Proceedings of the International Conference on Smart Electronics and Communication (ICOSEC 2020)
IEEE Xplore Part Number: CFP20V90-ART; ISBN: 978-1-7281-5461-9

Smart Field Monitoring using ToxTrac: A Cyber-Physical System Approach in Agriculture

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***Abstract*— Recent developments within the internet and the growth of sensor platforms have enabled the implementation and exchange of multi-disciplinary and cross-dominant data in different applications, used to connect physical devices (things) to the real world. This development also has a number of advantages for the agriculture sector: optimal resource management and the improvement of human labour (i.e. crop growth monitoring and selection, support for decision-making in irrigation, fertilizers, pesticides, agro-chemistry, etc.). In this work, the rodents and especially field rats are our primary emphasis. Around 80 percent of human food is obtained from grains and 50 percent of overall food loss is caused by pests. Till now only traditional optimization actions have been commonly used for pest management, such as traps, electrical fences, rodenticides, etc. Integrating pesticide management (IPM) is an effective and dedicated approach to the control of pesticides. It uses the latest knowledge about the pest's life cycle and its relationship with the environment. This paper demonstrates a smart pest control solution (SPEC) in order to track the rat's behaviour and activities in the field to the pest control experts /farmers so that they can apply traditional control methods more efficiently. In this paper, one new approach for animal detection is developed using ToxTrac and NS2 simulator. Simulation results show that agriculture monitoring using toxtrac and NS2 is an efficient system.**

Keywords*— *Agriculture, Rodents, Integrated Pest Management (IPM), Wireless Sensor Network, Network Animator, Cyber Physical Systems

I. INTRODUCTION

Pest is a significant issue in agriculture which causes tremendous harm such as eating plants, grains, food as well as digging areas of the field, spreading diseases causing fire, and so on [1]. The main types of pests are insects, birds, and rodents, while rodents are the most abundant and widespread of all mammals, such as moles, rabbits, raccoons, and mice. About 80grain and the pest results in the 50overall food loss. For example, a huge amount of damage by rodents has been reported in Japan [2]. Black rats usually destroy the vegetation by eating seeds, leaves, fruits, and twigs. Our main focus in this work is on rodents and, in particular, field rats [3]. In many communities, rodents are a hidden problem. Till now only conventional control measures such as traps, electric fences, rodenticides, etc have been popularly used for the pest control. The efficient and dedicated approach to pesticide management is Integrated PM (IPM). It uses information about the pest's life cycle and its associate's impact on the environment [4]. In combination with available pesticide methods, these data are used to deal with harmful damage to people, property, and the environment in a most economical and environmentally friendly way [5].

The main aim of IPM is on control, not elimination. It works to examine the pest and accurately recognize them so that appropriate control decisions are taken in conjunction with action thresholds. This paper demonstrates that any effective control program needs regular tracking of the rats along with the close integration to traditional methods which can facilitate making wise and efficient decisions for the pest control experts/farmers. In this paper developed a smart pest control solution (SPEC) [6] to track the rat's behaviour and activities in the field to the pest control experts /farmers so that they can apply traditional control methods more efficiently. Hence in this term paper, discussed a solution based on Cyber - Physical Systems (CPS) and various shortcomings and aspects of this problem.

II. LITERATURE REVIEW

From the last three decades, there is drastic development in mechatronic systems for cyber physical systems. In [7] authors have developed CPS agriculture model for potato crop, this paper describes integrated precision agriculture management for agriculture. In [8] authors describe management informatics systems for discrete planning of agriculture. They focus more on strategies for categories of a management system with its possibilities in different crops pests controlling. In [9] authors describing CPS system development using wireless sensor networks. By using MANET protocols, the CPS design was made for agriculture integrated model. In [10] authors describe the information processing technology, software and hardware design for CPS organic implementations. In [11] authors describe CPS design using artificial intelligence marketing. This method is a combined method with pest control and marketing after food production.

Authors in [12] gave an overview of the efficient urban water management cycle. It is a case study on Badalona urban area. In [13], the authors discussed real-time CPS monitoring tool for secured research. In [13] they gave performance results and preliminary analysis of CPS systems were discussed. Whereas in [14], they discussed CPS monitoring by using embedded computer systems to overcome the number of restrictions imposed by specifics of the CPS design and development.

III. PROBLEM STATEMENT

Any intelligent solution to the pest problem brings many challenges and requirements to develop new ideas and technology. The various challenges which have been encountered are as follows:

1. The core problem of the research is how to detect the rats in the agriculture field. Rat detection is most challenging in both sensors and processing aspect because of various reasons.
   a) The rat detection system (RDS) must operate in the dark environment as rats are nocturnal.
   b) The RDS should work in the presence of obstacles.
   c) Rats must be recognized from the other animals which are a very onerous task
   d) They live underground in the holes hence detecting them would be a key component.
2. Map of the field should be generated after collecting data from the WSN. Approximate location of the rats, places with the higher congestion, etc should be extracted via appropriate data mining techniques.
3. Cost is a major challenge, especially for large scale systems. The total cost should be affordable and appealing to the farmers/pest control experts.
4. Energy consumption is an important factor in case of insufficient power supply

IV. PROPOSED SYSTEM

In this term paper, presented the best solution along with discovering the possibilities of employing the Cyber-Physical System (CPS). The tracking system can be applied as a potential solution by detecting the movements of rodents via a field-deployed wireless sensor network and capturing, storing, and viewing the data. the analysis of the results is classified into two parts. The first creation of Motion Detection Node (MDN), second development of Wireless Sensor Network (WSN) by using MDN and Data Relay Node (DRN). MDN can be implemented in ToxTrac software whereas WSN created in NS2 software.

The operation of a smart monitoring system explained as follows:

- Sensors and thermal cameras (TC) were installed in the field for motion detection from rats and pests.
- Any pests or rats were found then by using ToxTrac Motion detection node will be created, like this many MDN will be created by using cameras and sensors which were installed in the field.
- The data from each MDN is processed and analysed by NS2 in Central Processing Node (CPN) and Data Relay Node (DRN).
- CPN will alert the farmers so that they can save their farm from pests and rats.

To incorporate a smart solution based on CPS, three basic elements must be considered for enabling the technologies. Sensors (data accretion system): Sensing the elements and the detection mechanism is the heart of the monitoring system.

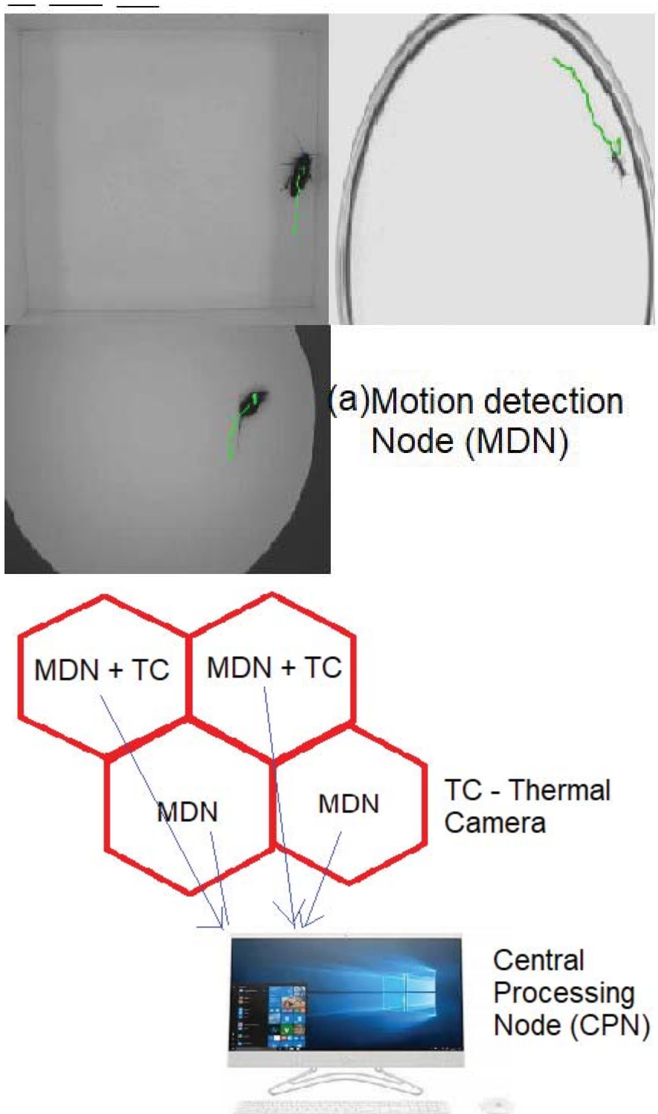

Fig 1: (a) Motion detection using ToxTroc
(b) creation of WSN using NS2

Sensor network: Developing a suitable design for a sensor network is necessary, where several factors like cost, energy etc has to be considered. To implement the above two components used an energy-efficient wireless sensor network (WSN).

Wireless Sensor Network: It is considered as a self-configured wireless network of sensor nodes for monitoring environmental conditions and for transmission of data to one main location through the network. WSN is subdivided into three elements

i) Data Acquisition
ii) Data communication
iii) Data computational system.

In the data acquisition part, all the sensor nodes are deployed according to particular network topology and perform sensing tasks then after completing the data acquisition task the sensor node performs data transmission. The energy consumption of the WSNs is aimed to reduce to prolong the network lifetime while scalability and efficient data communication have to be ensured.

Network architecture and the number of nodes is the primary factors for energy consumption whereas topology protocol and the routing algorithms are the key factors to minimize the energy consumption of the network.

Data Processing: Various processors should be performed on the data captured by the wireless sensor networks. The process is followed by data mining and analytic to extract desired information for the user. In this paper, a variety of motion sensors and thermal cameras (TC) are used. A TC captures the infra-Red (IR) video that allows us to detect rats in the thermal image based on body temperature of approximately 35 degrees. Figure 1 shows the details of the proposed system with a sensor network that is considered for the agriculture field. Here different biological facts are considered, such as trouble identifying rats in infrared images or videos, to solve major problems. Some beneficial factors are movement direction, body size, body temperature range, rats speed, etc.

V. TOXTRAC FOR DETECTION

ToxTrac will detect and track animals in rectangular pieces of the image containing the arenas where the animals were wanted to be observed. Inside the arena, the tracking areas are defined as uniform bright regions with no particular shape, where the tracked objects can be detected. If the arenas have dark corners or edges, these should be excluded from the tracking area.

TOXTRAC is open-source executable software for image-based monitoring. The main advantage of TOXTRAC is as follows:

- There is no need for detailed geometry information of the tracked bodies.
- Through the use of advanced desktop computers, TOXTRAC will display HD images at a rate of 25 frames per second.
- Quite robust against false positives during the simulation, a detection screen is got as shown in figure 2.

The various components of the detection screen are explained below as follows:

1. Navigate through the frames of the video sequence.
2. Displays the previous frame
3. Displays the next frame.
4. Select the previous sequence
5. Select the next sequence
6. Select the previous arena
7. Select the next arena
8. Threshold, this parameter selects the minimum intensity level (1-255) for the detected objects.
9. Select the size of the object in pixels.
10. Allows enabling or disabling the background subtraction algorithm.
11. Displays the original video frame.

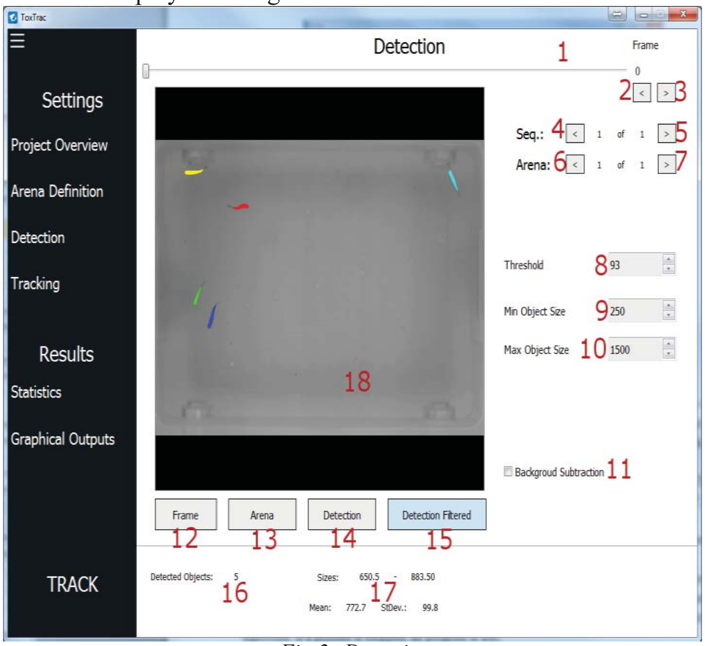

Fig 2: Detection screen

12. Displays the areas of the image excluded from the
13. Tracking area.
14. Displays the unfiltered detection.
15. Displays the filtered detection.
16. Displays the detected objects with the current parameters.
17. Displays the range of sizes of the detected objects, together with the mean and standard deviation of the sizes.
18. Displays current detection in the selected arena and video frame.

At the end, Result Screen is generated which shows the individual statistics as shown in table 1.

TABLE 1: PARAMETERS FOR TOXTRAC DETECTION

Global Statistics	***Value***
Average speed (mm/s)	10.62
Mob avg peed (mm/s)	19.96
Avg Accel (mm/sec2)	36.71
Mobility rate(rate)	0.21
Visible frames(frame)	1508
Invisible frames (frame)	1042
First visible frame (fame index)	0
Last visible frame (frame index)	2549
Visible time(hh:mm:ss)	00:01:00
Invisible time(hh:mm:ss)	00:00:40
Visibility rate(rate)	0.59

Invisibility rate (rate)	0.41
Number of Areas	80
Explored areas	12
Exploration rate (rate)	0.15
Total distance (mm)	1207
In transitions (transition)	0

Animals like rats, pests, cockroach etc, detection were shown in figure 2. After analysing the detection screen of ToxTrac software and considering the parameters the detected output from the thermal camera were shown in figure 2. These screens were analysed by toxtrac and sent the decision to the farmer by using WSN which implemented in the next section.

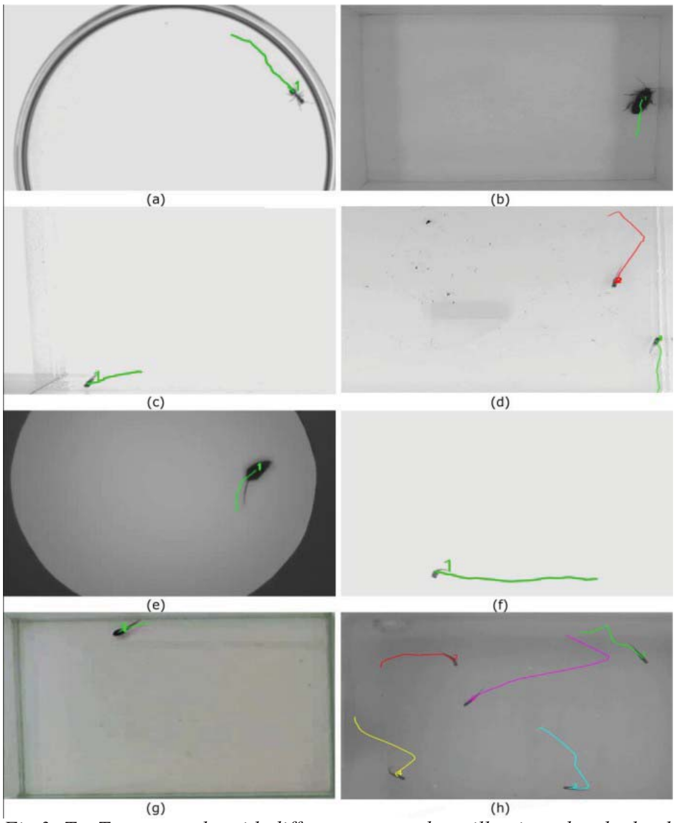

Fig 3: ToxTrac examples with different pests and rats illuminated under back light. (a) ant, (b) cockroach, (c) guppy 1, (d) guppy 2, (e) mouse, (f) salmon, (g) tadpole, (h) zebrafish.

VI. SIMULATION RESULTS

Simulation results are analysed Wireless Sensor Networks (WSN) using Simulator named NS2. It is a tool, utilized to examine the dynamic nature of the communication network. It allows the user with a command 'ns' which takes an input argument, the name of a TCL script file. In most of the cases, the simulation trace file which is generated in execution of the command is used for mapping the graph and/or generating an animation. Network Animator is an animation tool focused on Tcl / TK and utilized for viewing network simulation and real-world packet traces. Here eight wireless sensor nodes are created and then communication between all these nodes is achieved using TCP protocol. Between all these eight nodes a CBR session is created. The simulation is carried out for 30 msec. The routing protocol used is DSDV and the MAC protocol used is 802.11.

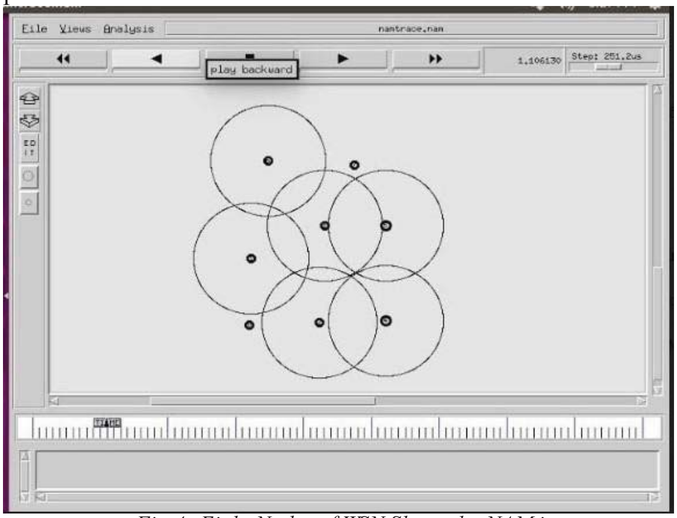

Fig 4: Eight Nodes of WSN Shown by NAM i

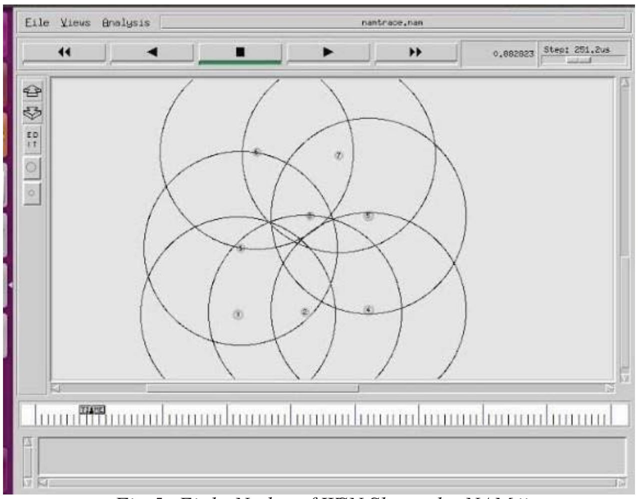

Fig 5: Eight Nodes of WSN Shown by NAM ii

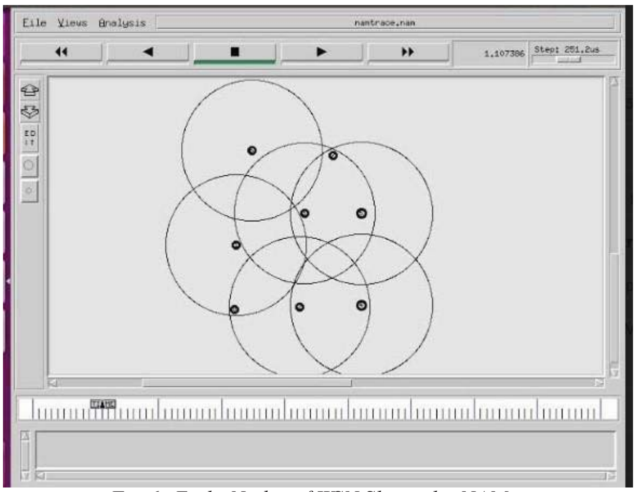

Fig 6: Eight Nodes of WSN Shown by NAM iii

Figure 4,5 and 6 shows the simulation results of the WSN network with 8 nodes with MAC routing protocol[15]. In this paper, the results in NS2 is analysed by using NAM (network animator) protocol. In each figure, the separation of the nodes were 30 degrees apart from each other. Simulation parameters of our WSN are shown in table 2.

TABLE 2: SIMULATION PARAMETERS OF WSN

Parameter	Value
Network simulator	NS-2 2.34
Channel type	Wireless channel
Network interface model	Phy/Wireless Phy
MAC protocol	IEEE 802.11
Data (traffic) type	CBR
Antenna model	Omni Antenna
Simulation area	1000*1000
Simulation time	300s
Data packet size	512
Propagation model	Two ray Ground
Number of nodes	60
Queue type	PriQueue
MAC rate	2 mbits/s
Network interface queue	DropTail/priQueue
Tx range	250 meters
Node placement	random

VII. CONCLUSION

A constant, intelligent surveillance system is important because of the huge loss of food and environmental destruction by rodents. A smart and autonomous solution consists of sensors, sensor networks, and data processing components. Developing an energy-efficient wireless sensor network is a major part of the project that have been concentrated on so far. The detection mechanism is based on open-source software TOXTRAC instead of sensors and thermal cameras because TOXTRAC is easily available and works similarly to thermal cameras. Further research is still in progress and researchers are working on the development of a simple prototype of the system.

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