DEVELOPMENT OF WIRELESS ACOUSTIC MONITORING SYSTEM

by

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WSN – Wireless Sensor Network

MFCC – Mel-Frequency Cepstrum

MIDI –Musical Instrument Digital Interface

PCM – Pulse Code Modulation

WAV – Waveform Audio File

ANT – Access Network Transport

LCD – Liquid Crystal Display

ADC – Analogue to Digital Converter

MISO – SPI Slave Data Output

MOSI –SPI Slave Data Input

SCK – SPI clock

CSN – SPI Chip Select

CE – Chip Enable

SD – Secure Digital

CAD – Computer Aided Drafting

RLNC – Random Linear Network Coding

XOR – Exclusive OR

PDR – Packet Delivery Ratio

ISM – Industrial Scientific Medical Band

EMG – Electro Myo Graph

IMU- Inertia Measurement Unit

MEMS – Micro- Electron – Mechanical Systems

MTM – Membrane Medical Tympani Form

WPAN- Wireless Personal Area Network

MPEG – Moving Picture Experts Group

USB – Universal Serial Bus

DAC – Digital Analogue Converter

CRC – Cyclic Redundancy Check

SD – Secure Digital

RFID – Radio Frequency Identification

ABSTRAK

Sistem pemantauan akustik sesuai bagi memantau kawasan sekitar pada ruang yang terbuka, hutan serta bangunan dan rumah dalam jarak 100 meter, 70 meter dan 40 meter. Sistem ini mengesan bunyi dan mengeluarkan arahan kepada sensor untuk mula merekod data akustik. Pengumpulan data melalui mikrofon telah digunakan untuk merakam bunyi dalam kelompok burung. Kajian ini menggunakan dua papan litar Arduino yang terdiri daripada mikrofon elektret, pembesar suara dan penghantaran adalah dua komponen tanpa wayar NRF24L01.Parameter yang ditetapkan adalah lebar jalur dan kehilangan paket melawan jarak. Persekitaran diuji pada ruang terbuka, bangunan dan rumah serta hutan. Isyarat hilang apabila ia mencapai jarak maksimum untuk pemindahan data. Berdasarkan NRF24L01 tanpa wayar, menyokong keputusan bahawa ia sesuai untuk sistem pemantauan akustik.

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ABSTRACT

Acoustic monitoring system is suitable to monitor the acoustic sounds in an open spaces, forests, building and houses within 100 meters, 70 meters and 40 meters. The system detects sounds and issue directives to other sensors for early record acoustic data. The collection of data through a microphone was used to record sound of birds in the group. The study utilises two circuit boards Arduino Uno, which is comprised of the electret microphone circuitry, magnifying the sound and important for the delivery of media are two NRF24L01 wireless components. Parameters set for throughput and packet loss versus distance. Environments are tested in an open space, in between building and houses and forests. Transmission lost if it reaches a maximum distance for data transfer. Based on the wireless NRF24L01, results supports that it is suitable for an acoustic monitoring system.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, the modern semiconductor design is leading to miniaturization of embedded system that converts the system into small size, low cost and low power consumption. Integration of all the components in one chip enables processor to be optimised for a given application. An embedded system is a device controlled by instruction stored in chip and operate as per the required task.

Wireless Sensor Networks (WSNs) is a network of sensors that use wireless as it communication medium. WSNs are widely used to monitor physical or environmental conditions such as temperature, air quality, motion and environmental monitoring. The radio transceiver, controller, energy source and the limitation on size and cost for the sensor node will be affect the energy, transfer speed, internal memory and bandwidth usage. WSN consist of large amount of node to monitor and detect the real time environmental activities in large scale area. The major challenges in designing the application using WSN are communication that required maximal focus on energy

efficient. Furthermore, the environmental condition required the networks to adapt over time to change in connectivity itself or it is called 'self –organization'.

With the explosion growth of WSN technology, the remote monitoring is achievable. WSN has been used in a variety of applications such as environmental monitoring, assisted healthcare, military and forest monitoring. The combination of sight, scent and sound can be translated into meaningful information to access forest condition. The sound of the forest can be recorded and assessed using acoustic monitoring system. The acoustic monitoring system objective, are to monitor and notify the sound in the surrounding area. Then it will activate the other node, to record the acoustic data.

A graphical implementation for the acoustic monitoring will provide the visual feedback for the current acoustic activities. The user is able to listen to the recording audio while it is being recorded. The recorded audio signal can be used for speech recognition purpose. The acoustic range for birds is from below 50 Hz to 12 kHz with the sensitivity between 1 kHz and 5 kHz. The acoustic sound quality of the habitat and the ambient sounds were varies together with the surrounding area for the range of frequency. The quality of the acoustic depends on nature of environment and its habitat. In the forest, low frequency and narrow bandwidth of acoustics can be found. Compare to open habitat, as example at field or by the side of road. Definition by low frequency in forest, it is because of the degradation sound reflection. In addition, rapid modulation including the high frequency is optimal for open habitats degradation but less across in open space.

Traditional way of identifying and classifying birds species are the listening to birds call. Listening method is still one of the methods used in bio acoustical research. Most of people and bird experts are able to recognize few common and hundreds of species. Signal and electronic recording equipment are the part for the acoustic sound. The recorded data will be stored and analysed using the personal computer. The acoustic sound signal are described and sorted according to the intensity, duration and several parameters using the sound analyser. The focus of this research is to design and develop wireless acoustic monitoring system to sample the environment sound and transmit the data back to the base station wirelessly. The system is demonstrated in the different environmental areas.

1.2 Problem Statement

The bioacoustics researchers have to collect data in the forest and other environment in order to identify the sound. There are a lot of devices in the market that have been used for bioacoustics monitoring. However, these systems are expensive and technology to monitor the specific environment as example in the forests, parks and buildings are far more complicated. The researcher will be having issues to place more devices at the large scale of site area. The price of each device could cost more than RM1000++ including their software to perform speech recognition on specified animal.

1.3 Aim and Objective

- To identify suitable hardware for the project development.
- To design and develop wireless acoustic monitoring system.
- To test and verify the performance of the system under different environments.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews about the existing work and related software and hardware platform, explanations the bioacoustics, method and concepts that being used for listening and frequencies. Defines how the bird produces their sound using syrinx and an introduction of NRF24L01 operation and functionality.

2.2 Literature Review

(Stattner, E et. Al., 2012) proposed a scheme for calculating acoustic bird song with a WSN. Sensors are used to record audio samples of bird song. This sample is used to take some kind of song fingerprints which are then used to identify species of birds, through the classification process. Technological developments and especially the emergence of micro devices such as wireless sensor enable the new method of study and monitoring of endangered species. An automated solution for calculating the bird singing, researcher used a sensor equipped with a microphone. In addition, the singings

of bird were the good indicator of overcrowding because it allows to estimates the bird population. Audio signal analysis has been studied extensively in the field of speech recognition, object detection and source localization. Because there are many analogies between human language and birdsongs, many techniques have been proposed to recognize bird songs. To identify any species, two processes of recognition are used, the parameterization process and classification process. Parameterization process allows the audio signal represented by a set of coefficients that described the signal. There are many existed parameterization methods. In parameterization process, the songs of bird were used to create a fingerprint. Then, the fingerprint is stored in a database. Finally, the classification algorithm is used to determine the species of birds according to their fingerprints.

(Wei-Ho et. Al., 2013) report that a sensor network is equipped with a microphone to estimate the number of birds in their habitat is more suitable for real environments. Exploitation of detection and comparison charts audio signal has been shown to give good results when a high number of sensors were deployed. Population size seems to be the most relevant factors that influence the outcome. Sensors are used to collect at regular intervals, the data such as temperature, light or sound to understand the bird habitat. In learning framework, there are two levels of recognition framework. The first stage is making a call or song classification. If an unknown sound clips are classified as a call, it is then handled by the call identifier in the second stage. Timbre and pitch are used to determine the bird species. Using its timbre, the sound of birds is converted to Mel-Frequency Cepstral Coefficient (MFCC). Then the analysis will use Gaussian mixture model. In its state of the pitch, we switch to the sound of birds in the

order of Musical Instrument Digital Interface (MIDI) notes and then use the model to analyse the information Bigram dynamic changes of note.

(Mporas, I et. al., 2012) mentioned that all voice data is converted to Pulse Code Modulation (PCM) Waveform Audio file (WAV) with a sampling rate of 22.05 kHz and 16 bit quantization resolution. The data is divided into two subsets, training and testing. Given bird vocalizations can generally be divided into two categories, namely call and song, the proposed system is built on the framework of a two-stage identification. Performance bird sound identification system proposed still leaves a lot of room to improve. Over the sound of birds in the other characteristics identification system should exploit to collect all the databases of bird song. The protection of endangered species is a must and relies to get the accurate data biodiversity, the conversation action were based on status of biodiversity monitored. The information, concerning bird's activity has been compiled by an ornithologist. Effort include recognition of their vocalization of birds, study the interaction between them and locating their habitat. The weakness of the observation for bird activity led to development of recognition the bird vocal automatically. The acoustic recognition of bird species will be automatic then involving the pattern for recognition processing and features extraction to classify the acoustic signal.

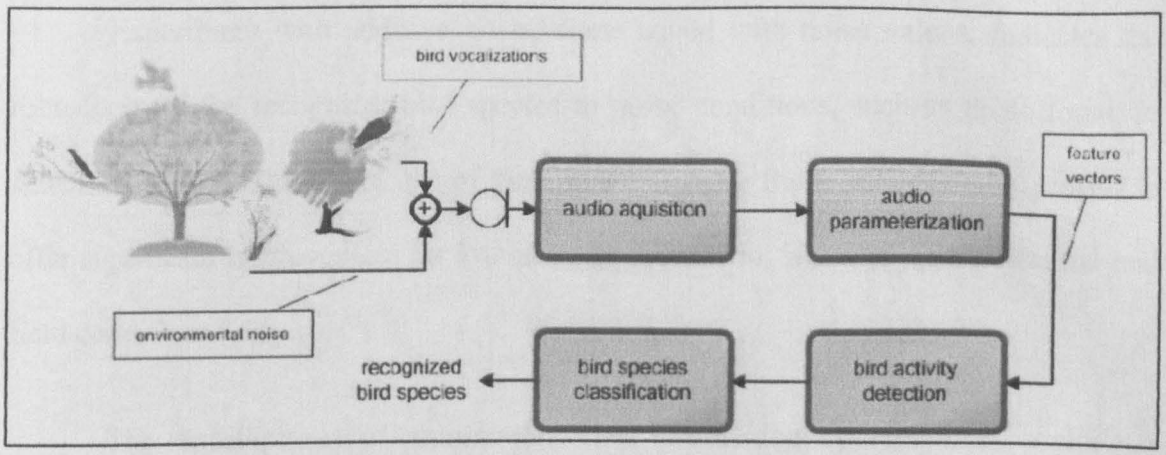

Figure 2.1: Block diagram for the species recognition scheme.

Automatic bird species recognition from audio to data offers 24/7 monitoring of the habitat and provide the necessary information for monitoring biodiversity, animal species population estimates, understanding the behaviour for the species. The recognition task falls in the category of audio pattern recognition tasks and briefly can be arranged in the acquisition phase audio, audio parameterization stage and stage classification. For species recognition in interference environment interval species classification stage is describe in Figure 2.1.

The acoustic signal captured by microphone, amplified the sampled at 32 kHz, so that a wide range of frequency for bird vocalizations of various types was covered. The 16-bits per sample used to ensure the sufficient resolution detail for subsequent processing signal. After pass the acquisition phase of the audio signal, the binary segmented for intervals with or without bird vocalizations. Finally, the interval bird vocalizations were processed by the block classification acknowledgment for species will be done.

Experiment with additive noise, some sound with noise values, indicates the robustness of the recognizer bird species in noisy conditions, such as those found in actual field. In addition, the use of post-processing per frame rate decision proved to offer significant improvement for low-noise to noise ratio, which is the case for the real field conditions noisy.

The development of autonomous data acquisition systems has provided a method to significantly reduce manual work and has the potential that helped researchers to answer scientific questions that were previously not feasible. However, the transition from WSN deployment in the laboratory to the real world deployment is still very challenging. The error-free system can be run independently in the real-world environments without user supervision has proved to be complex and the number of successful collaboration between computer and natural scientists is still limited in connection.

(Christ, P et. al., 2011) conclude during the deployment of WSN, network configuration details are often altered by changes in field conditions. Other aspects should also be noted, for instance, software updates, support timers, the selection of environmental sensors and waterproofing. The applications in industrial energy constraints, drugs and monitoring of human movement have been using low power WSN. The implementations of Access Network Transport (ANT) protocol and operate frequency at 2.4GHz for the wireless transceiver. The configurations with different number of transmitters, packet size, message frequency and tested for more than 500 set up. The combination data from multiple recipients reduced loss packet and number of consecutive lost for packets. Data stream of raw audio signal are benefits interpolation

technique can be implement for the short gaps in measurement. In addition, through several test configurations, transceiver suitable for the measurement of streaming through a couple of hours using the battery size of coin cell.

(Khairi, N. A., et. al., 2013) concluded the design of a WSN for a farm monitoring system. The systems allow farmers to monitor the surrounding environment as well as the animal movement. The system consists of three sensors, a microcontroller and a wireless transmitter. The sensor measures the temperature, humidity and motion of the animals before download the data into a microcontroller. The microcontroller will process the measured results and transmit the data using the wireless transmitter. At the receiver, the data will be processed and the result displayed on a Liquid Crystal Display (LCD) panel. By implementing ZigBee device as the wireless communication, it operated with 3.3V and it transmit the measured data from the microcontroller to the receiver with the maximum range of 1.5 kilometres, low power consumption and the ability to operate within the Industrial Scientific Medical band (ISM) 2.4 GHz frequency band. The microcontroller reads the analogue signals from the device one by one before converting into digital signals using the Analogue to Digital Converter (ADC). The system showed more than 95% to 99% accuracy as compared to commercial system. This device has a good potential to be used as a wireless sensor node. The block diagram for the wireless sensor node is described in Figure 2.2.

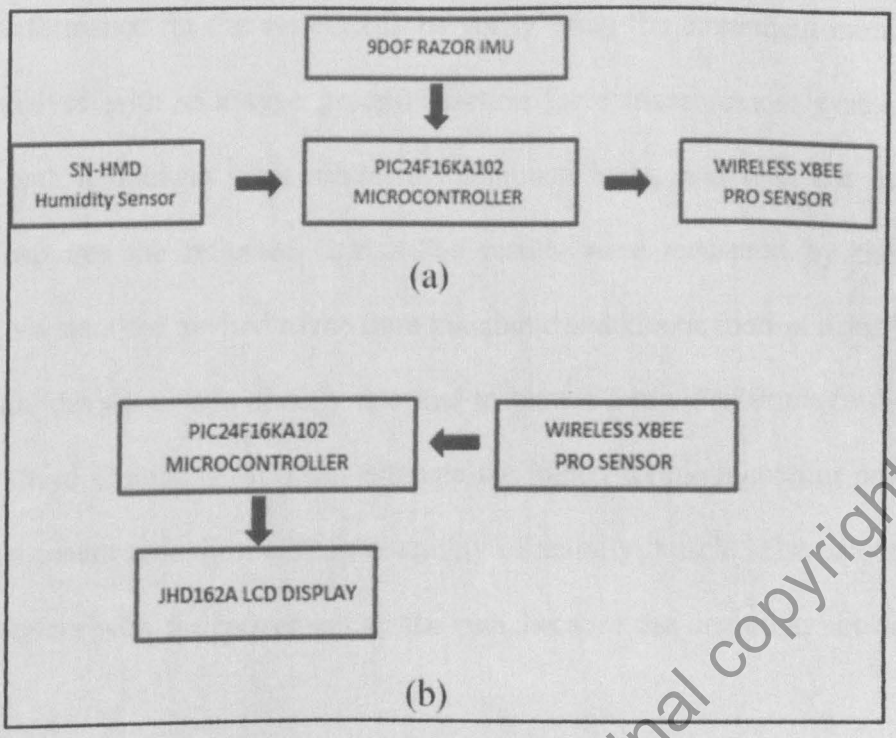

Figure 2.2: Wireless sensor node block diagram (a) transmitter (b) receiver

(Tovar, A. F., et. al., 2010) to sample the status of several wildlife habitat name White tail deer in Canada WSN to be implemented using the delay tolerant network. It was proposed using the high remote range to achieved using least quantity of sensor. The implementation is to acquire the ability to support other nodes fault. The simulations were created to monitor habitat wildlife and deploy the delay tolerant network for monitoring. WSN actually help to solved problems such as interference and delayed.

(Bae, J., Haninger, et. al., 2012) concluded wireless sensor use same frequency to communicate and a part of network to monitor system. The wireless monitoring was proposed and wireless communication measurement using array with the Arduino. The measurement and analyse data for the human body were connected to personal computer through internet.

The performance for the system can be verify using the movement monitoring and can be analyse with shoe-type ground reaction force measurement system. For example the optical markers were mounted on human body, and then the infrared camera will captures the reflected lights. The results were measured by the joint movement. It is a standard method to measure kinematic and kinetic motion data. To get the motion data, the sensor can directly attached to human body. For example the bio-sensor Electro Myo Graphy (EMG) can estimate the jointer torque human or postures. EMG is an instrument recording electrical activity of activity muscle. The use of such device can interfere with the movement of the user because the degree is not enough freedom paths.

Also, the relationship exoskeleton-type can be used to measure the movement only in the sagittal plane. Local wireless networks with ZigBee, based monitoring for the rehabilitation, have easy graphical to intrusive monitoring and do remote network. The system consist a transceiver, Inertia Measurement Unit (IMU) and board controller to build the wireless sensor for monitoring. Wireless node communicates using coordinator on personal computer through internet. The human body were monitored through local and remotely to site in the real times with transmitted data. The personal computer will be the host in the patient side and another in the physical therapy side. The data collected via personal computer were transmitted for analyse section. System and the proposed algorithm to gain analysis with ground reaction shoe type system force. The data for body movement can be obtained from the actual movement of the patient.

(Okada, H., et. al., 2012) concluded that the health monitoring also uses the WSN to monitor the body temperature of human and animal. For the low power consumption, the ultra-power signal also has low power consumption. Wireless communication already been used for the monitoring system. Method of measurement with kind and type of piezoelectric bimetal Micro-Electro-Mechanical Systems (MEMS) sensors that require almost no electricity and on chip selected circuit reference voltage generator diversity measures for the comparator to identify the output from the sensor.

Lower power technology used wireless sensor to monitor animal or human health monitoring system. Components need for the WSN is the receiver, signal processing and sensor. The Radio frequency Identification (RFID) system was applied in industrial to monitor the livestock or pets. The power consumption using the battery in WSN has been investigated. The most important thing is to reducing the power consumption to a minimum decides. Variable capacitor MEMS type thermometers, showing that it have the low powered specification. The acceleration of data can be verify except the number of times being used. The calculated power used for standby mode was 0.5μW.

(Saeed, B. et. al., 2011) Broadcasting is a linear transmission mechanism including audio and video traffic in real time. Several types of devices such as televisions, radios, computers and mobile devices (cell phone) are used as receivers to gain access to one broadcasted traffic flow at a time per channel with pre-scheduled start and end times. With the explosion of internet traffic seen over the past two decades, coupled with ever increasing need to access critical data at any location,

wireless networks have emerged as means of effectively communicating in an on-demand fashion from nearly any location. The challenges include bandwidth limitations, mobility impacts, energy consumption, unreliable transmission, security issues and dead spots.

Investigated the potential benefits of several Network Coding techniques, such as Random Linear Network Coding (RLNC), Reed Solomon (RS) codes and exclusive OR, where the Network Coding mechanism combines different packets generated by different sources into a single encoded packet and investigated various techniques for audio streaming. All selected protocols were implemented in Network Simulator 2 (NS-2). The section explains the simulation scenario in detail, which models an audio streaming application. Each simulation scenario is repeated 10 times with different node locations which are chosen randomly using Bonn motion, which allows us to report not only average performance results but confidence intervals for these averages performance results but confidence intervals for these averages as well. Through simulation the RLNC is able to adapt well to audio streaming applications and generate stable performance in term of packet delivery ratio (PDR), latency and jitter. RLNC delivers the highest value of PDR and the lowest value of latency and jitter.

2.2.1 Bioacoustics

(Fagerlund S. et. al. 2004) concluded that bioacoustics is an interdisciplinary science that combines biology and acoustics. Usually refers to the investigation of sound production, dispersion and reception in animals. It involves neurophysiological and anatomical sound production and detection of acoustic signals and the relationship to the media they spread through. The findings provide clues about the evolution of the

acoustic mechanism, and from it, the evolution of animals that employ them. In Bio acoustic concerning the relationship between the animal and acoustic environment including the impact of anthropogenic noise. Bioacoustics technique was recently proposed as a non-invasive method for estimating biodiversity. Listening is one of the main methods used in the study bio acoustical. An experienced observer can use animal sounds to recognize the "singing" of animal species, location and condition in nature. Investigation of animal sounds also includes recordings with electronic recording equipment signals. Due to a variety of media properties and their signals propagate through specialized equipment may be required instead of the usual microphone.

Computers are used for storing and analysis of sound recordings. Sound-editing software specifically used to describe and sort out the signal corresponding to the intensity, frequency, duration and other parameters. Voice used by the animals included in the scope of Bioacoustics including various frequencies and media. On the other side of the low-frequency spectrum of vibration frequency, is often not detected by the organ of hearing, but with other, less specific senses.

Many animal sounds, do not fall within the range of frequencies that can be detected by the human ear, between 20 and 20,000 Hz. Mechanism for sound production and detection are just as diverse as the signal itself. Research Bioacoustics developing and using digital technology, including hardware and software, to record and analyse the sounds of wildlife all over the world. By listening to the wildlife, we advance the understanding of animal communication, and monitoring the health of wildlife populations.