrically by Ammonium molybdate-$SnCl_2$ method at the wave length of 660nm. Soil organic matter content of the soil was done by the Walkley and Black (1934) method. Results were analyzed by SAS package and the mean separation was done by Duncan method (Probability 5%).

3 RESULTS AND DISCUSSION

3.1 Plant Height

Plant height data are summarized in Figure 2. Only 4th week mean plant height was significant (P=0.0166). Significantly highest mean plant height (23.3 cm) was observed in treatment T7 (FPF+PHC). Second highest mean plant height (18.5 cm) was observed in control treatment T8 (FPF). Plant height of 22.3cm, 21.7cm, 21.5cm, 21.5cm and 21.2cm were observed in treatments T6 (FPF+PC), T5 (FPF+CC) T2 (DRF+PC), T8 (FPF), T1 (DRF+CC) respectively. However these results were statistically not significant. Among the DRF treatments T1 to T4, control treatment T4 (DRF) showed the lowest mean plant height and among FPF treatments control treatment T8 (FPF) showed the lowest mean plant height. Plant height was increased by the application of all three types of bio-char compared to the respective control treatments (T4, T8). Overall, T7 showed the highest significant plant height. Bio-char applications has increased the plant height compared to fertilizer alone applied treatments. The findings of this research agree with Graber (2010) who has reported increased plant height in tomato crop was due to bio-char application.

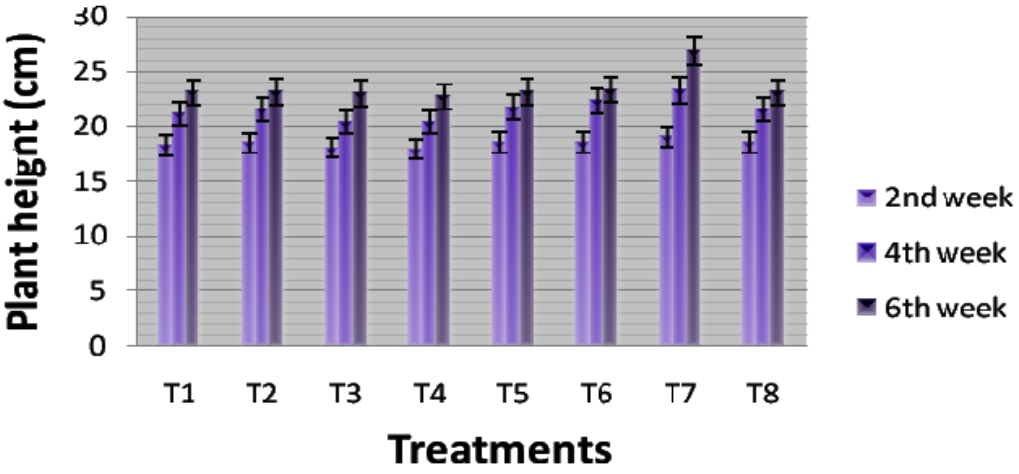

Figure 2: Effect of different treatments on height of Onion

3.2 Yield parameters

Number of cluster per plant

Number of cluster per plant data are summarized in Figure 3. Statistically significant highest mean of number of cluster per plant (7) was measured in the treatment T7 (FPF+PHC). Second highest mean of number of cluster per plant (6) was measured in T8 (FPF) followed by T2 (DRF+PC), T6 (FPF+PC), T4 (DRF Control) and T5 (FPF + CC) and T6 (FPF +PC) and these are statistically not significant from each other. The lowest mean number of cluster per plant (4) was observed in treatment T3 which is statistically not significant from T1 (DRF + CC), T4 (DRF) and T5 (FPF+CC).

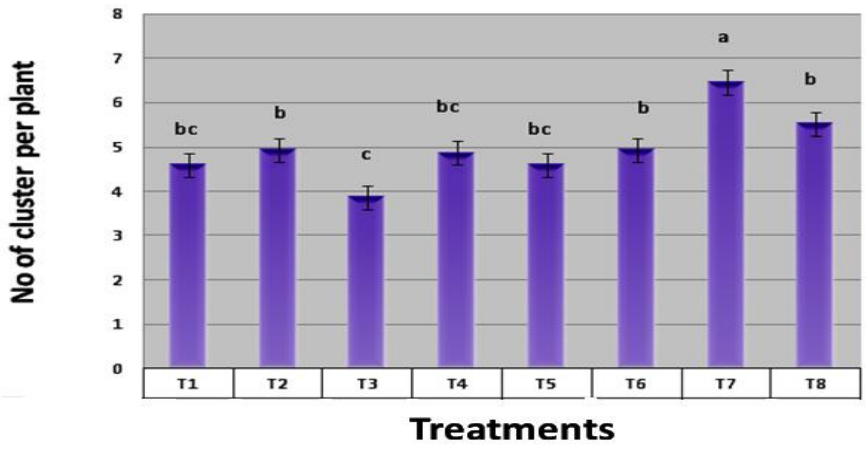

Figure 3: Effect of different treatments on number of cluster per plant

Cluster weight without leaves

Cluster weight without leaves data are summarized in Figure 4. Statistically significant highest mean of cluster weight without leaves (14.8 g) was observed in treatment T7 (FPF + PHC). Second highest mean of cluster weight without leaves (13.8 g) was observed in treatment T6 (FPF +PC) which is statistically not significant from T7 (FPF + PHC), T3 and T5 treatments. Treatments T1, T5, T6, and T8 were statistically significant. Treatment T1 (DRF+CC) was the lowest mean of cluster weight without leaves (9.5g). Compared to

control T4, increased cluster weight without leaves was observed only in treatment T3. Compared to control T8, increase in cluster weight without leaves were observed in treatment T5, T6, and T7.

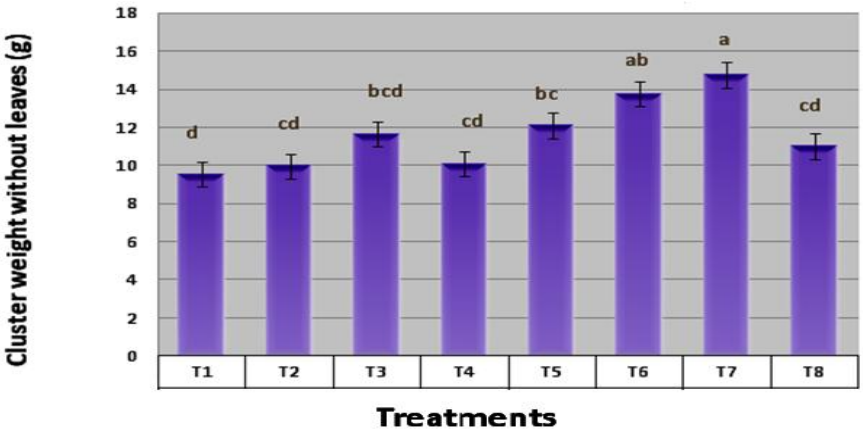

Figure 4: Effect of different treatments on cluster weight without leaves per plant

Fresh weight of the yield of onions

Fresh weight of the yield of onions data are summarized in Figure 5. According to the Figure 5, significantly highest mean fresh weight of yield (6750 kg/ha) was measured in T7 (FPF+PHC). Second highest mean fresh weight of yield (5100 kg/ha) was obtained in T6 (FPF+PC), followed by T3 (DRF+PHC) and these were statistically not significant to each other. Lowest mean fresh weight of yield (2650kg/ha) was observed in T1 (DRF+CC) followed by T2 (DRF+PC) and T4 (DRF) and these were statistically not significant to each other. Compared to control T4, increase in yield increase was observed only in treatment T3. Compared to control T8, increase in yield was observed in treatments T6 and T7.

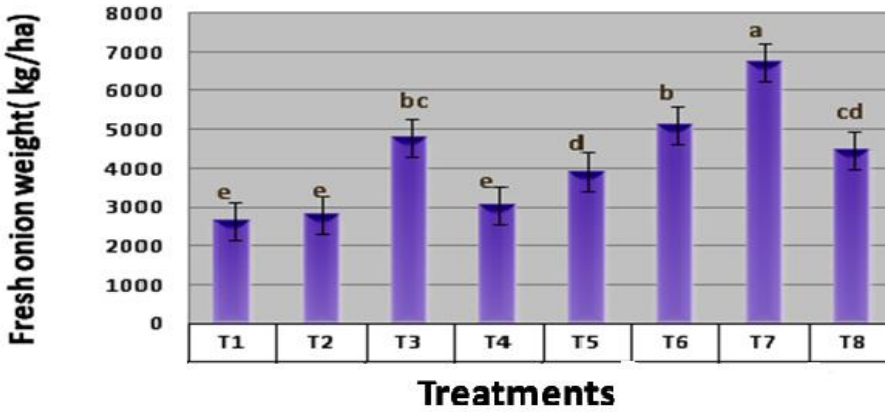

Figure 5: Effect of different treatments on fresh weight of Onion

Dry weight of the yield onions

Figure 6 shows the effect of different treatments on dry weight of the onions as yield. The highest average yield (6393.3 kg/ha) was obtained in treatment T7 (FPF + PHC) which was statistically significant to all other treatments. Second highest yield of 4566.7kg/ha was obtained in Treatment T6 (FRF+ PC) which is statistically not significant to the yield

(4433.3 kg/ha) of treatment T3 (DRF +PHC). The dry yield obtained was statistically significant in control treatments T4 (DRF) and T8 (FPF). Lowest dry weight of the yield (1966.3 kg/ha) was obtained on T1 (DRF+CC). Compared to control T4, yield increase was observed only in treatment T3. Compared to control T8, yield increase was observed in treatments T6 and T7. Among the FPF treatments T7 showed highest yield which was significantly different to treatments T5, T6 and T8. Among the DRF treatments T3 treatment showed highest yield which was significantly different to T1, T2 and T4. The results of field trial indicate that the application of bio-char improves the crop yield. Beneficial effects on crop yields by bio-char have been also documented in a number of pot and field trials (Asai *et* al., 2009; Chan *et* al., 2007; Major et al., 2010; Van Zwieten *et* al., 2010). Result revealed that the paddy husk char can give better yield when more fertilizer application than that of department recommendation. However better yield was obtained under paddy husk char even in department recommended fertilizer application.

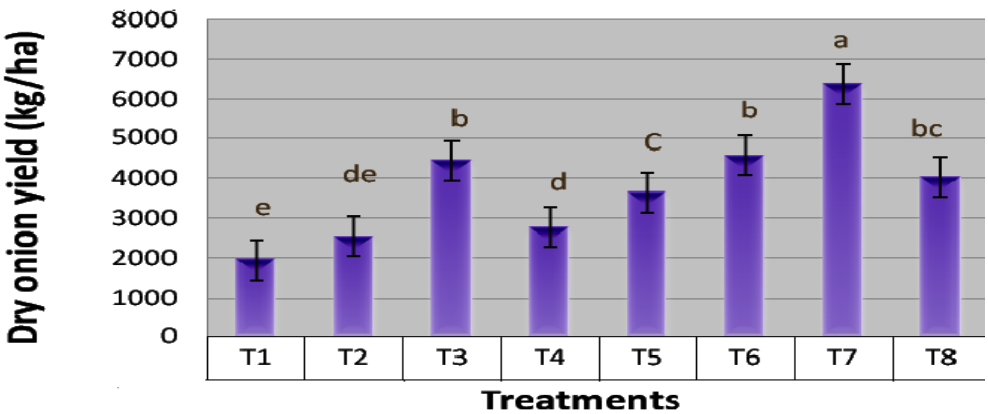

Figure 6: Effect of different treatments on dry weight of Onion

3.3 Soil parameters

Soil pH

The highest mean of soil pH (7.9) was observed in treatment T1 (DRF+CC) compared to all other treatments (Figure 7). However pH of treatments T1, T2, T3 and T4 are statistically not significant to DRF treatments. Among FRF treatments, the mean soil pH of treatment T6 (FPF+PC), T7 (FPF+PHC) and T8 (FPF) were statically not significant, but T5 (FRF + CC) treatment showed the highest pH which is statistically significant to other treatments. The lowest mean soil pH (7.2) was observed in treatment T8 (FPF). Among DRF treatments T1 to T4 soil pH was increased by the application of bio-char in all treatments compared to control treatment T4 (DRF). Among FPF treatments T5 to T8, soil pH was also increased by the application of bio-char in all treatments compared to control treatment T8 (FPF). Several studies have been reported that bio-char addition increases the soil pH (Deluca et al., 2006). The addition of bio-char to soil will amend the chemical and physical properties soils and turned into a valuable resource for improving crop yields on acid and infertile tropical soils where nutrient resources are scarce (Lehmann and Rondon, 2005). According to the results of soil pH in different treatments, higher rate of fertilizer application in FRF treatments had reduced the soil pH. In farmers practice fertilizer have high amount of urea than that in department recommendation fertilizer. Soil pH decreases after application of urea due to acidification resulting from

dissociation of urea to produce H+ ions (Yeboah *et* al., 2009). This may also be reason for the reduced soil pH in treatments related to farmers practice fertilizer compared to treatments related to DRF even in same type of bio-char applied treatments.

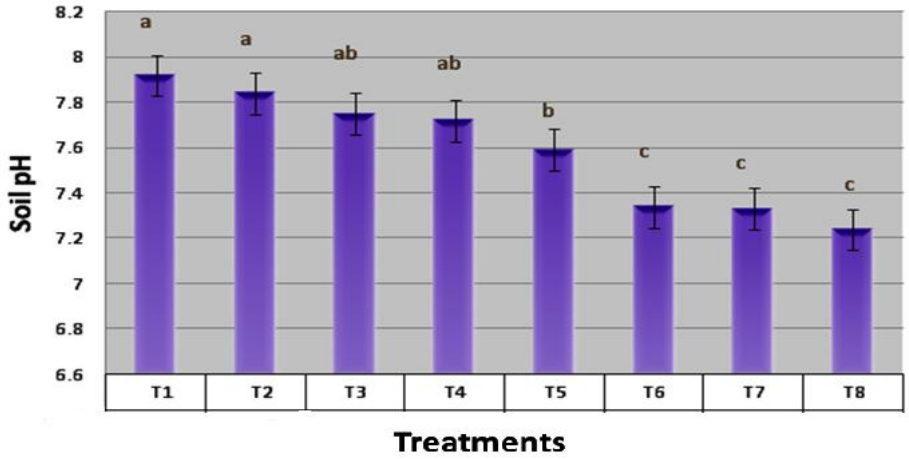

Figure 7: Effect of different treatments on soil pH

Electrical Conductivity (µs/cm)

Among the FRF treatments, highest electrical conductivity (108.3 µs/cm) was obtained in treatment T7 (FPF + PHC) and lowest electrical conductivity (89.9 µs/cm) in control treatment T8 which are statistically significant to each other (Figure 8). However treatment T5, T6 and T7 are statistically not significant to each other. Among the DRF treatments, the highest electrical conductivity (92.4 µs/cm) was observed in treatment T2 (DRF +PC) which statistically significant to T1, T3 and T4 treatments. Soil electrical Conductivity was increased by the application of all three types of bio-char compared to control. From treatments T1 to T4, Control T4 (DRF) is the lowest measured mean soil electrical conductivity. From treatments T5 to T8, Control T8 (FPF) is the lowest measured char improves the soil electrical conductivity. Nigussie *et al* (2012) reported of increased EC due to bio-char application at the rate of 10 tones/ha in Cr polluted soil which agrees with the results of this study.

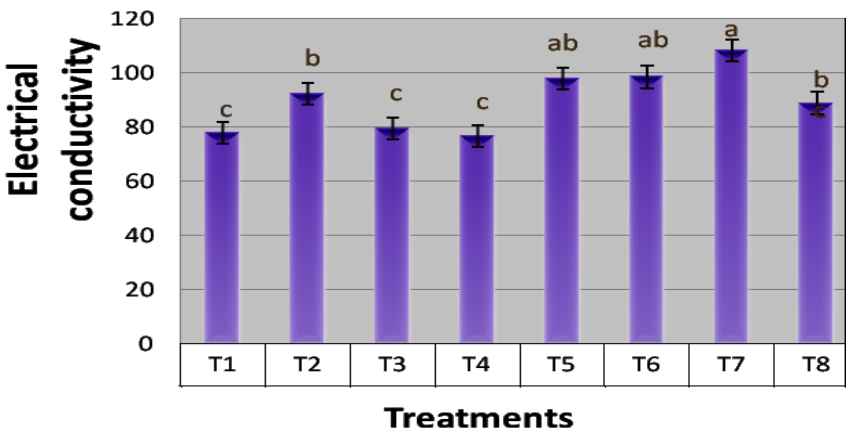

Figure 8: Effect of different treatments on soil EC (µs/cm)

Available phosphorous (kg/ha)

Available phosphorus data are summarized in Figure 9. Significantly highest available phosphorus (134.9kg/ha) was obtained in T7 (FPF+PHC) and the lowest available phosphorus (96.1 kg/ha) was in treatment T4 (DRF). Among the DRF treatments the highest available phosphorous (120.7 kg/ha) was obtained in T2 (DRF + PC), but it is statistically not significant to the available phosphorus content (107.3 kg/ha) of treatment T3 (DFR +PC). Lowest available phosphorus was obtained in control treatment T4 which is without biochar application. Similarly among the FPF treatments the treatment T7 is statically not significant to treatments T5 (FPF +CC) and T6 (FPF +PC), but statistically significant to the lowest available phosphorus treatment T8 (FPR) which is without bio char application. Soil available phosphorous was increased by the application of all three types of bio-char compared to control. The release of P from bio-char has long been recognized (Tyron, 1948), and the mechanism for direct P release from bio-char is not complex. Further Biochar may have an indirect effect on P availability and uptake by providing a beneficial environment for microorganisms that, in turn provide greater access to P from organic and insoluble inorganic pools, produce and recycle a highly labile pool of organic P and improve direct access to P through improved mycorrhizal activity (Deluca et al, 2006)

Available potassium (kg/ha)

Significantly highest mean of available potassium (103.4kg/ha) was observed in treatment T7 (FPF+PHC) to all other treatments (Figure 10). The lowest mean of available potassium (56kg/ha) was observed in treatment T4 (DRF). Among the DRF the highest available potassium was obtained in treatment T2 (DRF +PC) which is statistically significant to T1, T3 and T4. Soil available potassium was increased by the application of bio-char compared to control treatment T4. Among the FPF treatments T5 to T8, Control T8 (FPF) is the lowest measured mean soil available potassium (79.4kg/ha) but it is statically not significant to T5 and T6 treatments. Increased potassium availability was observed in bio-char amended treatments compared to the treatments for which fertilizer alone was applied. This is due to the higher K content of bio-char. The supply of available K in bio-char is typically high and increased K uptake as a result of bio-char application has been frequently reported (Lehmann et al., 2003b; Chan et al., 2007).

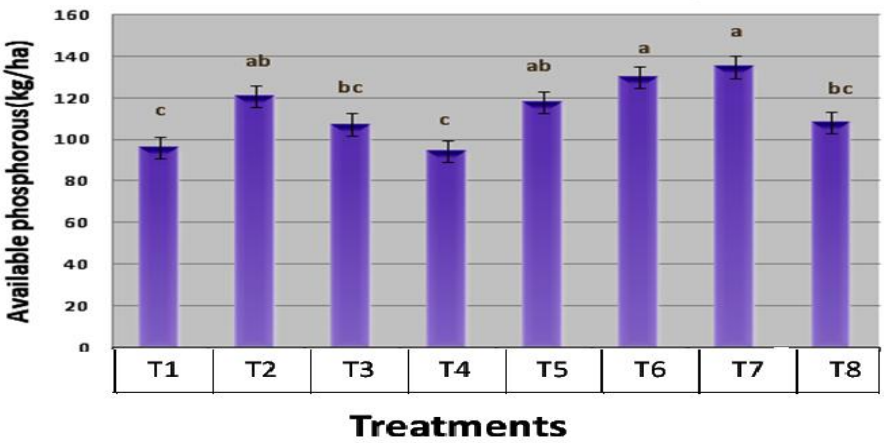

Figure 9: Effect of different treatments on soil available phosphorous

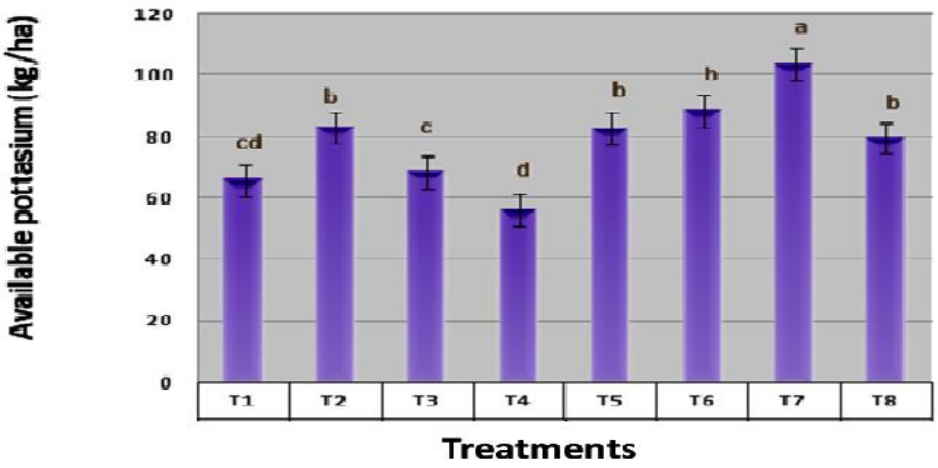

Figure 10: Effect of different treatments on soil available potassium

Soil Organic carbon

Soil organic carbon data are summarized in Figure 11. Significantly highest (0.98) and lowest (0.08) soil organic carbon percentages were obtained in treatments T1 (DRF+CC) and T8 (FPF) respectively. Among DRF treatments highest and second highest (0.84) percentage of soil organic carbon was obtained in T1 and T3 (DPF +PHC) treatments, but these treatments are statistically not significant to each other. The lowest soil organic carbon percentage was obtained in T4 treatment which is without biochar application. Among the FPF treatments significantly highest soil organic carbon percentage was obtained in T5 (FPF+CC) and the lowest soil organic carbon percentage was obtained in treatment T8 (DRF) which is without bio char application. Soil organic carbon percentage was increased by the application of all three types of bio-char compared to control. Nigussie *et* al (2012) reported significantly increased mean value of soil organic carbon (SOC) in soil amended with maize stalk bio-char. The highest values of organic carbon in bio-char treated soils indicate the recalcitrance of organic carbon in bio-char. Bio-char offers a way of safely storing C for long periods of time while enhancing the productivity of terrestrial ecosystems. Moreover, bio-char technology, like other biomass conversion approaches that include C sequestration options, offers a way to decrease the levels of CO_2 in the atmosphere (Lehmann and Joseph, 2007).

More over biochar can improve plant productivity directly as a result of its nutrient content and release characteristics, as well as indirectly, through improved retention of nutrients (Lehmann et al., 2003; Wardle *et al.,* 1998), improvements in soil pH (Rondon *et al*., 2007), increased soil cation exchange capacity (Liang *et al*., 2006), improved soil physical properties (Chan et al., 2008), including an increase in soil water retention (Laird *et al*., 2010). These effects may also act in concert to result in improved crop performance. Biochar is also thought that the porous and light nature of biochar can help to improve the structure of compacted soils and improve soil aggregation that also increases the water retention (Sohi *et al.,* 2010). Fresh biochar contains different proportions of ash, which is rich in minerals and benefits plant growth (Verheijen *et al.,* 2010). One important measurement of soil fertility is called the Cation Exchange Capacity. CEC of soil increases with biochar that increases nutrient retention and reduces the leaching losses. Increased nutrient availability (P and K), organic matter content due to applied charred biomass were observed at the end of the experiment.

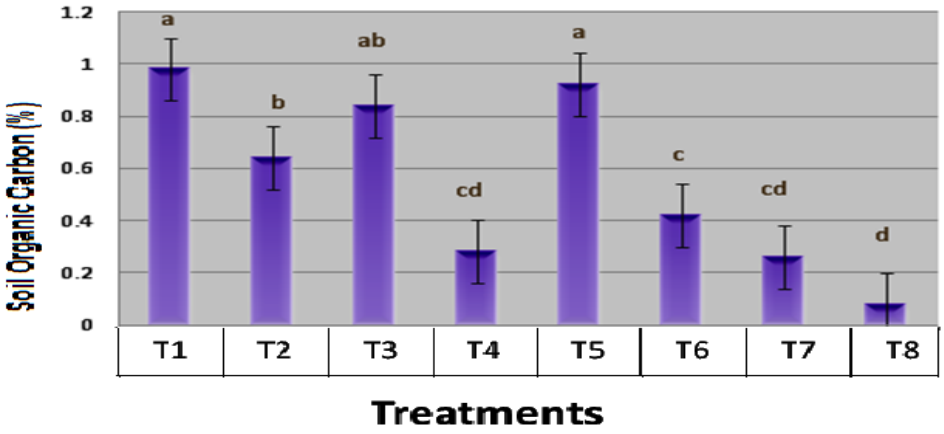

Figure 11: Effect of different treatments on soil organic carbon

4 CONCLUSIONS

Significantly highest mean fresh weight of onions as yield (6750 kg/ha) was measured in treatment T7 (FPF+PHC). This contributes to 57% of fresh weight of yield compared to the control treatment T8 (FPF). Similarly significantly highest 51% increase in fresh weight of onions as yield was measured in treatment T3 (DRF +PHC) compared to the control treatment T4 (DRF). Statistically significant 60% dry weight of onions as yield increase was observed in both treatments T3 (DRF+PHC) and T7 (FPF +PHC) respectively compared to control treatment T4 (DRF) and T8 (FPF).

Results of soil analysis at the end of the experiment reveals, which all treatments with bio char application have increased available P and available K compared to control treatments. Highest P and K availability was found in T7 (FPF + PHC). Reduced soil pH in treatments related to FPF and increased soil pH in treatments related to DRF was recorded even in same bio-char applied treatments. Soil Organic matter content was increased by the application of all three types of bio-char compared to control. All treatments have shown increased EC compared to Controls.

Therefore it could be concluded that paddy husk char has increased yield and performed the best when applied with FPF and DRF. Moreover, However, coconut char and palmyra char has the potential to increase yield with both DRF and FPF. Paddy husk is freely available in the paddy field of Jaffna District. Paddy Husk Char could be easily produced with low cost to increase the yield of onions.

5 ACKNOWLEDGEMENT

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Infant Cry Detection System with Automatic Soothing and Video Monitoring Functions

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Abstract - *The aim of this research is to develop a portable, efficient and cost effective automatic infant's cry detector and self-soother with real time monitoring system for employed parents.*

The cry detection algorithm has developed according to the crying signals and it is segmented using the short time energy function which is used as a voice activity detector to disable the operation of the algorithm when voice activity is not present. The features are extracted using MFCC (Mel Frequency Cepstrum Coefficients) and pitch frequency. Statistical properties are calculated for the extracted features of MFCC and pitch frequency. K-NN (K-Nearest Neighbour) algorithm classifier is used to classify the cry signal. The system can easily identify the infant cry and it is verified using K-NN with accurate results by proposed detection algorithm.

The combination of Pitch and MFCC gives more promising approach to cry detection than using only MFCC. The total average accuracy of MATLAB simulation is 80.8335% and on the device accuracy was77.5% for cry detection.

Immediate cry detection and self-soothing system helps to increase baby's cognitive development process. This all in one module approach gives great benefits to the first-time parents, adoptive parents, caretakers, researchers or physicians by both economically and scientifically.

Key words – ***Cry detection, MFC, K-NN, Pitch detection, Soothing system***

1 INTRODUCTION

Infant cry is the first verbal communication of new born baby with the world. The crying of the infant is a common phenomenon and probably one of the most difficult problems which parents have to face when taking care of a baby.

The cry of an infant is a biological siren to alert for the care giving environment about their needs to motivate the listener to respond. Most of the times, caretaker's advocates' follow strict routines to train the child for regular feeding, waking and sleeping pattern without considering their emotional and physical needs. Researchers have found babies whose cries are usually ignored will not develop healthy intellectual and social skills [15].On the other hand, leaving a distressed baby to cry on a regular basis could damage the brain development.

Currently there are many types of baby monitoring systems with wearable option, android applications, wirelessly controlled camera systems etc. Most of these systems are

covered only home using Wi-Fi or Bluetooth. Due to this condition, employed parents (especially mothers) cannot ensure the safety of their babies because, they are unable to connect with the child when they're at working places. There are few products which have remote monitoring facilities. However, those are priced high-end products which are not affordable in developing countries like Sri Lanka. Further, these products are not easy to set up and by fixing near to the baby may cause health hazards due to electromagnetic radiation.

This product is designed for an affordable cost and it can be used from birth to 12 months of babies with ability to detect the infant's crying immediately and send notification to warn parents/caregiver while a soft sound and lights playing to sooth the baby. On the other hand, if the parent has any doubt about babies, they can connect to the home wireless network and check the baby using a mobile phone in real time at any time while ensuring the safety of the baby. The other benefit of this product is, it is important for hearing impaired parents because the parent can get notifications through android application which is password protected, and hearing-impaired parent can configure their phone into the vibration mode. Parents can watch live video stream from the baby's room when the notification received.

2 OBJECTIVES

This research work was carried out to achieve the following objectives,

(a) Study feature extraction methods in audio processing and develop a cry detection algorithm in different approaches of feature extraction and classification methods.

(b) Design and implement infant's cry detection device, by applying the developed cry detection algorithm with self-soothing and video monitoring functions.

3 LITERATURE REVIEW

3.1 Theoretical Background

Automatic Speech Recognition systems (ASR)

Automatic Speech Recognition (ASR) is the process of converting a speech signal to a sequence of words, by means of an algorithm. Five modules can be identified to develop an ASR. [1]

i. Speech Signal acquisition.
ii. Feature Extraction.
iii. Acoustic Modelling.
iv. Language & Lexical Modelling.
v. Recognition.

Feature extraction requires more attention in speech recognition because recognition performance depends heavily on this phase. The main goal of the feature extraction step is to compute a parsimonious sequence of feature vectors providing a compact

representation of the given input signal. The feature extraction is usually performed in three stages. The first stage is called the speech analysis or the acoustic front end. It performs Spectro temporal analysis of the signal and generates raw features describing the envelope of the power spectrum of short speech intervals. The second stage compiles an extended feature vector composed of static and dynamic features. Finally, the last stage transforms these extended feature vectors into more compact and robust vectors that are then supplied to the recognizer. [1]

There are various techniques used for feature extraction. Cepstral Analysis, Mel Cepstrum Analysis, Mel-Frequency Cepstrum Coefficients (MFCC), Linear Discriminant Analysis (LDA), Fusion MFCC, Linear Predictive Coding (LPC) Analysis and Perceptually Based Linear Predictive Analysis (PLP) are some of the techniques being used.

After feature extraction, the most important step is speech recognition. Basically, there are three approaches of speech recognition [1]. Those are Acoustic Phonetic Approach, Pattern Recognition Approach and Artificial Intelligence Approach.

3.2 Literature survey of similar products

Comparison of similar products is shown in table 1.

Table 1: Comparison of similar products in the market for baby care with cry detection

Product name	Methodology	Price	Drawbacks
Why Cry – Baby Cry Analyzer Monitor [7] 	This sound sensitive device is programmed to recognize different pitches and then digitally analyses and transmit the baby's cry into one of five simple expressions – hungry, bored, annoyed, sleepy or stressed.	US$ 52.34 (LKR ~7800)	1. No real time video monitoring option 2. No self-soothing system included 3. The alarm is sound based, need to be in the range to hear the alarm
Wireless Baby Crying Detector with Parental Alarm[8] 	This crying detector consisting with transmitter and receiver. Once the baby cry or other noise occurs, the receiver starts to make electronic crying noise. It's a low cost and compact design.	US$ 10.70 (LKR ~1600)	1. Low sensitivity of cry detection 2. Alarm is sound based and not useful for hearing impaired 3. No self-soothing system included 4. Limited Range (in between 50-60 m)

Cry translator 	A simple and lightweight. It is designed to be handled with one hand and attend to baby with the other. Notify the reason for crying. Can soothe baby with the sound of the beating of a heart or lullabies.	79.90 € (Euro) (LKR ~12800)	1. No alarming system to care giver when baby needs attention 2. Expensive 3. Limited range /No real time video monitoring option.
Wi-Fi, baby 2.0 	This monitors video and hear audio from the baby's room via an iPad, iPhone, PC, Mac, Android phone, or Android tablet. The video and audio streams live from a single Wi-Fi Baby unit set up in the child's bedroom.	**US$ 230** (LKR ~34500)	1. Do not detect the crying of a baby 2. Always need to watch the baby video and pay attention to the audio. 3. Only covers home wireless network

4 METHODOLOGY

The block diagram of the proposed system is shown in Figure 1. This system consists of 2 units; child unit and parental unit.

The child unit consists with a data processing unit, which interfaces with camera, speaker, microphone and self-soothing system with wireless connectivity (Wi-Fi). For the data processing, single board computer has been used. Parental unit is a smart phone, laptop or tablet with internet connectivity. Child unit connected with home internet connections via Wi-Fi or Ethernet. Parental unit and child unit are connected via internet. A notification will be given to the parent if baby is crying continuously. Then the parent can operate the system remotely according to his or her wish. It can be connected to the internet and can check his/her child online with a mobile phone in real time.

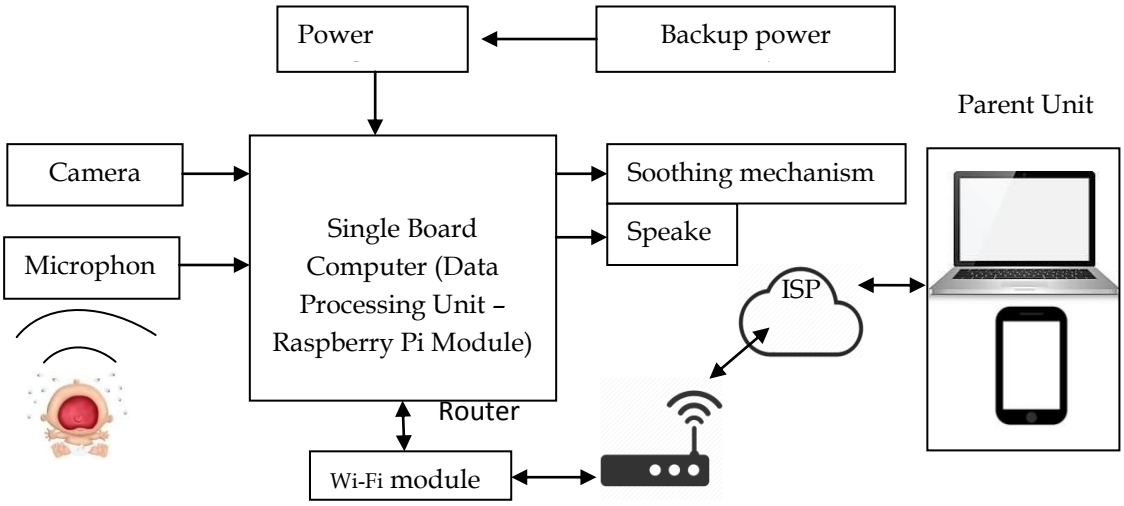


Figure 1: Block Diagram of the proposed infant cry detection and soothing system

Automatic cry detection system

When the baby starts crying, at a predetermined time a microphone picks up a cry from the baby as an audio signal. At a certain sampling frequency, an A/D converter samples the audio signal received by the microphone and convert it. An audio Analyzer analyze the audio signal samples by the A/D converter and computes a characteristic quantity based on a frequency spectrum (Feature extraction).
After signal processing, data processing unit classifies the pattern from a recognition model by training it with infant cry samples (reference) and give the decision logic whether it is crying or not.

Self-Soothing system

When the cry detection algorithm detects the sound input as cry at a predetermined time, a signal given to the two DC motors and 1st rotating lamp will be rotated continuously while the 2nd rotating lamp gives glow effect. Furthermore, the glowing effect can use the black perspective sheets with beautiful carvings which includes base to project different shapes on ceilings or walls, also according to different colours, these sheets can be changed manually, which will be very user friendly, and gives more realistic output to the baby at his developmental stage other than being bored by seeing the same light effect. The projection shapes and colours have been selected according to research papers [14] which are based on cognitive development of child at infancy period. In raspberry PI module (Single Board Computer), easily can operate the self-soother by using GPIO (General Purpose Input Output).

LED illusion mirror effect can be used for more glow effect and it affect to the babies' visual systems development, and at just 3 months of age, they have appeared perceive colours in a way that is analogous to adults. And simultaneously with the above process plays his favorite lullabies, or white noises soothe him, which are stored in raspberry PI as a sound library, after this sequence if baby continuously crying then notification will be sent to the parent.

From the proposed product, parents get instant notification when a cry detected. They can control (Playing music, call on their own voice) the soothing mechanism. Also, from live video streaming feature, parents can view their child real time. Further, crying sample can be saved for later statistical analysis.

The design of the system consists with two main subsystems.

- Cry detection algorithm
- Soothing mechanism and video streaming function

Overall integration of various modules also part of the design. Figure 2 shows the flow chart of the overall system.

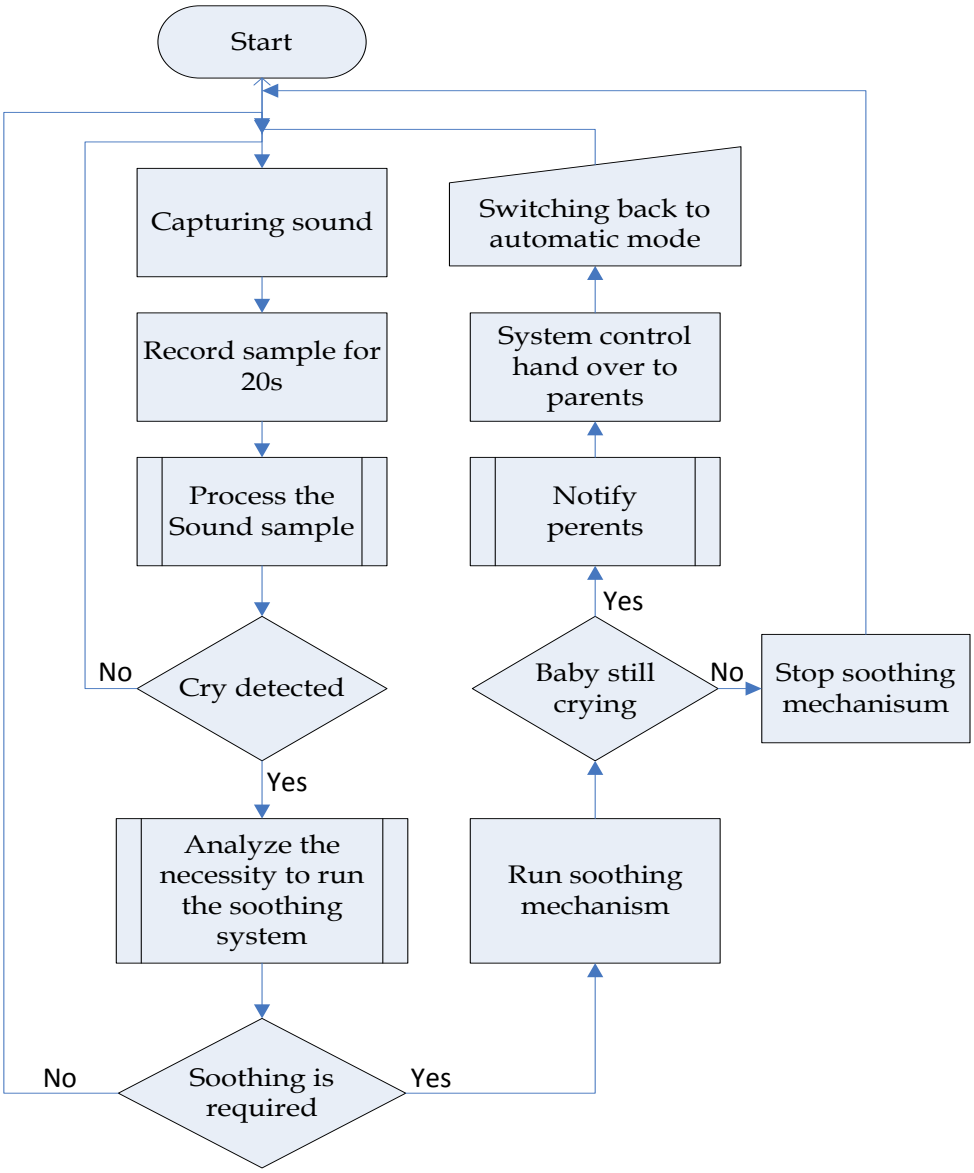


Figure 2: Top level flow chart of the system

4.1 The Cry Detection Algorithm

The proposed algorithm is composed of three main stages:

i) ***Voice Activity Detector (VAD)*** for detecting sections with sufficient audio activity. Short time energy is used as a VAD.

Short-time energy:
Where $E_n$is the energy of the sample 'n' of the audio signal, x [m] is the discrete time signal and w[m] is a rectangle window of size 'N'. The rectangle window function is defined by the expression below: w[n] = 1, 0 ≤n≤N-1; else w[n] =0

$$E_n = \frac{1}{2N}\sum(x[m].w[n-m].w[n+m])^2$$

ii) ***Feature to be extracted***

As mentioned in the section 3.1, there are various methods to extract the feature of the audio signal. In the proposed algorithm, two features have extracted from the cry audio signal.

Pitch: It's a fundamental frequency of a periodic wave form. In humans, pitch is determined by the frequency of the vibration of vocal chords.

- Adult males average at 120 Hz, [85,155]
- Adult females average at 210Hz, [165, 255]
- Infants average at 450hz, [250, 700]

Modified autocorrelation Method used for detecting the fundamental frequency of the infant cry based on the center clipping method which gives more accurate results.

Steps of Modified Auto Correlation Method for Pitch Frequency extraction [6]

Figure 3 shows the block diagram of the pitch detection algorithm. The segmented audio signal is first required to be low pass filtered to 900Hz. Then the signal is digitized at a 10 kHz sampling rate and sectioned into overlapping 30ms (300 samples) sections for processing. Since the pitch period computation for all pitch detectors are performed 100 times/s, every 10ms, adjacent sections are overlapped by 20ms or 200 samples. The first stage of processing is the computation of a clipping threshold *CL* for the current 30-ms section of speech. The clipping level is set at a value which is 68% of the smaller of the peak absolute sample values in the first and last 10-ms portions of the section. Following the determination of the clipping level, the 30-ms section of the speech is center clipped, and then infinite peak clipped. Thereafter, clipping the autocorrelation function for the 30-ms section is computed over a range of lags from 20 samples to 160 samples (2-ms-20-ms period). Additionally, the autocorrelation at 0 delays is computed for voice/unvoiced determination. The autocorrelation function is then searched for its maximum value. If the maximum exceeds 0.55 of the autocorrelation values at 0 delays, the section is classified as voiced and the location of the maximum is the pitch period. Otherwise, the section is classified as unvoiced.

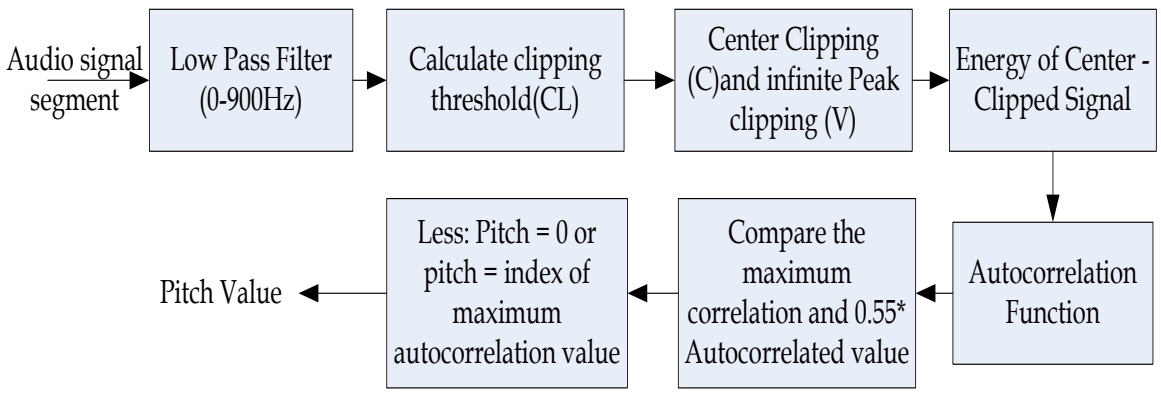


Figure 3: Block diagram of pitch detection algorithm using the modified autocorrelation method

Mel-Frequency Cepstrum Coefficients (MFCC)

MFCC provides a representation of the short-term power spectrum of a signal. These coefficients are obtained by multiplying the short-time Fourier Transform (STFT) of each analysis frame by a series of *M* triangularly-shaped ideal band-pass filters, with their central frequencies and widths arranged according to a Mel -frequency scale. The total spectral energy $E[i]$ contained in each filter is computed and a Discrete Cosine Transform (DCT) is performed to obtain the MFCC sequence.

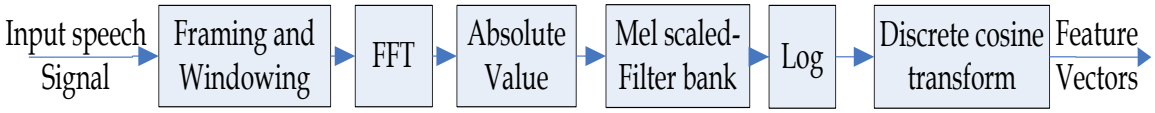


Figure 3: Steps to calculate MFC coefficients

Framing and Windowing: -First split the signal up into several frames such that, analysing each frame in the short time instead of analysing the entire signal at once. At the range (10-30) ms, most part of speech signal is stationary. It is necessary to work with short term or frames of the signal. Windowing is performed to avoid unnatural discontinuities in the crying segment and distortion in the underlying spectrum. The choice of the windowing is a tradeoff between several factors. In speaker recognition, the most commonly used window shape is the hamming window [3].The hamming window W_H (n), defined as,[6]

$$W_H(n) = 0.54 - 0.46\, cos\left(\frac{2n\pi}{N-1}\right)$$

The hamming windows is used since, MFCC will be used which involves in the frequency domain. (Hamming windows will decrease the possibility of high frequency components in each frame due to such abrupt slicing of the signal.)

Fast Fourier Transform (FFT): To convert the signal from time domain to frequency domain preparing for the next stage (Mel frequency wrapping).Spectral analysis shows that cry signals have different timbres in speech signals correspond to the different energy distribution over frequencies. Therefore, usually perform FFT to obtain the magnitude, frequency response of each frame.

Mel-scaled the filter bank: The speech signal consists of tones with different frequencies. For each tone with an actual Frequency, f, measured in Hz, a subjective pitch is measured on the 'Mel' scale. The *Mel-frequency* scale is linear frequency spacing below 1000Hz and a logarithmic spacing above 1000Hz.Using the following formula to compute the Mel(f) for a given frequency *f* in Hz:

$$\mathrm{Mel(f)} = 2595 * \log_{10}(1 + \mathrm{f}/700)$$

One approach to simulate the subjective spectrum is to use a filter bank; one filter for each desired Mel frequency component. The filter bank has a triangular band pass frequency response, and the spacing as well as the bandwidth is determined by a constant Mel-frequency interval.

The reasons for using triangular band pass filters are twofold:

- Smooth the magnitude spectrum such that the harmonics are flattened to obtain the envelope of the spectrum with harmonics.
- Reduce the size of the features involved.

Discrete cosine transforms, or DCT: In this step, we apply DCT on the 20log energy E_k obtained from the triangular band pass filters to have L Mel-scale Cepstral coefficients. The formula for DCT is shown below.

$$C_m = \sum_{k=1}^{N} \mathrm{Cos}\left[\frac{m(k-0.5)\pi}{N}\right] E_k \,, m = 1,2, \dots \dots L$$

Where N is the number of triangular band pass filters, L is the number of Mel-scale Cepstral coefficients. Usually we set N=20 and L=12. Since we have performed FFT, DCT transforms the frequency domain into a time-like domain called quefrency domain. The obtained features are similar tocepstrum; thus, it is referred to as the Mel-scale Cepstral coefficients, or MFCC.

iii) Classification using k-nearest neighbours (k-NN) algorithm

This algorithm operation is there to compare a given new record with training records and finding training records that are similar to it. It searches the space for the k training records that are nearest to the new record as the new record neighbours. In this algorithm nearest is defined in terms of a distance metric such as Euclidean distance. Euclidean distance between the two records (or two points in n-dimensional space) are defined by:

If $x_1 = (x_{11}, x_{12} \dots x_{1n})$ and $x_2 = (x_{21}, x_{22} \dots x_{2n})$

$$\mathrm{dist}(X_1, X_2) = \sqrt{\sum_{i=1}^{n} (X_{1i} - X_{2i})^2}$$

Where x_1 and $x_2$are two records with n attributes. This Formula measures the distance between two patternsx_1 and x_2.The K-nearest neighbour classifier is a supervised learning algorithm where the result of a new instance query is classified based on the majority of the k-nearest neighbour category.

4.1.1 Methodology of Infant Cry Detection

The aim of the detection algorithm is to classify each incoming segment of a stream of input audio signals as 'cry' or 'no cry' The algorithm analyses the signal at various time-scales (segments of several seconds, sections of about 1 second, and frames of several tens of milliseconds). Figure 4 shows the audio processing algorithm to detect cry signal.

- A VAD is applied and the amount of activity is calculated for each segment.
- Each segment is further divided into sections of 1 second, with an overlap of 50%.
- If the activity duration of a given section is below toa predefined threshold (30%) [4], the section is considered as having insufficient activity, and is classified as 'no cry' or '0'.

- If the activity is above the threshold, the section is divided into short-time frames (with duration of 32 msec and a hop size of 16 msec). [4]
- Each frame is classified either as 'cry' or as 'no cry', based on its extracted features using a k-NN classifier.
- For each section, if at least half of the frames are classified as 'cry', the whole section is considered as 'cry', Otherwise, it is considered as 'no cry'.
- Use K-NN classifier to classify the data *in* which each frame is classified either as a crying sound ('1'), if close enough to cry training samples, or as 'no cry' ('0'). The signal is divided into consecutive and overlapping segments, each of 10 seconds, with a step of 1 second.

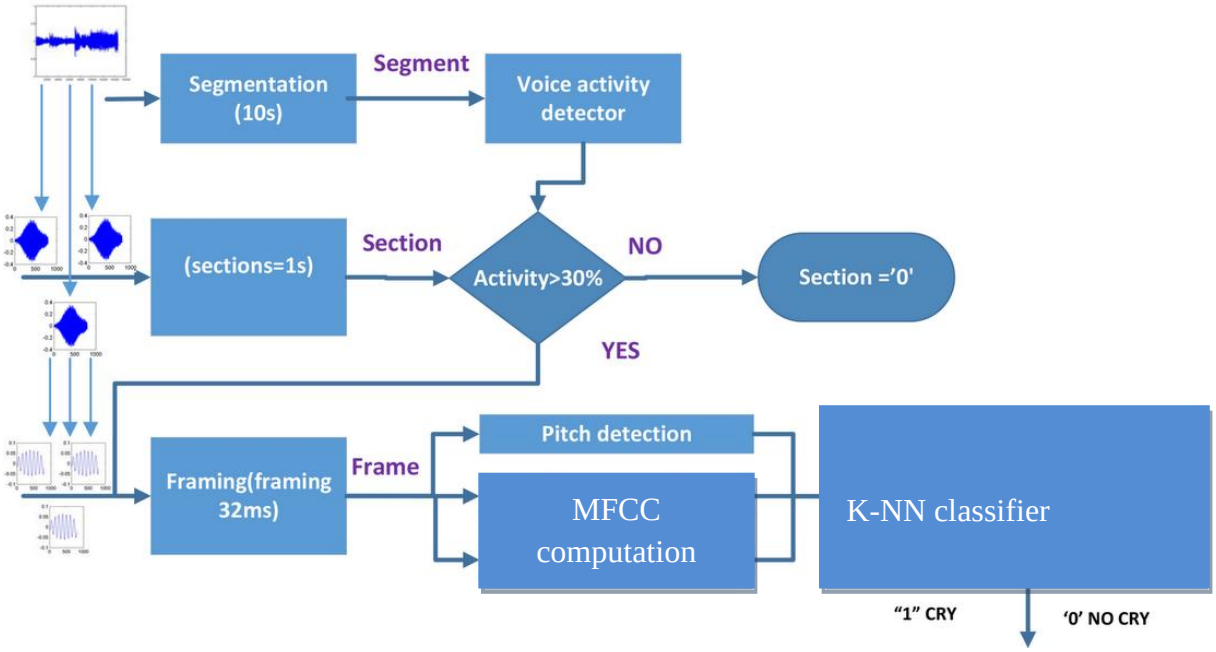


Figure 4: Infant cry detection algorithm –block scheme

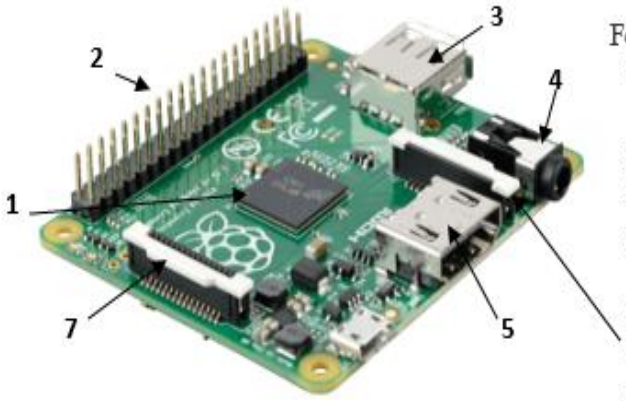
5 IMPLEMENTATION

Implementation has done in three steps.

1) Hardware implementation
2) Implementation of audio processing
3) Implementation of video streaming, parent monitoring and notification system

5.1 Hardware Implementation

For the prototype, Raspberry A+ Single board computer has been used. Main reasons for the selection is, its support multimedia and it has enough processing power and memory capacity to process audio processing algorithms introduced in section 4.

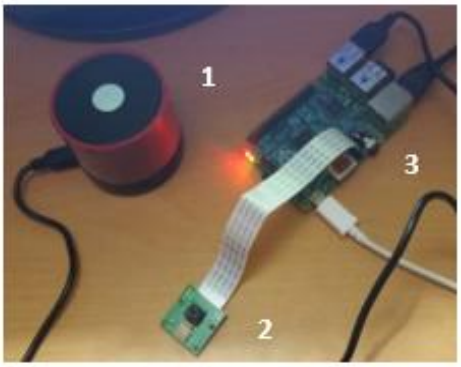


Features

1 700MHz Broadcom BCM2835 CPU 256MB RAM
2 40pin extended GPIO
3 1 x USB 2 port
4 4 pole Stereo output and Composite video port
5 Full size HDMI
6 CSI camera port
7 DSI display port

Figure 5: Raspberry Pi A+ single board computer and its components

For the video calling feature, Raspberry Pi compatible 5Mega pixel camera module has been used. This module capable of 1080p video and still image and it can connect to Raspberry Pi directly with CSI (Camera Serial Interface).Speaker system integrated via Raspberry Pi via USB hub. It has built in microphone and able to pay and store music files in MP3 format.



Components

1 USB compatible Speaker system
2 Raspberry compatible 5MP camera
3 Raspberry Pi B+ board (for testing purpose)

Figure 6: Interconnection of Speaker, Camera and Raspberry PI board.

Implementation of the Soothing system

Figure 7: Implementation of Soothing system (Mechanical and Electronic circuit)

Figure 7 shows the implementation of the mechanical arrangement of the soothing system. The right-hand side picture shows the fabrication of the Microcontroller based soothing control system.

5.2 Implementation of Audio Processing Algorithms

All the audio processing algorithms first implemented and tested in MATLAB 2014b environment. Later MATLAB Code converted to C code and uploaded to the Raspberry Pi board. In order to test the system, various crying samples are required.

Data collection

The large number of baby cries has been recorded from daycare centers, neighbours and online databases, then fed to the computer. The signal is stored on the computer as a lossless WAV PCM file. Cry signals of babies ranging in age between 0-15 months. Collected data mainly has 3 voice domains; voice of baby, voice of the adult and mixture of baby & adult. It is assumed all the babies were healthy, Noise free environment (not engaged with engines, passersby, car horns, high hammering sounds, etc). Downloaded baby laugh/ splashes/ sneezing/ music and rattle sounds /giggles /happy vocals ranging between 0-15 months as negative samples. There are 150 training data, each of which represents the all sound forms, including cry and non-cry. 120 testing data are there respectively, including cry and non-cry.

Testing the Algorithm in MATLAB

According to the algorithm,

- **Sample Data-**Sample data is the data that use instantly to check the results, according to the accuracy of the system simulations, we can change the sample size which we input to the system. The example MATLAB code is shown in Figure8.

- **Training Set-**It is the set that installed in the programmed memory and it used for distance calculation with sample data, 45 data set as the training set. With 37 babies cry samples and 08 non-cry samples and after that, gradually increased the training set 45 to 75 and 75 to 120 samples and 120 to 150. MATLAB implementation is shown in Figure 9.

- **Group Matrix-**This matrix defines the domains (baby cry domain, baby non-cry domain) of each and every data in training set.

- **Output -**Output is given according to the input sample size, each sample input data is calculated with each and every data in training set. All data in the training set are defined in the Group matrix as it belongs to cry or not. As an example, consider a one sample data, this sample is calculated with each and every data in the training set for obtaining the distance values and find out shortest distance given by which training data, then according to definition of group matrix algorithm identify the nearest neighbours of the sample data. MATLAB output results shown in Figure 10.

```
Command Window
>> % Matlab Function - knnclassify
% Syntax :
% Class = knnclasify(sample,training,group)

%Sample Matrix
A = [
    0.704,558.2278;
0.683,525.2134;
0.895,760.3448;
0.702,490;
0.955,958.6957;
0.937,938.2979;
```

Figure 8: MATLAB code of Training matrix

```
%Training Matrix
B = [
0.688,450.7042;
0.595,324.2647;
0.625,412.1495;
0.655,428.1495;
0.750,588;
0.712,472.596;
0.698,490;
0.795,572.7273;
0.760,604.1096;
0.757,595.9459;
0.775,612.5;
0.785,630;
0.735,537.8049;
0.699,501.136;
0.715,495.5056;
0.698,479.3475;
0.778,621.1268;
0.812,711.2903;
0.789,630;
```

Figure 9: MATLAB code of sample matrix

Figure 11 shows the MATLAB plot of variation Pitch Frequency against MFCC values. It confirms the other research finding, infant pitch frequency between 350-700Hz.

```
%Function
Class = knnclassify(A,B,G);

% Display result
disp('Result:');
disp(Class);
Warning: KNNCLASSIFY will be remo
data using ClassificationKNN.pred
> In knnclassify at 80
Result:
    'CRY'
    'CRY'
    'CRY'
    'CRY'
    'NOTCRY'
    'NOTCRY'
```

Figure 10: Output of KNN algorithm

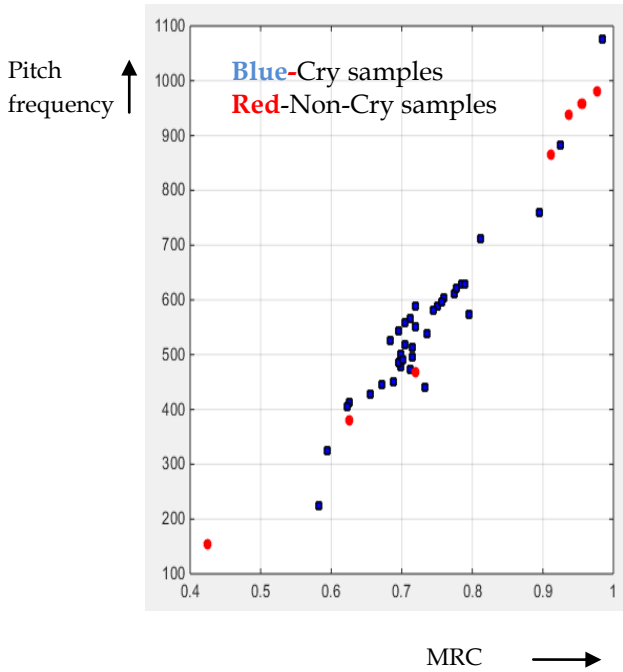


Figure 11: Graph of MFCCv'ss Pitch Frequency

5.3 Implementation of parent device application and video calling function

Parent device of the infant cry detection system is an android application which can be installed on a smart phone or a tablet computer. Once it linked to the home wireless network, users can install the application on the mobile device and have unlimited access to the video feed from the baby's room. The application is password protected to prevent outsiders from gaining access (Figure 12).

The login screen gives the IP address to connect the device after typing correct user name and pass word it enables to connect to the system. Then the application gives the option to on/off the self-soothing notification on the user's mobile device. By clicking on the top of the right side of the application (three dots) will give the user to disconnect or turn off the device.

Video calling feature implemented using available application called "VLC player". It has been installed and configured with the Raspberry Pi Operating system.

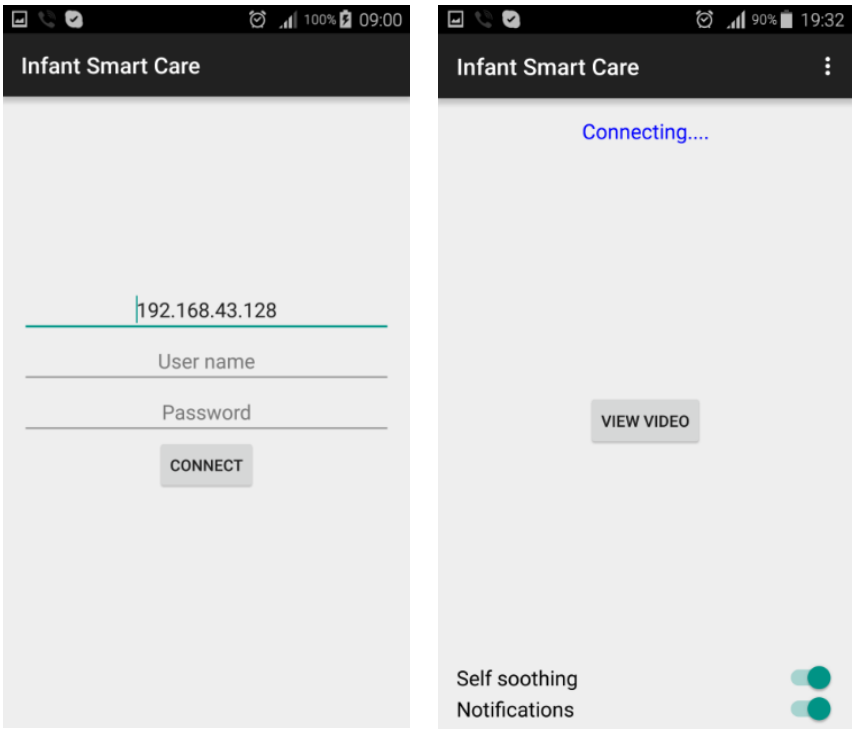


Figure 12: Menus of the Android application

6 RESULTS AND DISCUSSION

In this testing phase 150 training sample, and testing samples with 6 types of cry samples which have each 10 samples, as positive testing samples, and 60 testing negative samples to evaluate the performance of the algorithms. Testing was carried out in both MATLAB simulation and Raspberry Pi based prototype device.

When downloading and recording cry/laugh samples have been categorized mainly as above mentioned 12 categories, in this simulation it's detected only whether its cry or not cry. Table 2 shows the summary of testing results.

MATLAB simulation shows the cry detection accuracy 81.667% and on device shows the 78.33% accuracy which means low accuracy output than the MATLAB simulation results, this is because the MATLAB is a total theoretical simulation, but when testing it in practically there are some other noises can be added to the system, 60 negative samples shows 80% of non-cry detection accuracy and the device shows 76.667% non-cry detection accuracy. This means the average classification accuracy of the device is 77.5%.

Table 2: Summary of Test results in MATLAB Simulation and on Device

Positive	**Test Samples**	**MATLAB simulation**		**Accuracy**	**On device**		**Accuracy**
		Detected as cry	**Detected as non-cry**		**Detected as cry**	**Detected as non-cry**	
Pain	10	9	1	90%	9	1	90%
Screaming	10	8	2	80%	8	2	80%
Yell moan	10	9	1	90%	8	2	80%
frustrated	10	8	2	80%	7	3	70%
Whining	10	8	2	80%	7	3	70%
Upset	10	7	3	70%	8	2	80%
				81.667%			78.333%
Negative	**Test samples**	**MATLAB simulation**		**Accuracy**	**On device**		**Accuracy**
		Detected as non-cry	**Detected as cry**		**Detected as non-cry**	**Detected as cry**	
laugh	10	8	2	80%	8	2	80%
Happy vocal	10	7	3	70%	7	3	70%
giggles	10	8	2	80%	8	2	80%
gurgle	10	9	1	90%	8	2	80%
Adult baby speech mixture	10	7	3	70%	7	3	70%
Music play/rattle sounds	10	9	1	90%	8	2	80%
				80%			76.667%

Table 3 shows how is the effect of increasing number of training samples can increase the accuracy of the system.

Table 3: Effect of the increasing of Number of samples

No of training samples	MATLAB simulation	On Device
45	65.75%	60.22%
75	72.356%	68.003%
120	77.22%	73.58%
150	80.8335%	77.5%

Proposed infant cry detection algorithm is based on 2 decision levels in different time scales and classified either as 'cry' or 'non-cry' based on its spectral characteristics.

Multiple time scale analysis and detection levels are aimed in providing a classifier with high detection rate, whether the total average accuracy up to now is 80.8335% (Simulation) and 77.5% (On device).This can be improved by adding more training data

to the system as reference to the sample matrix. The detection rates fall in relatively broad range, whereas missed detection rate has a narrow range.

The main objective of this study is the development of a cry detection algorithm by applying different approaches in feature extraction and classification. Results show the developed algorithm working with acceptable accuracy. However, Soothing system needs to be tested with the real environment to test how babies responded to the soothing mechanism which is not done under this study. Also, feedback from parents about the overall product should take into consideration, before moving to the next level.

7 CONCLUSION AND FUTURE WORK

With the help of the proposed cry detection algorithm, it can easily identify the infant's cry and verified it by using KNN with accurate results. Other than using only MFCC, the combination of Pitch and MFCC gives a more promising approach to cry detection.

Employed statistical model based voice activity detector in order to determine when is the cry detection algorithm should analyse the input signal. This leads to reduction of power consumption. All of these can improve the recognition accuracy.

Cry detection has been challenging because of the highly variable nature of input speech signals. Speech signals in training and testing sessions can be different due to many facts such as:

- Baby's voice change with time
- Health conditions. For example-deaf/asthma
- Speaking rates
- Variations in recording environments play a major role.

Therefore, increasing more training samples of different noises and speeches would give more accurate results.

Future work:

- Improve the Accuracy of the cry detection algorithm by training with more samples.
- Test the soothing system in real environment and get parents' feedback regarding the overall product.
- Improve the audio processing algorithm to detect and notify the reason for baby cry.
- Improve the android application with more features.

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Smartphone-Based Activity Recognition Model (SBARM)

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Abstract - *This research aims to use context awareness data from Android mobile devices in activity recognition. This paper presents about a smart phone-based activity recognition model which can automatically record people's daily activities. The capability to recognize human activities is useful in different sectors such as healthcare, eldercare, target advertising and in many research platforms. Great deal of researches has been carried out in activity recognition using wearable sensors and mobile devices. But wearing sensors on human body can bring inconvenience and discomfort to the user. To avoid this mobile device can be used as an unobtrusive device in activity recognition. Even there has been several researches done using mobile devices, relatively little practical work has been in the area of applications. With this motivation, this project investigates the ability to recognize activities of a smart phone user such as Idling or phone-not-on-person, walking, running, jogging, climbing up stairs, climbing down stairs, travelling or driving and shopping through a smart phone. The data collection of this research has been carried out using the smart phone sensors over a period of 4s time window. Due to the limited memory availability of the smart phone, the collected data was sent to the server which provides the storage and processing. Then it has been pre-processed in order to eliminate noise and redundancy of data and the time domain features Mean, Variance and Standard deviation were extracted. Then the data is split into training set and test set. The training set is used to train the activity recognition algorithm and the test set is used to evaluate the recognition algorithm after training. The extracted features are the input data needed for the Hidden Markov Models (HMM) which is used in order to construct the activity recognition model.*
The recognized activities can be viewed in android dashboard application integrated with any applications.

Keywords: *Activity Recognition Model (ARM), Hidden Markov Model (HMM), smart phone, sensors*

1 INTRODUCTION

User context awareness is one of the emerging properties used in mobile applications and services in the area of ubiquitous computing. Human activity recognition is an important area of machine learning research because of the requirement of real-world applications. Getting to know the daily activities will be very useful for healthcare, eldercare, research platforms and target advertising.

There have been several researches done in activity recognition using mobile devices instead of wearable sensors which are obtrusive and uncomfortable to the user. But relatively little practical work has been in the area of applications. With this motivation, SBARM is proposed and designed to recognize daily activities through a smart phone.

2 LITERATURE SURVEY

Activities can be divided into two categories namely complex high-level activities such as cleaning, cooking or simple low-level physical activities, such as walking and running (Dernbach *et. al.*, 2012) Some existing works have explored user activity inference methods with accelerometer sensors. They can be divided into two major approaches: sensor-worn lab experiment approach and sensor-enabled mobile phone approach.

Some of the earliest work on wearable sensor based activity recognition used multiple accelerometers placed on different parts of the body and demonstrated that the use of dedicated accelerometers can provide good results in activity recognition (Bao and Intille, 2004), (Ravi *et. al.*, 2005), (Krishnan, *et. al.*, 2008). Then the idea was expanded with the inclusion of additional sensor information. For example, Lee and Mase proposed a system for recognizing activities using information about the user's location and inertial sensors such as accelerometers and gyroscopes (Lee and Mase, 2002). The collected data from five accelerometers placed on various body locations along with a heart rate monitor for implementing a real-time system to recognize thirty gymnasium activities (Tapia *et. al.*, 2007). It uses small sensors attached to a user's body or clothing. But using body sensors require daily effort from the user to wear and maintain them or else they are useless for collecting data (Lara and Labrador, 2013).

There have been few studies similar to the one proposed in this report, instead of placing different sensors on person's body that use commercially available mobile devices to collect data for activity recognition. Current generation smart phones are equipped with a variety of sensors such as GPS sensors, microphones, camera, light sensors, proximity sensors, temperature sensors, accelerometers, gyroscopes and compasses. These devices have become a part of our daily lives. Thus, the ubiquity and unobtrusiveness of the phones and the availability of different wireless interfaces, such as Wi-Fi, 3G, and Bluetooth, make them an attractive alternative platform for multisensory based HAR (Ustev *et. al.*, 2013).

For example, researchers have considered six activities to recognize user activities which are walking, jogging, ascending stairs, descending stairs, sitting, and standing using cell-phone accelerometer sensors (Kwapisz *et. al.*, 2010), (Yang, 2009), (Kwapisz *et. al.*, 2011). Some studies use the Smartphone GPS sensor to recognize transportation related activities (NA, 2005). It has used multiple sensors such as accelerometer, microphone, and pressure sensor for activity recognition (Khan, *et. al.*, 2014).

3 METHODOLOGY

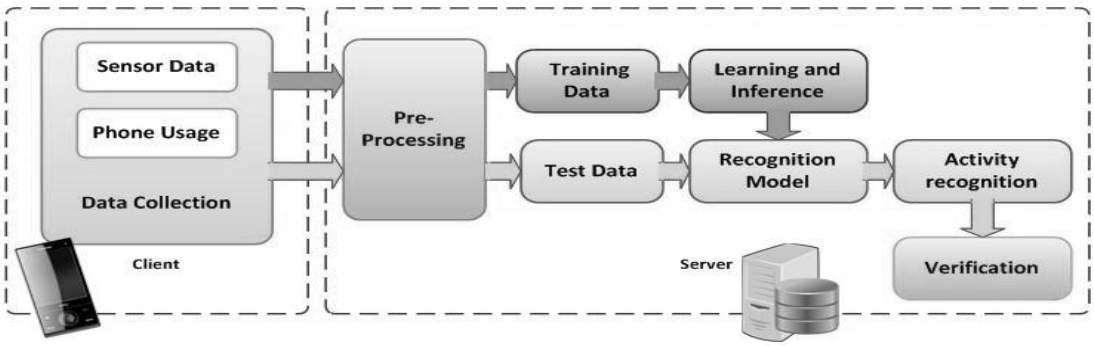

Figure1: Block diagram of SBARM

The block diagram of the system is shown above in Figure 1. The system comprise with two phases which are training phase and the testing phase.

- The recognition process starts with collecting data from the smart phone sensors and user performed activities on the phone
- Then the available sensor data is preprocessed to produce training and test data
- In training phase, Hidden Markov Modelis used to generate an activity recognition model from the dataset of extracted features
- In testing phase, the test data is sent to the activity recognition model to produce the recognized activity
- Finally the verification is done manually

Sensors

The smart phone sensors investigated in this project are shown in the Table 1.

Table 1: Inertial Sensors

Sensors	Description	Common Use
GPS Sensor	Longitude & Latitude Tolerance: 30% of measurements within 50m	Track location
Acceleration Sensor	Measures the acceleration force in m/s2 that is applied to a device on all three physical axes (x, y, and z), including the force of gravity. Range: 0…19.613	Motion detection (shake, tilt, etc.)
Gyroscope Sensor	Measures a device's rate of rotation in rad/s around each of the three physical axes (x, y, and z). x-axis(roll), y-axis(yaw) & z-axis(pitch) Range: 0…8.727	Rotation detection (spin, turn, etc.)
Proximity Sensor	Measures the proximity of an object in cm relative to the view screen of a device. This sensor is typically used to determine whether a handset is being held up to a person's ear. Range: 0…5	Phone position during a call
Magnetic field Sensor	Measures the ambient geomagnetic field for all three physical axes (x, y, z) in µT. Range: 0...2000	Creating a compass
Orientation Sensor	Measures degrees of rotation that a device makes around all three physical axes (x, y, and z). x-axis(-180<=pitch<=180) y-axis(-90<=roll<=90) & z-axis(0<=azimuth<360)	Determining device position

Activities

Proposed activities for this model are listed below,

- Idling/ Phone-not-on person (Sitting, Standing and etc.)
- Walking
- Running
- Jogging
- Climbingup stairs
- Climbing down stairs
- Travelling/Driving
- Shopping

Flowchart

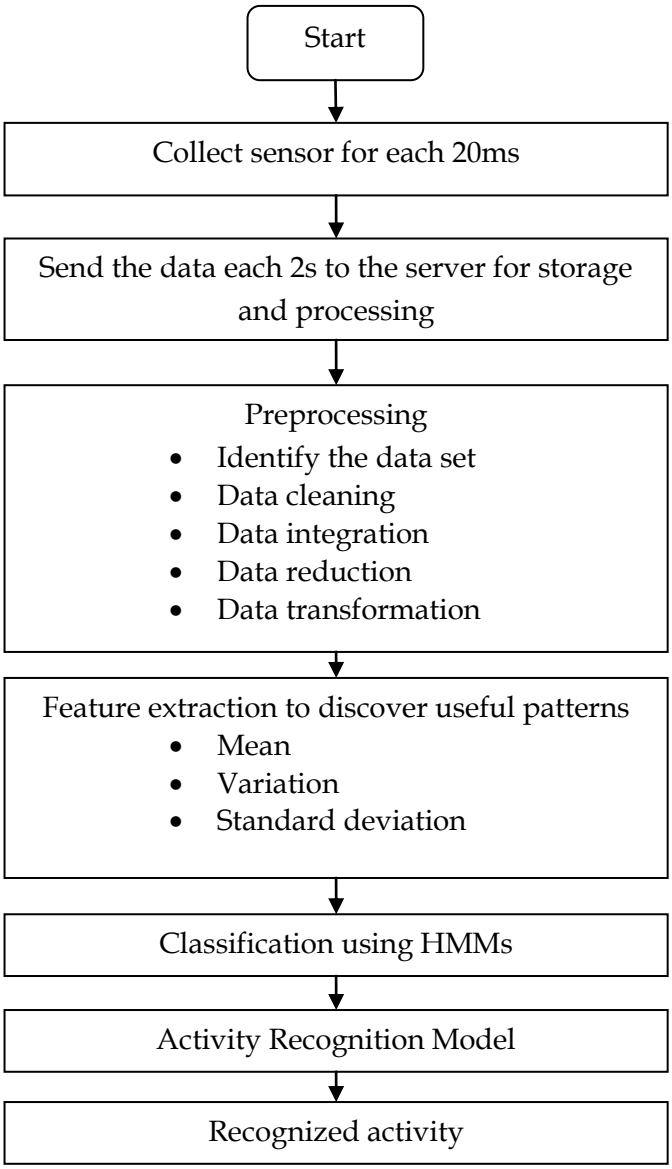

Figure 2: Flowchart of the system

4 IMPLEMENTATION

Android smart phone application has been developed to collect data and to send data to server for storage. Then Weka tool (V 3.7.11) has been used for further pre-processing and implementation of the activity recognition model.

Samsung Galaxy S2 smart phone is being used for data collection. Using this smart phone, data collected for different physical activities. They are walking, travelling and idle/phone-not-on-person. Only one participant used to perform these activities for a few minutes. As these are repetitive activities, so the amount of time for each activity was kept between 3-5 minutes, which gave enough examples for the evaluations.

Table 2: Activity performed by user

Activity	Smartphone on Body Position	Duration
Walking	Right Hand	3-5 minutes
Idle/Phone-not-on-person	Phone on the table while sitting	3-5 minutes
Traveling (By Bus)	Right Hand	10-15 minutes

Below fig. 3 shows the attribute patterns of all 3 activities; walking (dark blue), traveling/driving (red) and idling/phone-not-on-person (light blue).

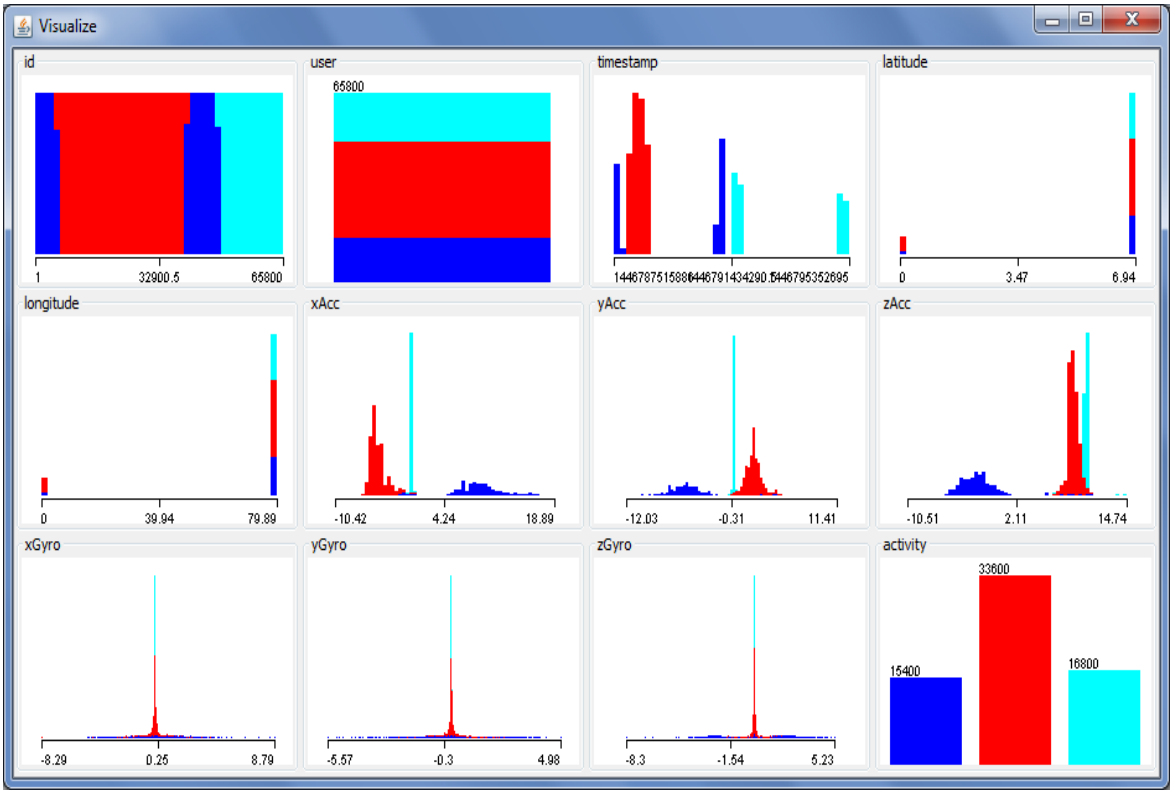

Figure 3: Attribute patterns for all activities

WEKA machine learning tool (Waikato Environment for Knowledge Analysis) was used for preprocessing and classification. Dataset were converted as csv (comma separated values) file format in order to use in Weka.

Selected Attributes:

- Timestamp
- Latitude
- Longitude
- xAcc (Accelerometer X-axis)
- yAcc (Accelerometer Y-axis)
- zAcc (Accelerometer Z-axis)
- xGyro (Gyroscope X-axis)
- yGyro (Gyroscope Y-axis)
- zGyro (Gyroscope Z-axis)
- Activity Label (Class)

Extracted Features: Maximum, Minimum, Mean & Standard deviation

Features were normalized and bounded within [-1, 1]

5 TEST EVALUATIONS

10-fold cross validation used for the evaluation. In 10-fold cross-validation, the data set is divided into 10 bins. Out of these ten bins, nine (90%) are used for training and one (10%) for testing. This process is repeated ten times, each time with a different bin for testing, thereby using all data, both for training and testing.

HMM classifier and Naïve Bayes classifier were used for classification.

Below Table 3 shows the classifier output for both HMM and Naïve Bayes.

Table 3: Classifier output

	HMM	Naïve Bayes
Correctly Classified Instances	23.4%	98.6%

Test dataset of activity walking and idle/phone-not-on-person has sent to the model built using HMM and Naïve Bayes, and the results shows in the Table 4.

Table 4: Test cases

Activity Performed	Expected Output	HMM Recognition Probability	Naïve Bayes Recognition Probability
Walking	Walking	100 %	100 %
Sitting	Idle/Phone-not-on-person	0 %	0 %

6 CONCLUSION

This project is focused on automatically recording physical activities of a user and views it in dashboard application on Android phone.

The three main contributions of this research are identification of the need to apply unobtrusive devices and applications of context awareness, the investigation for the use of classification algorithms for activity recognition, as well as the design of prototype application for the proposed model.

Many of the proposed solutions so far have investigated the use of sensor devices that are regarded as obtrusive and inconvenience for users to adopt their daily activities. This model is a solution for the above challenge in the way of using mobile phone sensors.

As per the results, it is hard to conclude that the HMM method always provide better results. Also the size of the dataset is small, since it is only collected from only one person and collected during a small time period. So if HMM can be trained with more data, the model can be improved.

Future works will be focused on improve the model with more recognition accuracy and to recognize more activities such as sitting, standing, sleeping and etc.

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