PEST MONITOR AND CONTROL SYSTEM USING WIRELESS SENSOR NETWORK (WITH SPECIAL REFERENCE TO ACOUSTIC DEVICE WIRELESS SENSOR)

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Abstract -Agriculture has increasingly become dependent on chemical pesticides to control the pests that damage the crops. Heightened concern over the environmental effects of pesticides, coupled with increased pest resistance and secondary pest outbreaks, severely limits the effective pesticides available to farmers. As weather patterns change, crops mature, and cattle graze pastures for food, farmers must decide when to irrigate pastures, apply fertilizer, or move cattle to another pasture. A farmer relies on a combination of experience, visual observation, intuition and he has to perform periodical surveys over a widespread plantation which is a time consuming activity. Acoustic detection technology is a far better substitute to these laborious tasks. Sugarcane takes 10-18 months to grow and is therefore liable to be attacked by a number of insects, pests and diseases. Its production declines by 19 - 20 % by their attacks. To increase the crop productivity, management of insect-pest and diseases is of great significance. Sugarcane is infested by about 288 insects of which nearly two dozen causes heavy losses to the quality as well as quantity of the crop. In this project we will be focusing on a pest control and monitoring system for efficient sugarcane crop production, which is a staple crop grown in Pune. The main pests that affect sugarcane are top shoot borer, stalk borer, rood borer and sugarcane wooly aphid. Apart from this, the main diseases that affect sugarcane crop are Red rot, Smut, Grassy Shoot and Wilt. The system uses an acoustic device sensor which monitors the noise level of the pests and gives an indication to the farmer through an alarm when the noise crosses a threshold. The dissemination of is done via a network of wireless sensors connected to a control room computer. Transmission and reception of field data is through ZigBee 802.15.4 digital communication device standard. The system covers large areas with very low energy consumption.

Keywords*-SNR-Signal to Noise ratio, AMDF- Average Magnitude Difference Function, ZibBee-802.15.4 protocol for data transmission*.

1. INTRODUCTION

1.1 BACKGROUND AND CONTEXT

Pests and diseases cause great economic loss to farmers through reduced yields and increased costs of pesticides and other control measures. The early detection of hotspots of insect or disease attack in crop paddocks is critical for timely and targeted application of pesticides. Precise knowledge of areas where pest or disease activity has started would enable the farmer to apply just the right amounts of pesticides to the affected areas, thereby yielding both economic and environmental benefits. The common method for detection of pest or disease damage in crops is by visual inspection of the foliage in the field. Such methods are labor intensive and costly, and only a limited number of field samples can be examined at any one time. Also with field scouting methods small areas of pest/disease onset in healthy paddocks may often go undetected. Furthermore the effects of many pest/disease infestations are often not noticeable to the human eye, until it reaches an advanced stage when it becomes too late to control the outbreak. Remote sensing provides an alternative cost effective method to obtain detailed spatial information for entire crop fields at frequent intervals during the cropping season. It is already known that important changes in plant growth and function caused by nutrient and water stress, disease symptoms, etc. are detectable through their canopy reflectance (especially in the near infrared) much earlier than these effects become visible to the human eye. Besides the above mentioned technologies, acoustic detection is the best and most cost-effective. Acoustic sensors are able to distinguish between various pests which give this technology an edge over others. India is the 2nd largest producer of sugarcane (Saccharum spp.) with production of 277,750,000 tons in the world. It is major cash crop of Maharashtra. The main reasons for loss in production are pests and insects. Sugarcane is infested by about 288 insects of which nearly two dozen causes heavy losses to the quality as well as quantity of the crop, as detail given below in Table.1. The scenario of insect pests and diseases varies in sub-tropical and tropical belt of sugarcane. Top borer and stalk borer are found pre-dominantly in sub-tropical areas whereas internodes borer and early shoot borer and among disease rust & eye spot are prevalent in tropical region. Several management strategies have been developed as a result of research and development work. In order to save environment from chemical pollution, use of bio-control has been given utmost attention. The management technologies have been integrated as per need for increasing the efficiency

Sr. No.	Name of Pest	% reduction in cane yield	% reduction in sugar recovery
1.	Early shoot borer	22 to 33	2
2.	Internode borer	34.88	1.7-3.07
3.	Stalk borer	upto 33	1.7-3.07
6.	Rood borer	35.00	0.3-2.90
7.	Scale insect	32.60	1.5-2.5
9.	Black bug	35	0.1-2.8
10.	Pyrilla	31.60	2.0-3.0
12.	White Fly	86.00	1.4-1.8
13.	White grub(H)	80	5.0-6.0
14.	Whiter grub(L)	100	complete drying
15.	Termite	33	4.5

Table.1: Extent Of Losses Due To Different Insects & Pests In India

Fig 1. Sugarcane Borer

Any type of pest control activity is divided into three main segments, which are: Analysis of the symptoms causing pests as well estimating the extent of damage caused by them, Identification of pests and differentiating between their types i.e. detection, Management of the detected pests using biological control and other available environment friendly methods. The block diagram given below describes the general structure of acoustic detection systems:

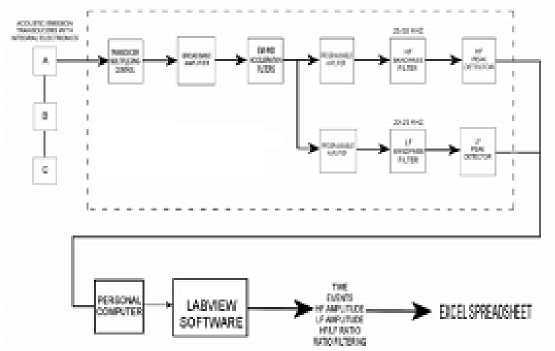

Fig 2. Block Diagram

Some of the important features of the acoustic sensor that makes it the sensor of our choice are: Listening Device, self-monitoring system, radio Frequency remote access, wireless Network functionalities, long battery lifetime / Low power system, no need for specialists on the field.

Fig 3. Acoustic Wireless Sensor

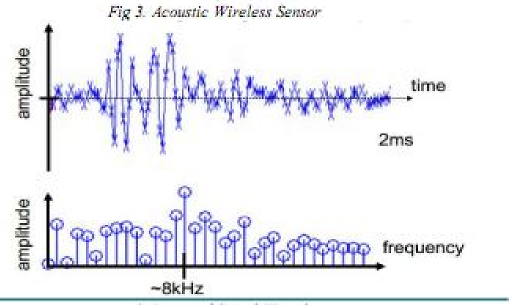

Fig 3 .Received Signal Waveform

1.2 A BRIEF HISTORY OF WSN AND PEST CONTROL

The first recorded instance of pest control takes us back to 2500BC when the Sumerians used sulphur to control insects. Then around 1200BC the Chinese, in their great age of discovery towards the end of the Shang Dynasty, were using chemicals to control insects. The Chinese continued to develop ever more sophisticated chemicals and methods of controlling insects for crops and for people's comfort. No doubt the spread of pest control know-how was helped by the advanced state of Chinese writing ability. Although progress in pest control methods undoubtedly continued, the next significant scrap of evidence does not come until around 750BC when Homer described the Greek use of wood ash spread on land as a form of pest control. Around 500BC the Chinese were using mercury and arsenic compounds as a means to control body lice, a common problem throughout history. In 440BC the Ancient Egyptian's used fishing nets to cover their beds or their homes at night as a protection from mosquitoes. . From 300BC there is evidence of the use of use of predatory insects to control pests, although this method was almost certainly developed before this date. The Romans developed pest control methods and these ideas were spread throughout the empire In 200BC, Roman censor Cato encouraged the use of oils as a means of pest control and in 70AD Pliny the Elder wrote that galbanum resin (from the fennel plant) should be added to sulphur in order to discourage mosquitoes. In 13BC the first recorded rat-proof grain store was built by the Romans. The first known instance where predatory insects were transported from one area to another comes from Arabia around 1000AD where date growers moved cultures of ants from neighboring mountains to their oasis plantations in order to prey on phytophagous ants which attacked date palm. At this point pest control was carried out by farmers and some householders as an everyday activity. By the early nineteenth century however, this changed as studies and writings started to appear that treated pest control as a separate discipline. Increasing use of intensive and large scale farming brought matching increases in the intensity and scale of pest scares such as the disastrous potato famine in Ireland in 1840. Pest control management was scaled up to meet these demands, to the point that dedicated pest controllers began to emerge throughout the 20th century. In 1921 the first crop-spraying airplane was employed and in 1962 flying insect control was revolutionized when Insect-o-cuter started selling fly killer machines using ultra violet lamps. Pest control is still carried out by farmers and householders to this day. There are also pest control specialists (sometimes called pasties'); many are one-person businesses and others work for large companies. In most countries the pest control industry has been dogged by a few bad practitioners who have tarnished the reputation for the highly professional and responsible majority.

2. MOTIVATION AND PROBLEM DEFINITION

Agriculture has increasingly become dependent on chemical pesticides to control the pests that damage the crops. There is heightened concern over the environmental effects of pesticides, coupled with increased pest resistance and secondary pest outbreaks, severely limits the effective pesticides available to farmers. As weather patterns change, crops mature, and cattle graze pastures for food, farmers must decide when to irrigate pastures, apply fertilizer, or move cattle to another pasture. A farmer relies on a combination of experience, visual observation, intuition and he has to perform periodical surveys over a widespread plantation which is a time consuming activity. Acoustic detection technology is a far better substitute to these laborious tasks. Main problem of the project can be defined as the establishment of an acoustic pest detection system comprising of acoustic sensors which are deployed in the sugarcane field or farm area and are connected through a wireless sensor network (WSN) to a computer which runs a database management software and detection algorithm. Outdoor field trials of WSNs pose problems that do not occur in lab experiments. Some of the reasons are harsh environmental conditions (e. g. low temperatures), long-term unattended operation, and complex deployment process, connection to the wired world, and large number of nodes. This section discusses the setup of a field trial of a WSN and evaluates different alternatives. There is a wide range of sensor node hardware available, ranging from small devices with 8-bit microcontrollers as CPUs, 2–100 KB of working memory, 64–1024 KB of flash secondary storage, and a low-power radio operating at 10 Kbit/s up to larger devices with 32-bit CPUs, megabytes of working memory and secondary storage, and supporting the Bluetooth wireless standard, such as the Intel Mote. Obviously, the performance of an algorithm will strongly depend on the selected hardware; especially the quality of the transceiver and communication technology is of high importance. Outdoor applications present an additional set of challenges not seen in indoor experiments. Most sensor node hardware is still of prototypically nature and does not come with a packaging suitable for outdoor deployment. To withstand variable weather conditions, protective packaging that minimally obstructs the sensing and communication functionality has to be provided. In most cases custom enclosures are too costly. If the accuracy of sensor values is not of importance, off the-shelf rain-proof boxes with a rubber seal, antennae inside, wrapped in plastic are sufficient. The effect of the packaging on the quality of the communication must be analyzed prior to deployment. Another aspect that is usually not present in indoor experiments is the variation in temperature during the trial. Temperature directly affects battery voltage, which in turn affects radio communication.

3. MAJOR CONTRIBUTIONS

Pest control plays a crucial role in farming for without it, plants will die or not bear fruit. Pests are a natural enemy to farmers because they hinder farm production. Farmers have to use different methods of controlling pests. Common forms of pest control involve traps, field burning, air guns, hunting, poisoned bait, natural rodent control, destruction of infected plants, poison spray, sterilization, and eliminating breeding grounds via drainage of still water or proper management of waste. By implementing one of these methods, farmers can fully maintain the sound health of their farms and agricultural produce. Monitoring pest insect population is currently a key issue in crop protection. At farm level it is routinely operated by repeated surveys by a human .This is a labor and time consuming activity, and it would be of great advantage for farmers to have an affordable system of doing this task automatically. This system is using an acoustic device sensor that is able to monitor the noise level of pests and gives an indication to the farmer through an alarm when the noise crosses a threshold.

4. AREAS BEING INVESTIGATED

Major Insect Pest Management Of Sugarcane Crop Sugarcane is a long duration crop of 10-18 months and therefore is liable to be attacked by a number of insect pests and diseases. According to an estimate, sugarcane production declines by 20.0 and 19.0 % by insect pests and diseases respectively. To increase the crop productivity, management of insect-pest and diseases is of great significance. Due to diversity in agro-ecological conditions the importance of insect pests and disease varies and therefore, management strategy should be adopted accordingly. Sugarcane is infested by about 288 insects of which nearly two dozen causes heavy losses to the quality as well as quantity of the crop, as detail given below in Table.1. The scenario of insect pests and diseases varies in sub-tropical and tropical belt of sugarcane. Top borer and stalk borer are found pre-dominantly in sub-tropical areas whereas internodes borer and early shoot borer and among disease rust & eye spot are prevalent in tropical region. Several management strategies have been developed as a result of research and development work. In order to save environment from chemical pollution, use of bio-control has been given utmost attention. The management technologies have been integrated as per need for increasing the efficiency.

5. SYSTEM DESIGN AND FRAMEWORK

We are proposing a pest monitor and control system for efficient sugarcane crop production. The system will be using an acoustic device sensor which will monitor the noise level of the pests and whenever the noise crosses the threshold it will notify the farmer of the area where the infestation is occurring. This will help to induce automation in the field of farming and reduce the efforts of farmers. Through acoustic detection technology there will be no need of the farmer to go to each and every part of the field and perform periodical surveys over widespread plantation. This will help to reduce time and increase the productivity and help to grow better and healthier sugarcanes. The collection of the noise levels will be done using a number of wireless sensor nodes spread over an area.

Program Operation	Cycles	Time(μsec)
Acquire data from ADC	1088	272
Energy Computation	1552	388
Shifting buffer	1024	256
Windowing	1024	256
AMDF calculation	5120	1280
Pitch estimation	1120	280
Event posting	162	40
Command Calling	130	32
Post a task to scheduler	92	22
Total	11312	2826

Table 2. Complexity Measurements For Different Parts of The AMDF

These wireless sensor nodes will be connected to a base station to which the sensors will transmit the noise levels whenever the noise level crosses a threshold level after comparison through a comparator. The base station will then transmit the information to the control room computer which will indicate to the farmer where the infestation is occurring so that the necessary action can be undertaken. The transmission and reception of the data is done through zigbee 802.15.4 digital communication standard. We would like to highlight the details of the setup.

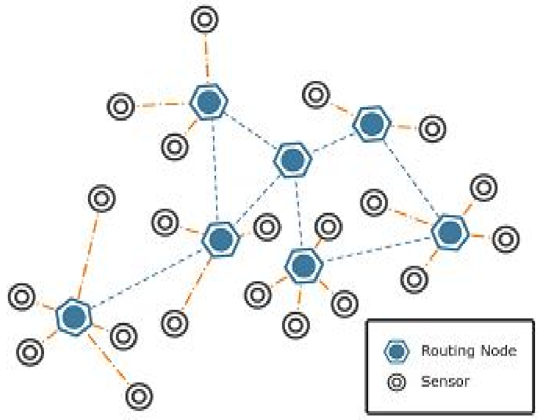

Fig 4. Placement of sensor nodes over an area

APPLICATION

The acoustic detection systems can be applied to other fields such as termite detection in homes, wetland monitoring thus making it quite a diverse detection technology for pests and insects.

5.1 WIRELESS DATA TRANSMISSION USING ZIGBEE 802.15.4 TECHNOLOGY

Most algorithms developed for wireless sensor networks must take into account efficiency because of the limited resources available on the mote. In fact, a number of algorithms are available that attempt to reduce energy consumption in WSNs [17]. In an effort to maintain acceptable performance and speed, we have analyzed the complexity of the energy and AMDF calculations on the mote. In Table 2. we list a number of operations performed in the program and the corresponding required clock cycles and time. It is apparent that the operation requiring the most clock cycles is the AMDF. This is because of the nested loops (0(n2) complexity) required to implement it. For future implementations of the algorithm, we are seeking less costly ways of computing pitch periods of acceptable quality. Taking into account all computations, for a single frame of 64 samples, a total of 11312 clock cycles are required, which translates to approximately 2.8 Msec in actual time.In this analysis, additions, multiplications, and lower level subroutines that are called as TinyOS are not taken into account. Although the additions and multiplication may not change total complexity of the algorithm significantly, the lower level subroutines can potentially have a large impact. As there are a number of Issues related to the efficient transmission of the acoustic data over the wireless network, thus we are aking use of the zigbee technology. The acoustic wireless device sensor will send the information over the Zigbee network in an FFT algorithm format The Zigbee Gateway Device is a stand-alone device that can meet the IP connectivity requirements of most applications. The specification and hence the devices that stem from the specification were purposely designed to be generic in nature, stopping at a level that was in no way Zigbee public application profile specific. This flexibility allows host applications to use generic gateways to communicate with any public application profile installation without modification. Application-specific details are relegated to the host. However, it was also envisioned that the Zigbee Gateway specification and the resulting implementation would serve at an Application Programming Interface specification so that developers of Gateways could build application-specific devices. The main idea was that the specification would provide a foundation so that developers could add their application-specific code, whether in the form of an energy service portal or an in-home device, to allow homeowners to interact with any number of applications, including lighting or entertainment control infrastructure. This would allow for standardized gateways to be used in any Zigbee standards, including ZigBee Smart Energy, ZigBee Home Automation, ZigBee Telecom Service. The ZigBee Gateway specification was focused to meet the common functionality essential to a gateway for ZigBee standards, or public application profiles

5.2 INDICATION AT THE RECEIVER END

Thus data from the various sensor nodes will be displayed at the operators end in the form of FFT format of the audio signal as shown in Fig 4. Thus the operator can continuously observe the noise level being collected by the various sensors and a comparator that is set to a particular threshold level, if it detects a sound level above this threshold level , it will immediately give an alarm signal to turn inform the operator about abnormal situation of the pest attack over a particular area of the field. We have given a snapshot of the operator's screen monitoring the signal form various nodes in Fig 5.

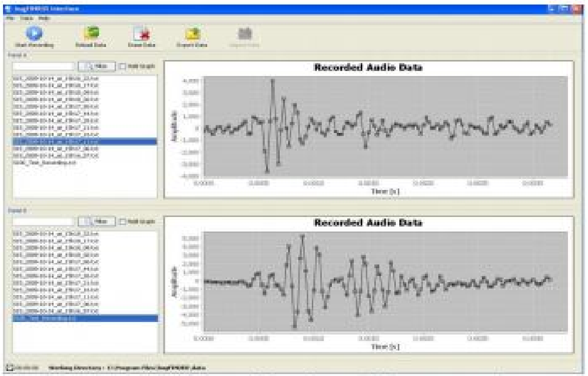

Fig5. FFT waveform of the audio signal from sensor node

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6. IMPLEMENTATION OF THE SYSTEM

A farmer can then take the necessary measures to spray insecticides over the crops and will help to detect infestation at a very early stage and will greatly reduce the percentage of sugarcane crop being destroyed annually. The system proposed will be able to cover large amount of area with very low energy consumption.

6.1 EXTENSION OF THE PROJECT

Since we are focusing on very limited pests like top shoot borer, rood borer and sugarcane wooly aphid and diseases like red rot and smut, these pests and diseases require similar pesticides in order to check their infestation so we can also have an automatic pest spraying mechanism that will automatically spray pesticides wherever the infestation is occurring. This will further automate farming to grow better and healthier crops

7. CONCLUSION

Our primary objective is to create a pest monitoring and control system for Sugarcane using WSN in order to check the infestation and notify the agriculturist of the area of the field where the infestation is taking place so as to reduce the efforts of farmers to go to every part of the field and check the growth of pests. This will help farmers make optimal decisions pertaining to efficient use of pesticides. This results in inducing automation in the field of farming in order to grow better and healthier Sugarcanes.

8. ACKNOWLEDGMENT

We would like to thank Mahatma Phule Krishi Vidyapeeth College of Agriculture, Shivaji Nagar, Pune and National Institute of Pest Management for their contribution in the development of our project and sharing their valuable database on pest management with a over 100+ years of research. We also like to thank the Department of Electronics Engineering, Bharati Vidyapeeth Deemed University, Pune for accepting our project and providing us all the research facilities and guidance.

REFERENCES

[1] "Rapid on-site monitoring of pesticide residues with MIP sensors", Mohammad Al Kobaisi, A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy at School of Applied Sciences RMIT University.

[2] "Ultra-Sensitive determination of pesticides via cholinesterase-based sensors for environmental analysis", Frank Davis, Karen A. Law, Nikos A. Chaniotakis, Didier Fournier, Tim Gibson ,Paul Millner, Jean-Louis Marty, Michelle A. Sheehan, Vladimir I. Ogurtsov,Graham Johnson, John Griffiths, Anthony P. F. Turner and Seamus P. J. Higson.

[3] "Immunosensors for pesticide determination in natural waters", E. Mallat, D. Barceloè, C. Barzen, G. Gauglitz, R. Abuknesha.

[4] "Trends in Flow-based Bio sensing Systems for Pesticide Assessment", Beatriz Prieto-Simón 1, Mònica Campàs 1, Silvana Andreescu 2 and Jean-Louis Marty 1,* Department of Chemistry and Biomolecular Sciences, Clarkson University, Potsdam, NY 13699-5810, USA.

[5] "Sensing technologies for precision specialty crop production", W.S. Lee, University of Florida, Agricultural & Biological Engineering Department; V. Alchanatis, Department of Sensing, Information and Mechanization Engineering, Institute of Agricultural Engineering, Israel; Yang, U.S. Department of Agriculture (USDA), Agricultural Research Service (ARS), Kika de la Garza Subtropical Agricultural Research Center; M. HirafujiNational Agriculture and Food Research Organization, National Agricultural Research Center and University of Tsukuba, Japan .

[6] "Wireless Underground Sensor Networks for Agriculture", Xiaoqing Yu, Pute Wu, Wenting Han and Zenglin Zhang, Northwest Agriculture and Forestry University, Shaanxi, Yangling 712100, China.;National Engineering Research Center for Water Saving Irrigation at Yangling, Institute of Soil and Water Conservation of Chinese Academy of Sciences, Shaanxi, Yangling 712100, China.;Research Institute of Water-Saving Agriculture of Arid Regions of China, Shaanxi, Yangling 712100, China.

[7]"Taxonomy of Wireless Micro-Sensor Network Models", Sameer Tilak,Nael B. Abu-Ghazaleh, Computer System Research Laboratory, Dept. of CS, Binghamton University, Binghamton, NY ;Wendi Heinzelman, Electrical and Computer Engineering, University of Rochester, Rochester, NY. [8] "A Survey of Fault Management in Wireless Sensor Networks", Lilia Paradis and Qi Han, Department of Mathematical and Computer Sciences, Colorado School of Mines, Golden, CO 80401.

[9] "Authentication Protocols for Ad Hoc Networks: Taxonomy and Research Issues", Nidal Aboudagga, Jean-Jacques Quisquater, UCL Crypto Group, Université Catholique de Louvain, Belgium; Mohamed Tamer Refaei, Mohamed Eltoweissy, Luiz A. DaSilva, Bradley Department of Electrical and Computer Engineering, Virginia Tech, USA.

[10]"Multipath Routing in Wireless Sensor Networks: Survey and Research Challenges", Marjan Radi , Behnam Dezfouli, Kamalrulnizam Abu Bakar, Faculty of Computer Science and Information Systems, Universiti Teknologi Malaysia (UTM),Johor 81310, Malaysia; Malrey Lee , Center for Advanced Image and Information Technology, School of Electronics & Information Engineering, ChonBuk National University, Korea.

[11] "Taxonomy of Localization Schemes for Wireless Sensor Networks", A. Youssef, M. Youssef Computer Science Department University of Maryland College Park, MD, USA.

[12] "Taxonomy of Routing Protocols for Wireless Sensor Networks", Gergely ´ Acs, Levente Butty´an ,Laboratory of Cryptography and Systems Security (CrySyS) Department of Telecommunications, Budapest University of Technology and Economics, Hungary.

13]"Classification and Comparison of Routing Protocols In Wireless Sensor Networks", Rajashree.V.Biradar,Department of Information Science and Engineering, Ballari Institute of Technology and Management,Bellary-583104, Karnataka, India.; V.C .Patil, Department of Electronics and Communication Engineering, Ballari Institute of Technology and Management,Bellary-583104, Karnataka, India.; Dr. S. R. Sawant, Dr. R. R. Mudholkar, Department of Electronics, Shivaji University, Kolhapur-416004, Maharashtra, India.

[14] "Agro-Sense: Precision Agriculture Using Sensor-Based Wireless Mesh Networks", Anurag D, Siuli Roy and Somprakash Bandyopadhyay,Indian Institute of Management Calcutta,Kolkata, India.

[15]"Taxonomy for Wireless Sensor Networks Services Characterisation and Classification", Luís M. Borges, Fernando J. Velez, Instituto de Telecomunicações, DEM, Universidade da Beira Interior, Calçada Fonte do Lameiro, 6201-001 Covilhã, Portugal.

[16] "Wireless Sensor Networks In Agriculture: For Potato Farming",Kshitij Shinghal Department Of E&C Engg., Moradabad Institute Of Technology, Moradabad, India.;Dr. Arti Noor Department Of M. Tech. Vlsi Design Group, C-Dac, Noida, India;Dr. Neelam Srivastava Department Of E&C Engg., Institute Of Engineering & Technology, Lucknow, India.;Dr. Raghuvir Singh Academic Advisor, Shobhit University, Merrut, India.

[17] "An Efficient Wireless Sensor Network for Precision Agriculture", Manijeh Keshtgary, Amene Deljoo, Dept. of Computer Eng. & IT Shiraz University of Technology Shiraz/Iran.

[18] "A Novel Integrated Wireless Sensor Network Architecture For Disaster Prevention", Md. Abdullah-Al Mamun, Yuji koi,Naoshi Nakaya, 1Department of Computer and Information Sciences, Graduate School of Engineering, Iwate University, Japan

[19] "Intelligent Humidity Sensor for -Wireless Sensor Network Agricultural Application", Kshitij Shinghal, Department of E&C Engg., Moradabad Institute of Technology, Moradabad, INDIA.; Dr. Arti Noor Department of M. Tech. VLSI Design Group, C-DAC, Noida, INDIA, Dr. Neelam Srivastava, Department of E&C Engg., Institute of Engineering & Technology, Lucknow, INDIA.; Dr. Raghuvir Singh, Shobhit Institute of Engineering and Technology, Gangoh (SIET), INDIA.

[20]"Application of Wireless Sensor Networks For Greenhouse Parameter Control In Precision Agriculture", D.D.Chaudhary,Sinhgad Institute of Technology, Lonavala, Dist. Pune. MS. India.; S.P.Nayse,Ph.D. Scholar, Sant Gadgebaba University of Amravati. MS. India; L.M.Waghmare,Shri Guru Govind Singh Institute of Technology, Nanded. MS. India.

[21] "Topology Optimization in Wireless Sensor Networks for Precision Agriculture Applications", Katsalis Konstantinos, Xenakis Apostolos ,Kikiras Panagiotis, Stamoulis George University Of Thessaly ,Volos, Greece.

[22] "Wireless sensors in agriculture and food industry—Recent development and future perspective", Ning Wang, Department of Bioresource Engineering, McGill University, Canada ; Naiqian Zhang, Kansas State University, Manhattan, KS, USA; Maohua Wang,China Agricultural University, Beijing, PR China.

[23] "Wireless Sensor Networks for Paddy Field Crop Monitoring Application", Santhosh Simon, K Paulose Jacob ,Department of Computer Science, Cochin University of Science and Technology, Kerala, India.

[24] "Water Management Barrier And System", Taylor, Jaren (Logan, UT)[

[25] "Sensor Node And Sensor Network System", Tanaka, Takeshi (Akishima, JP), Yamashita; Shunzo (Musashino, JP), Aiki; Kiyoshi (Hachioji, JP).