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Multi-agent based context aware information gathering for agriculture using Wireless Multimedia Sensor Networks

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ABSTRACT

Wireless multimedia sensor networks (WMSN) can be used in a wide range of applications such as monitoring agriculture, infrastructures, military operations, disaster management and so on. Energy conservation is a major concern in WMSN applications. This paper proposes a multi-agent based context-aware information gathering using WMSN for monitoring agriculture. Three kinds of contexts are considered in this paper such as detecting an emergency, temporal and computational contexts for detection of diseased plants, weeds, fire and interpret the soil fertility based on the soil parameters. This work considers contexts driven by a sensor node. Whenever the context is detected the information will be sent to the sink node. The proposed scheme works as follows: Every sensor senses the information and updates the node knowledge base. Based on the sensed information node interprets the context such as disease affected plants, soil fertility, fire, and growth of weeds. The sensor nodes begin to transmit the stored information to the cluster heads with the help of Path Finding Agent (PFA). Cluster heads aggregate the information received by the sensor nodes in the field before sending this information with the help of Querry Agent (QA) to the sink node. At the sink node all the information will be sent to the end-user, but in case of the fire detection, the immediate action will be taken by the sink node itself to turn on the sprinklers. Once the sensor finishes the assigned task (sensing, communicating) then automatically it goes into sleep mode. To detect plant disease and weeds, content-based image retrieval is used to compare with the healthy or useful plant images respectively. For performance analysis, the proposed scheme is simulated using NS2. Some of the performance parameters considered in this work are context detection time, delay, fusion time and energy consumption.

1. Introduction

Wireless Sensor Networks (WSN) comprises of tiny sensor nodes that have sensing, computation, and wireless communication capabilities. A tiny sensor node communicates within a short distance and collaboratively works to fulfill the application specific objectives of WSN. In [1], the author has emphasized on demand for re-consideration of computational capabilities in traditional WSN. The sensor nodes may be equipped with multi-resolution cameras which collects a huge amount of multimedia data apart from the basic sensor nodes which collect scalar data. Wireless multimedia sensor network (WMSN) is a network of multimedia-enabled sensor nodes that are capable of sensing, computing and communicating multimedia data. WMSN demands sophisticated hardware that processes the multimedia data and reduces the amount of energy required for the communication as discussed by the author in [2,3]. Most of the WMSN have a lot of redundant data, hence these redundant data can be processed and aggregated in an efficient manner, which in-turn reduces the energy consumption and prolong the lifetime of the battery. In order to conserve the network lifetime of the WMSN, context-aware computing along with software agent technology is proposed in this work.

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A system is context-aware if it uses context to provide relevant information and service to the user. Context-based information gathering for WMSN needs to have proper information and measure of the context what we are using to represent the system. Context-aware computing helps to retrieve the relevant information from the environment, which in turn can conserve the network lifetime of WMSN as discussed in [4].

Software agents can be employed for information gathering to prolong the network lifetime as given in [5]. Agents can be static or mobile. Static agents reside at a particular location and perform the task by collecting the sensed information and storing in the node database. Further, it provides information to the mobile agents. Mobile agents perform the task by moving throughout the network environment thereby collecting the data from each sensor node and providing it to the sink node as given in [26–29].

The modern technologies such as wireless multimedia sensor networks along with context-aware decision-making capabilities are important to change the agricultural practices for better productivity. The wire-free nature of WMSN is suitable for monitoring the agricultural needs. Context-aware sensor network helps in conserving energy utilization in the network thereby enabling smart decision in productive agriculture monitoring. The sensor nodes are deployed randomly throughout the field. The sensor node collects various information such as soil moisture, leaf wetness, soil pH, temperature, atmospheric pressure etc. Based on these values the sink node provides the solution.

The motivation for carrying out the proposed work is, in countries like India, agriculture is a major occupation and acts as a backbone for the nation's economy. Two main drawbacks can be observed with respect to agriculture, which is water management and low productivity. WMSN helps in providing the solution for problems in agriculture such as monitoring of crops for disaster detection, soil fertility, plant disease and weeds detection. As agriculture is a rich domain for context awareness, agriculture scenario is considered for the proposed work. This article concentrates on improving the low productivity issue by considering WMSN for agricultural context.

The proposed agent-based context-aware information gathering using WMSN in monitoring agriculture addresses the following issues: (i) to detect the disease affected plants in the irrigated land; (ii) to recognize the growth of unwanted plants within the crop; (iii) to check the fertility of the soil periodically; (iv) to detect fire disaster in the field; (v) to prolong the network lifetime in wireless multimedia sensor networks.

1.1. Related works

Some of the related works on context-aware agriculture using wireless sensor networks are as follows: Agriculture is a very important aspect of human society. Use of a proper method for irrigation is important in the field of agriculture. The article [6] focuses on, detection of plant diseases which includes three major parts: image segmentation, feature extraction and classification. Image segmentation part extracts the regions affected by the disease for an input image. Feature extraction part converts the segmentation results into feature extract vectors. Classification part decides whether the plant in the input image is sick based on comparing the feature information of the input image. The work presented in [7] has discussed periodic maintenance of drip irrigation. Zigbee is one of the good technologies for controlling irrigation over large agricultural sector areas for growing crops. This proves to be a real-time feedback control system which monitors and controls all the activities of drip irrigation system efficiently. Article [8], explains about a pyramid context-aware model. A context-aware sensor grid is implemented to add precision for decision making and control process in agriculture. As described in [10,11], the scalar WSN is used to detect the fertility of the soil. An alarm system is used in emergency situations and conditions when the plant is in danger. When critical conditions threat a plant, the alarm system is enabled. In [12], the author explains about Coupling of a camera with the scalar WSN node enables to meet most of the requirement of environmental data collection and event detection. The low-cost charged coupled device (CCD) camera is used to detect the disease infected plants. In [9], the author has described the architecture of context-aware sensor grid system. Context-aware sensor grid is a combination of three promising technological domains that are context-aware computing, grid computing, and sensor networks. The sensed information is communicated from the sensor nodes to the sink node using agent technology. Agents are the autonomous programs located in an environment, which perform dedicated tasks either by itself or by interacting with other agents in the environment as explained in [13]. Software agents are of two types: static agents and mobile agents. Mobile agent systems perform tasks by roaming in an environment and interacting with other mobile agents as well as the nodes in an environment. Mobile agents also aggregate the data from all sensor nodes and help in routing the aggregated data to sink node as mentioned in [14]. The work proposed in [15], explains the context-aware image fusion using the multi-agent system for wireless military sensor networks using wavelet-based transformation for image fusion. A WSN system is proposed in [16], for use in precision agriculture applications, where real-time data of climatic and other environmental properties are sensed and control decision are taken based on it to modify them using Zigbee protocol. As irrigation method depends on the weather conditions, soil structure and variety of crop cultures, a greenhouse technology enabled with wireless sensor networks for automatic environment monitoring is proposed in [17] for precision agriculture. In [18], the authors have tried to explore how sensors and sensor networks have been utilized in crop production process from a user perspective. The work in [20] explains the concepts of auto color correlogram and it also deals with the performance of the content based image retrieval (CBIR) system using color features. The techniques used for color feature extraction are explained as HSV histogram, color correlogram and color moments in [21]. Texture feature extraction is achieved by Gabor wavelet filter as given in [22]. A combination of local, global and k-mean using wavelet transforms for content-based image retrieval is explained in [23]. Similarity measurement can be done with the help of Manhattan distance as explained in [24]. Precision farming using wireless sensor network technology to improve agriculture in Egypt is discussed in [25].

Context-aware wireless irrigation system (CAWIS) is proposed in [19], where a context-aware system is proposed using wireless sensor networks to minimize the wastage of water in irrigation process. CAWIS is used for comparing the proposed work, agent-based context-aware agriculture (ACAA) using WMSN.

Some of the drawbacks of existing precision agriculture techniques using wireless sensor networks are that most of the works consider only real-time scalar data to improve the agriculture process. The performance of WSN with respect to energy conservation of the sensor nodes and prolonging the network lifetime of WSN is not considered in most of the existing works. Also a very few literature exists for energy conservation in sensing, processing and transmission of multimedia data in WMSN.

1.2. Our contributions

The proposed scheme considers contexts driven by a sensor node. Whenever the context is detected the information will be sent to the sink node. Our contributions for the proposed scheme is as follows: (1) Modeling the event detected area of WMSN using context aware computing for agriculture scenario. (2) Usage of static and mobile agents for information gathering and detection of context based on soil fertility, fire, diseased plants and weeds. (3) Improvement in performance parameters such as context detection time, fusion time, energy consumption, cluster head selection time etc. when compared to the existing systems.

The rest of the paper is organized as follows: Section 2 presents a context-aware model for agriculture. Section 3 explains the content-based image retrieval for plant disease and weed detection. Section 4 describes the agent technology. Section 5 presents the simulation model and performance parameters. Section 6 discusses the results and Section 7 gives the conclusion of the work.

2. Context aware model for agriculture

Context is any information that can be used to characterize the situation of an entity. This section consists of the mathematical model required for simulation.

2.1. Network environment

The network environment shown in Fig. 1 consists of sensor nodes and a sink node. Sensor nodes are randomly distributed in the field. The sensor node senses the data and updates the knowledge base. Sensor node comprises of an agent platform with static and mobile agents, camera and other sensory devices such as soil pH, moisture, temperature and smoke detection. A sensor node is said to form a cluster around it based on the communication range. A sensor node has different sensory devices connected to it. Once the information is sensed by the sensor node, it compares the information with a threshold value; if it is not in the threshold range, a message is sent to sink node via cluster head using the multi-hop technique.

2.2. Context detection model

Let 'Cd' be the context detection based on soil fertility/ fire detection/ growth of weeds/ diseased plants considered in this scheme.

$$\mathrm{Cd(i)} = \left\{ \begin{array}{ll} 0; & Pi < Pi_{th} \\ 1; & Otherwise \end{array} \right\} \quad (1)$$

where i = 1,2,3,. . .. .,n

'Pi_{th}' be the threshold of the context detected where '$P1_{th}$' be the threshold of the soil fertility context, '$P2_{th}$' be the fire detection context, '$P3_{th}$' be the growth of weeds context and '$P4_{th}$' be the diseased plant context.

2.2.1. Soil fertility

The fertility of the soil can be measured as a combination of several parameters like soil moisture, the salinity of soil (soil electric conductivity), soil PH, soil temperature and so on as given in [30].

The threshold values of soil parameters like soil PH and soil electric conductivity can vary based on the geographic region of agricultural land and the type of crop cultivated in that land. In this work, only soil moisture and soil temperature parameters for Indian soil are considered for simulation along with their respective threshold values as given in Table 1. The threshold values are relative to the geographic area of agricultural land.

2.2.2. Fire detection

The occurrence of fire can be detected as a combination of several parameters like temperature, smoke, humidity, light intensity, carbon monoxide in smoke and atmospheric pressure as given in [31]. The various threshold values for detection of fire are as given in Table 2. The atmospheric pressure varies with the region of the agricultural land situated from sea level. Temperature, smoke and carbon monoxide are three parameters that help detection of fire with high probability. Hence these three parameters along with

Table 1
Soil Fertility Parameters.

Soil Fertility Parameters	Sensor (manufacturer)	Threshold
Soil Moisture (%)	EC-5 (Decagon)	80%
Soil Temperature (°C)	THERM200 (vegetronix)	42 °C
Soil PH	EC-250 (Stevens water)	6.5
Soil Electric Conductivity (mS/m)	WET-2 (Dynamax)	25 mS/m

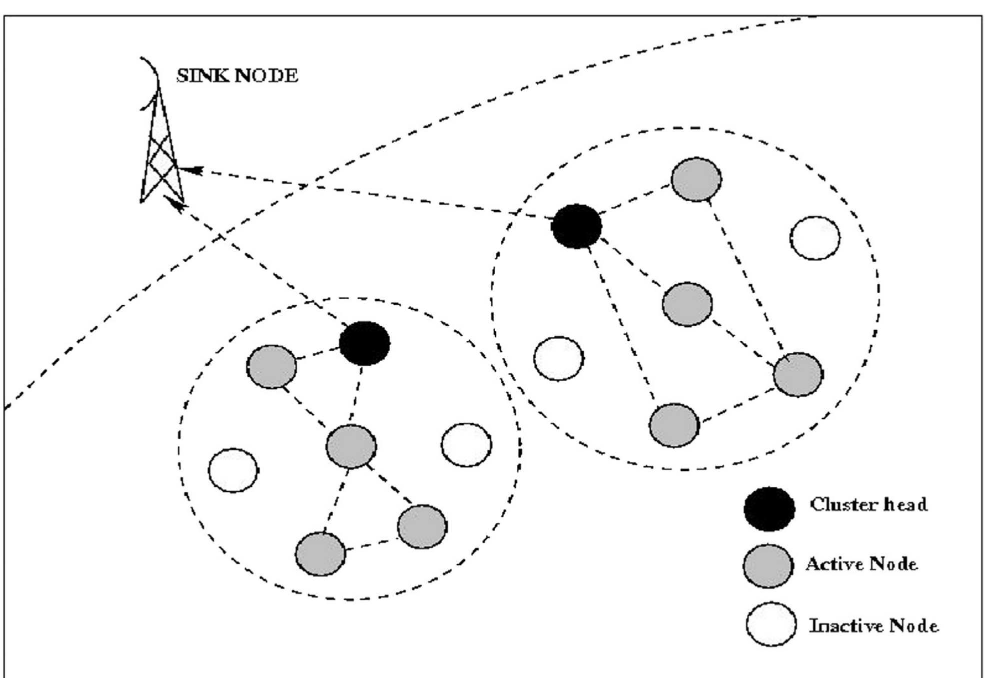

Fig. 1. Network Environment.

Table 2
Fire Detection Parameters.

Fire Detection Parameters	Sensor (manufacturer)	Threshold
Humidity (%)	STDS75 (STM)	50%
Temperature (°C)	HIH-4000-001 (Honeywell)	70 °C
Light Intensity (Lux)	BH1750FVI (DLI)	700 Lux
Carbon Monoxide (ppm)	GGS-200T (UST)	50 ppm
Atmospheric Pressure (mbar)	MS5540B (Interseema)	500 mbar
Smoke (OD/m)	EC01000 (Honeywell)	0.025 ± 0.005 OD/m

their respective threshold values are considered for simulation in this work.

2.2.3. Growth of weeds

Identification of weeds using digital images is discussed in [32]. In the proposed system, some of the useful plant images are stored in the database. If the captured image exceeds the threshold of the stored image then the weeds are detected. The threshold considered in this work is 85 percent.

2.2.4. Disease detection

Some of the diseased plant images are stored in the database. If the captured image exceeds the threshold of the stored image then the diseased plants are detected. The threshold considered in this work is 88 percent.

3. Content-Based image retrieval for plant disease and weed detection

The process of retrieving a set of images from a database storing images by matching similarity is called Image retrieval. The visual contents of the image such as color, shape or features is considered for similarity matching between the images stored in the database and the query image, then such kind of image retrieval is called as content-based image retrieval (CBIR). In the proposed work, to detect plant disease and weeds, CBIR is considered. Useful and healthy plant images are stored in the node knowledge base of the sensor node. The camera-enabled sensor nodes are turned on to sense the agricultural field periodically. The captured image is checked for the similarity of the images stored in the node knowledge base. If the images captured are similar, then the captured image is dropped else the captured image is stored and related message is sent to the sink node.

3.1. Proposed CBIR system

The CBIR system considered for the proposed work has the visual contents of the images in the database that are extracted and described by multi-dimensional feature vectors which are stored in the database related to the relative image. For feature extraction in the proposed system, color and texture features are considered. For color feature extraction color moments, HSV (Hue, Saturation, Value) histogram and auto color correlogram are used. A color moment is a method of image indexing, where the image can be interpreted as mean, standard deviation, skewness, and kurtosis. In this scheme, only mean and standard deviation color moments are considered. HSV histogram provides perception representation according to human visual features. HSV histogram ignores spatial organization of pixels in images, auto correlogram is considered as it describes the correlation of the image color as the function of their spatial distance. For texture feature extraction discrete wavelet transform (DWT) is used. In CBIR, texture feature plays a very important role in computer vision and pattern recognition, especially in describing the content of images. In this work, DWT is applied on a set of texture images that is extracted from approximation and detail coefficients of DWT decomposition. The image is decomposed into four sub-bands and critically sub-sampled by applying DWT. These sub bands which are labelled as low high (LH1), high low (HL1), high high (HH1) represents the finest scale wavelet region (Detailed images), while the sub-band low low (LL1) corresponds to coarse level coefficient (Approximation image). To obtain next level of decomposition, the sub-band LL1 alone is further decomposed and critically sampled which results in two-level wavelet decomposition.

Once the feature extraction is done, those values will be stored in the form of a feature vector. Similarly, features of the captured image will be extracted. Then similarity comparison is done between the captured image and database images. Manhattan distance is considered for similarity matching. Indexing is used to quickly locate data without searching every row in a database table. Then the images are sorted in ascending order according to the similarity distance with the captured image. Then the images with minimum distance are retrieved. The proposed CBIR system uses the statistical metrics precision-recall to validate the retrieval accuracy. Fig. 2 shows the steps involved in CBIR.

3.2. Proposed Algorithm

Nomenclature:

n: Number of images in database, **s**: Stored images in database, **c**: Captured images by sensor nodes, **L**: Length of database, **dv**: Distance Vector, **p**: Precision, **r**: Recall, **fc**: Feature Vector of captured image, **fs**: Feature vector of stored images, **md**: Manhattan Distance, **fv**: Feature Vector

Algorithm 1: Plant disease and Weed detection using Content-based image retrieval

```
Begin
if n ≠ 0 then
for i in 1: L loop
fsi:= feature_vector (si)
end for
while (s)
fc:= feature_vector (c)
for i in 1: L loop
Compute md of fc with fsi
Perform indexing by sorting
Retrieve si having least dv
Compute p and r values
if fc = fsi then
drop c
else
update Node Knowledge Base with c
end if
end for
end while
else
image database does not exist
end if
End
Begin feature_vector
Input image
Compute color histogram of the image
Compute correlogram and color moments value
Compute RGB image to HSV image
Compute wavelet coefficients of the image
Output fv
```

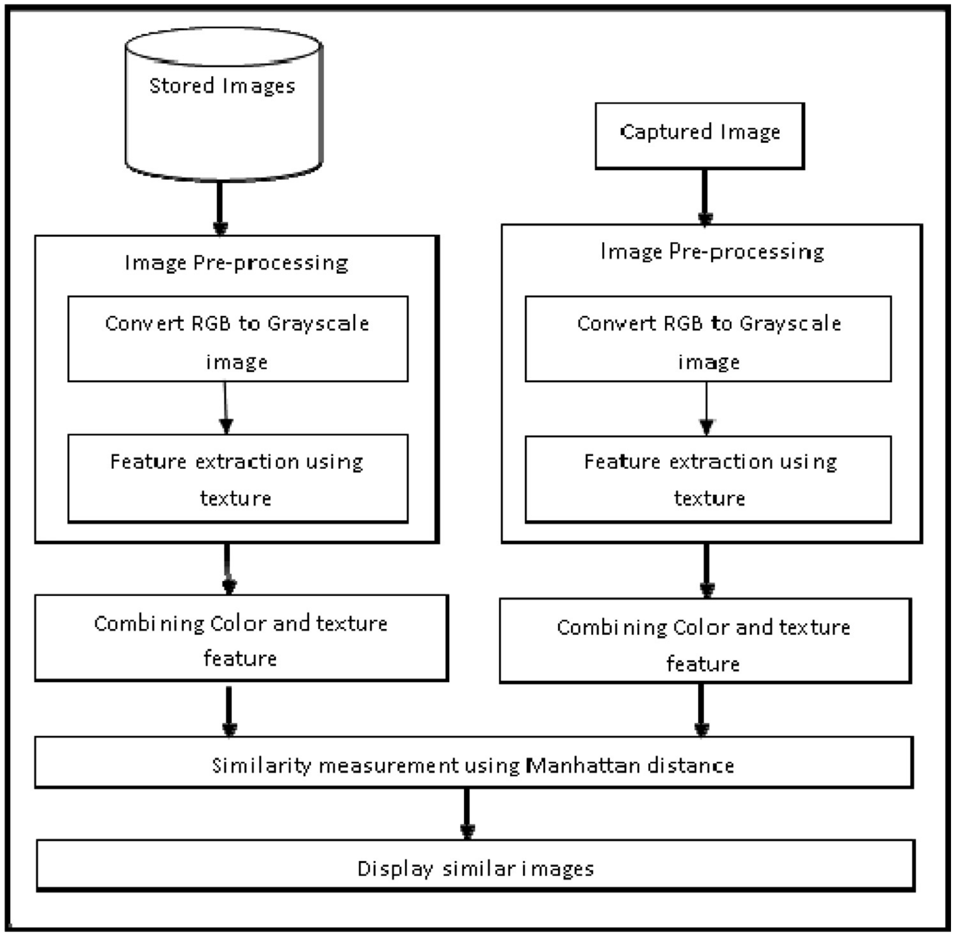

Fig. 2. Flow Diagram of CBIR.

4. Agent technology

WMSN comprises of static sensor nodes and sink nodes (also called as end nodes that require information). A sensor node is said to form a cluster around it based on the communication range. Each cluster will have cluster head node. Sensor nodes are geographically distributed and collect the information at the time of context detection. Every sensor node of WMSN has predetermined value. Once the information is sensed by the sensor node, it compares the information with predetermined value, if it is out of range, a message is sent to its cluster head saying that it is an active node. Sink node is the node, which requires the information from different sensor nodes. Routes to get the information from each of the nodes or a set of nodes are available with sink node, which is supplied by the nearest cluster head node. Each node in WMSN comprises of an agent platform and the proposed agent information transformation model. There are two kinds of agencies proposed in this work, they are sensor node agencies and sink node agencies.

4.1. Sensor node agencies

The sensor node agency consists of agents such as sensor manager agent, sensor knowledge base and pathfinding agent as shown in Fig. 3.

4.1.1. Sensor manager agent (SMA)

It is a static agent that resides in all the sensor nodes of WMSN. It creates pathfinding agent (PFA) and node knowledge base (NKB) and is responsible for synchronizing the actions of the agents within themselves and outside agents too. SMA updates the NKB with sensed information, capture time and signal strength. It compares the sensed value with threshold values residing in NKB and interprets the context. If the context is detected then it computes arbitrary midpoint between the source and destination node and intermediate nodes around the reference axis between the source and the destination node. It also computes hop distance factor. In sleep mode, SMA does not transmit any information to sink. It monitors the battery life; if the battery is exhausting, it sends the information about the status of the battery to the sink node. It sends information of the node such as node id, location information, context, and signal strength information to the sink node, if and only if it has a signal strength above the predefined threshold set by the sink.

4.1.2. Node knowledge base (NKB)

This knowledge base is read and updated by the SMA. NKB comprises of node id, active mode/sleep mode, sensing time, threshold values, input values, bandwidth required to transmit, signal strength and location of the node as shown in Table 3.

4.1.3. Path Finding agent (PFA)

It is a mobile agent which resides in all sensor nodes. If the context is detected then SMA generates PFA and its clone for route discovery. PFA carry information of each node such as node id, residual energy, hop count, bandwidth and hop distance. Then this collected information is sent to the cluster head.

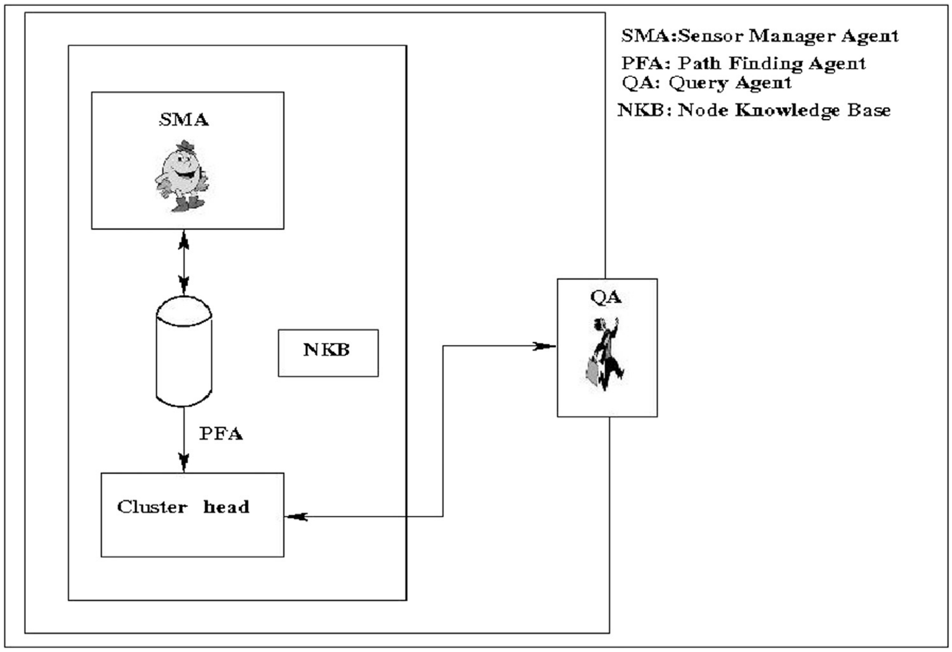

Fig. 3. Sensor Node Agency.

Table 3
Sample data of Node Knowledge Base.

Node ID	Location	Status	Battery in volts	Signal strength in %	Power in milliwatts	Stored images	Captured images	The bandwidth required for Tx in%	Context
4	(3,7)	Active	7.9	75	14.0	st1.jpg st2.jpg st3.jpg st4.jpg st5.jpg	ct.jpg	15	12:15 PM Disease detected

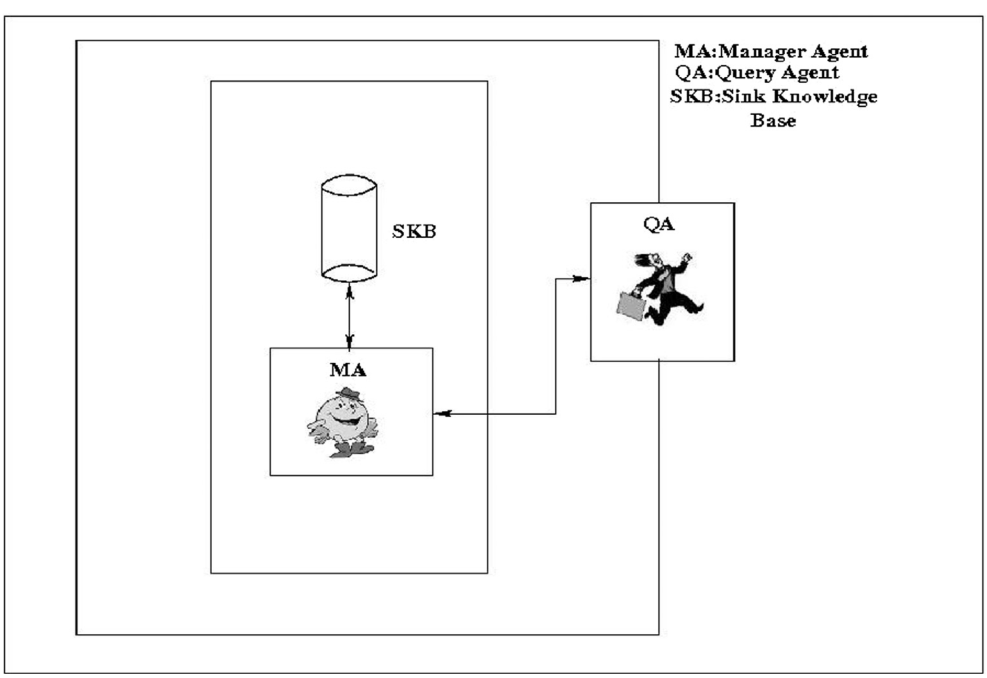

Fig. 4. Sink Node Agency.

4.2. Sink node agency

The sink node agency consists of agents such as manager agent, sensor knowledge base and query agent as shown in Fig. 4.

4.2.1. Manager agent (MA)

This agent resides in the sink node of WMSN and is a static agent. It creates query agent (QA) and sink knowledge base (SKB) and is responsible for synchronizing the actions of the agents within themselves and outside agents. It monitors and updates the SKB when context occurs. MA checks for active sensor node's locations information from the SKB and generates the optimum routes. When the context is detected, the information is given to the user by monitoring the network either by alert alarm or by updating in the user database.

4.2.2. Sink knowledge base (SKB)

It is the knowledge base that can be read and updated by MA. It stores the information about the node id, context information, time of sensing, signal strength, the bandwidth required to transmit the image of each active node, available network bandwidth, and locations of the active nodes as shown in Table 4.

4.2.3. Query agent (QA)

Whenever the query is sent from sink node, the information from all the sensor nodes has to be sent. The sensor nodes are divided into clusters. All the sensor nodes in the cluster send the sensed information to its cluster head. The information from all the cluster heads is fused and sent to sink node. The process of fusion takes place from the farthest cluster. The farthest cluster is decided based on the Euclidian distance.

4.3. Agent Interactions

Sensor nodes are geographically distributed throughout the field and collect the information at the time of context detection. LEACH protocol [23], is used for cluster head selection. Once the cluster head is selected, it advertises the same to all the sensor nodes. Then the sensor nodes decide to which cluster it belongs depending on the signal strength. Agent Interaction sequences of the proposed scheme are presented in Fig. 5.

1. Senor node agent interaction information can be explained as given below:

Table 4
Sample Data of Sink Knowledge Base.

Node ID	Location	Status	Battery in volts	Signal Strength in%	Power in milliwatts	Bandwidth required for Tx in%	Context
3	06,09	Active	8.3	79	3.1	13	10:00 AM Fertile soil
4	03,13	Inactive	–	0	–	–	–
6	05,07	Inactive	–	0	–	–	–
8	10,04	Active	7.9	83	4.5	10	11:20 AM Disease detected
9	05,15	Active	7.5	75	8.5	15	12:15 PM Fire not detected
10	12,01	Inactive	–	0	–	–	–
12	02,08	Active	8.0	80	7.0	18	2:00 PM Non-fertile soil

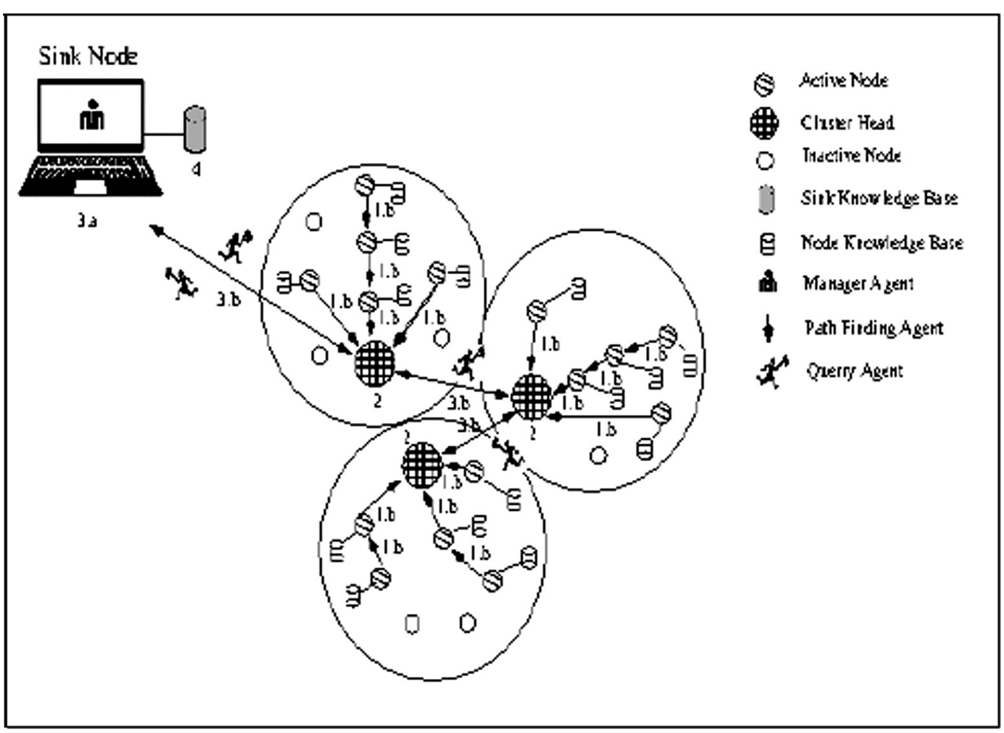

Fig. 5. Agent Interactions.

   a. Sensor node senses the information and updates it in the NKB whenever the context is detected.
   b. SMA sends the status as active to its cluster heads.
2. SMA generates PFA and its clone for route discovery and sends the sensed information to the cluster head. All the information from all the sensor nodes is stored in the cluster head.
3. Sink node agent interaction information can be explained as given below:
   a. The MA generates the QA and provides the routing information.
   b. The QA reaches the farthest cluster head and collects the information. The farthest cluster is decided based on Euclidian distance. The QA reaches next nearest cluster and collects the information from cluster head. Likewise, QA collects and fuses the information from all sensor nodes and reaches the sink node.
4. Then MA of sink node updates SKB and provides the information of all the sensor nodes to the user. If required, MA takes necessary action by turning on/off the sprinkler or motor.

4.4. Proposed algorithms

Nomenclature:

n: number of nodes, **i**: sensed information of sensor nodes, $\mathbf{i_{th}}$: threshold values, $\mathbf{n_{active}}$: active node, $\mathbf{n_{inactive}}$: inactive node, **SMA**: Sensor Manager Agent, **PFA**: Path Finding Agent, **MA**: Sink node Manager Agent, **QA**: Querry Agent, **CH**: Cluster Head

Algorithm 2: Agent Interactions

Begin
for i **in** 1: n **loop**
SMA checks for n_{active}
if $n = n_{active}$ **then**
SMA updates NKB with i
if $i \geq i_{th}$ **then**
SMA generates PFA and sends it to respective CH
MA generates QA which aggregates and collects i from every CH
else
drop i
end if
else
$n = n_{inactive}$
end if
end for
End

Nomenclature:

i: Information from various sensor nodes, $\mathbf{i_{th}}$: Threshold values, $\mathbf{i_{1th}}$: Healthy plant images stored in database, $\mathbf{i_{2th}}$: Images of useful plants stored in database, $\mathbf{i_{3th}}$: Soil moisture, $\mathbf{i_{3thmax}}$: Maximum threshold of soil moisture which is 100%, $\mathbf{i_{4th}}$: Soil temperature, $\mathbf{i_{5th}}$: Temperature of the field, $\mathbf{i_{6th}}$: Carbon monoxide level, $\mathbf{i_1}$, $\mathbf{i_2}$: Camera Sensors, $\mathbf{i_3}$, $\mathbf{i_4}$: Soil fertility sensors (soil moisture and soil temperature respectively), $\mathbf{i_5}$, $\mathbf{i_6}$: Fire detection sensors (Temperature and Carbon Monoxide respectively)

Algorithm 3: Context Detection

Begin
While (i)
if $i = i_1$ **then** goto Disease_detection
else if $i = i_2$ **then** goto Growth_weeds
else if $i = i_3$ **or** $i = i_4$ **then** goto Soil_fertility
else if $i = i_5$ **or** $i = i_6$ **then** goto Fire_detection
else goto End
end if
end while
End
Begin Disease_detection
if $i_1 = i_{1th}$ **then**
drop i_1
else
update NKB
end if
End Disease_detection
Begin Growth _weeds
if $i_2 = i_{2th}$ **then**
drop i_2
else
update NKB
end if
End Growth_weeds
Begin Soil_fertility
while ($i_3 \leq i_{3thmax}$)
if $i_3 < i_{3th}$ **and** $i_4 \geq i_{4th}$ **then**
update the NKB
MA turns on the motor
else if $i_3 < i_{3th}$ **then**
MA turns on the motor
else
drop i_3, i_4
end if
end while
End Soil_fertility
Begin Fire_detection
if $i_6 \geq i_{6th}$ **and** $i_7 \geq i_{7th}$ **then**
update the NKB
MA triggers the alarm and turns on the sprinkler
else
drop i_6, i_7
end if
End Fire_detection

5. Simulation model and performance parameter

The simulation of the proposed model is done using the NS2 platform. We discuss a generalized simulation model, simulation procedure and some of the performance parameters.

5.1. Simulation model

In the simulation model, we consider "N" number of nodes in the area of length "L" and breadth "B". A network consists of N static nodes that are randomly placed within a given area. We find

Table 5
Simulation Inputs.

Parameter	Notation	Value
Length	L	5000 m
Breadth	B	5000 m
Number of nodes	N	1–80
Transmission range	Rx	300 m–500 m
Varying Image Sizes	px	32 × 32, 64 × 64, 128 × 128, 256 × 256 (8, 12, 16, 24) bits/pixel
Bandwidth	Bw	4 Mbps

some static and mobile agents between sensor nodes and sink node.

The transmission of packets is assumed to occur in discrete time. A node receives all packets heading to it during receiving interval unless the sender node is in a non-active state. For simplicity, we have considered the channel to be error free. Table 5 shows the various simulation inputs considered.

5.2. Simulation procedure

Simulation procedure involves following steps:

1. Generate sensor network environment.
2. Sensor node sends the context information to sink node.
3. Apply the proposed scheme.
4. Compute performance parameters of the system.

5.3. Performance parameters

Some of the performances considered to evaluate the proposed scheme are as follows:

- **Delay:** It is the time taken to send the sensed information from the sensor node to the sink node. It is expressed in terms of milliseconds.
- **Cluster head selection time:** It is the time taken to form the clusters and select the cluster head based on the energy. It is expressed in terms of milliseconds.
- **Context detection time:** It is the time required to sense the information and detect the context. It is expressed in terms of milliseconds.
- **Energy consumption:** It is the total energy required to transmit the data from sensor nodes to the sink node. It is expressed in terms of millijoules.
- **Fusion time:** It is the time taken to fuse the information from all the sensor nodes and transmit to the sink node. It is expressed in terms of milliseconds.
- **Correlation:** It is the mutual connection between two sensor nodes. For multimedia data, correlation can also be considered as similarity measurement between two frames.

6. Results

This section consists of various simulation results of this work such as cluster head selection time, delay, context detection time, energy consumption, fusion time and so on.

6.1. Delay based on communication range and number of nodes deployed

As the number of nodes increases, there is a gradual increase in the delay of each sensor nodes. As the communication range and the number of nodes increases, there is a gradual increase in the delay as shown in Fig. 6.

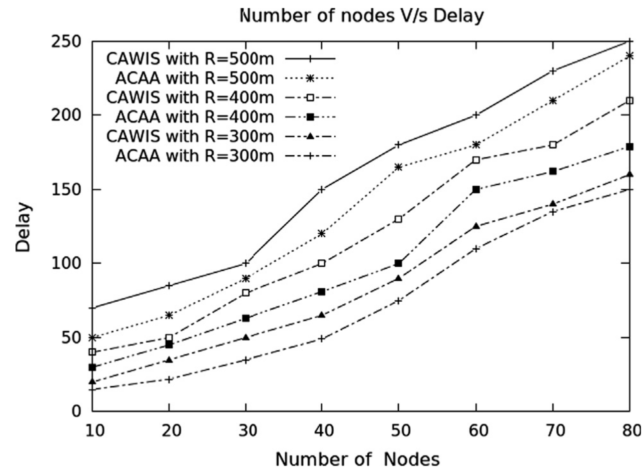

Fig. 6. Number of Transmitting Nodes vs. Delay in milliseconds.

6.2. Cluster head selection time based on the communication range

As the number of nodes increases, the time taken to form clusters is more, as shown in Fig. 7. Hence the time taken to select the cluster head is also more. As the communication range increases the number of sensor nodes increases hence the time taken to select cluster head is more.

6.3. Context detection time based on the communication range

As the number of sensor node increases, the time taken for context detection also increases. From the Fig. 8, it can be understood that, as the communication range increases the time taken for context detection will be more.

6.4. Energy consumption based on communication range and number of nodes

As the number of sensor nodes increases, the energy required to transmit the information from sensor nodes to sink node will be more. Hence the energy consumption will be more as the number of nodes is involved in the communication. As the communication range increases the distance between sensor nodes and sink node increases hence the energy consumption is more. Fig. 9 shows the energy consumption for different transmission ranges.

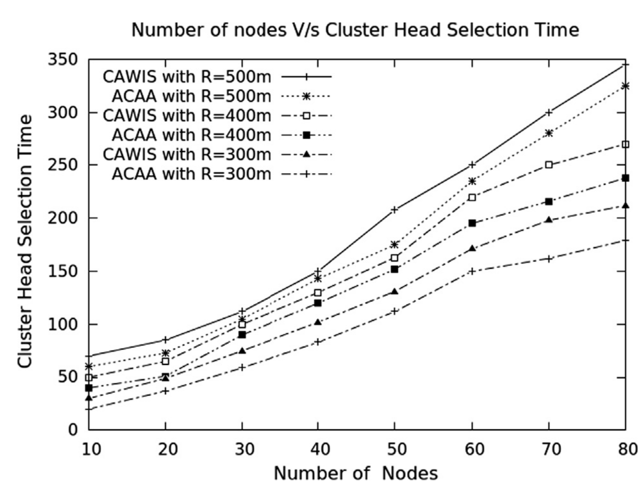

Fig. 7. Number of Transmitting Nodes vs. Cluster Head Selection Time in milliseconds.

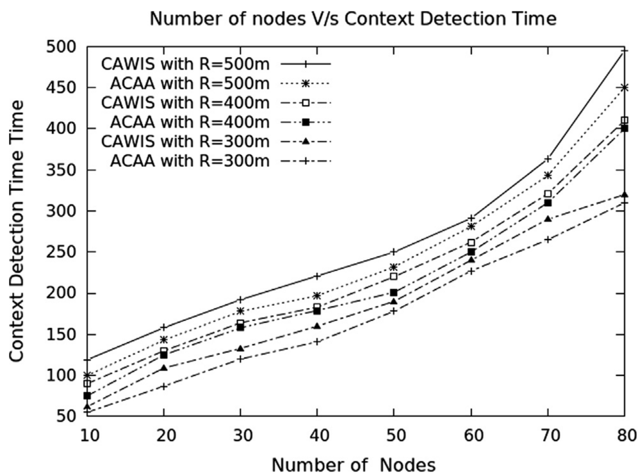

Fig. 8. Number of Transmitting Nodes vs. Context Detection Time in milliseconds.

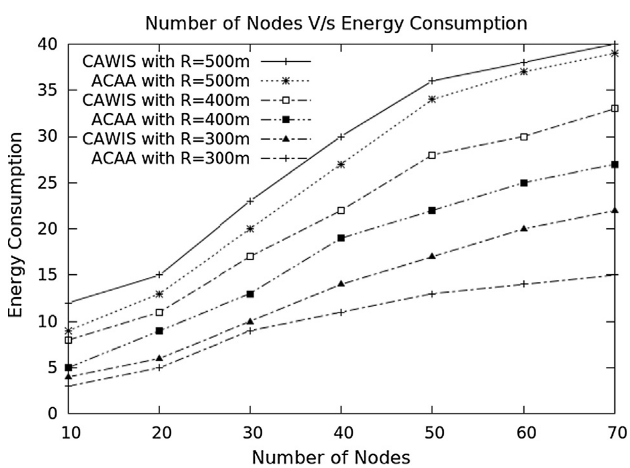

Fig. 9. Number of Transmitting Nodes vs. Energy Consumption in millijoules.

6.5. Fusion time based on communication range and number of nodes

As the number of nodes increases the information sensed in each sensor nodes will be more. All the sensed information after comparing has to be fused and sent to sink node. Also as the communication range increases the time required for fusion will be more. Fig. 10 shows the time taken for fusion of information based on communication range and number of nodes.

6.6. Correlation based on sensing range and number of nodes

Correlation is the mutual connection between two sensor nodes. As the number of nodes increases the correlation between nodes also increases. In Fig. 11, the communication range is considered to be 300 m. As the sensing range and the number of nodes deployed in the communication range increases, the correlation among nodes increases.

6.7. Context detection time based on context

As the number of nodes increases the time required for context detection will be more. Context such as fertility of the soil and fire detection require less time when compared to disease detection and weeds detection. Images are transmitted for disease and weeds detection, hence the time required for disease detection and weeds detection will be more as shown in Fig. 12.

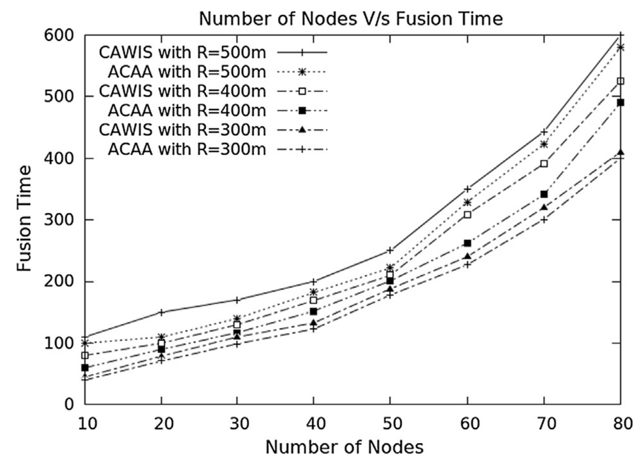

Fig. 10. Number of Transmitting Nodes vs. Fusion Time in milliseconds.

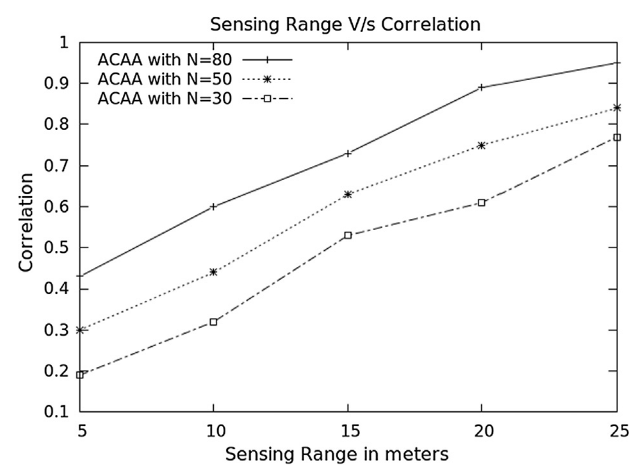

Fig. 11. Sensing Range vs. Correlation.

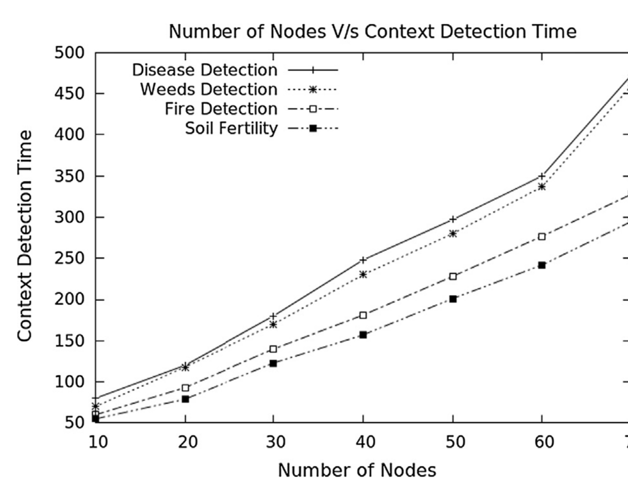

Fig. 12. Number of Transmitting Nodes vs. Context Detection Time in milliseconds.

6.8. Energy consumption based on context

As the number of nodes increases the energy required for context detection will be more. Context such as fertility of the soil and fire detection require less energy compared to disease detection and weeds detection as represented in Fig. 13. As images are trans-

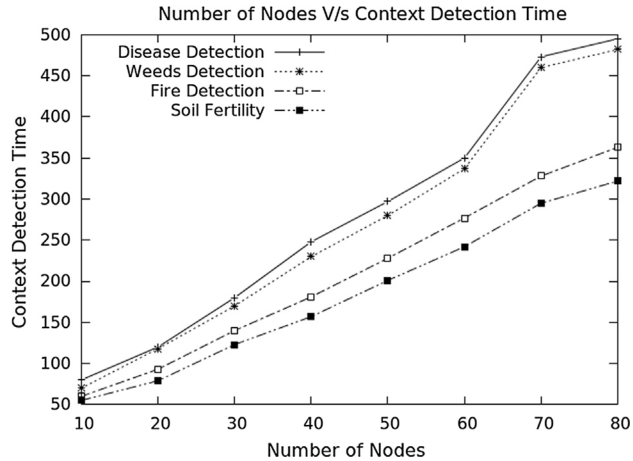

Fig. 13. Number of Transmitting Nodes vs. Context Aware Energy Consumption in millijoules.

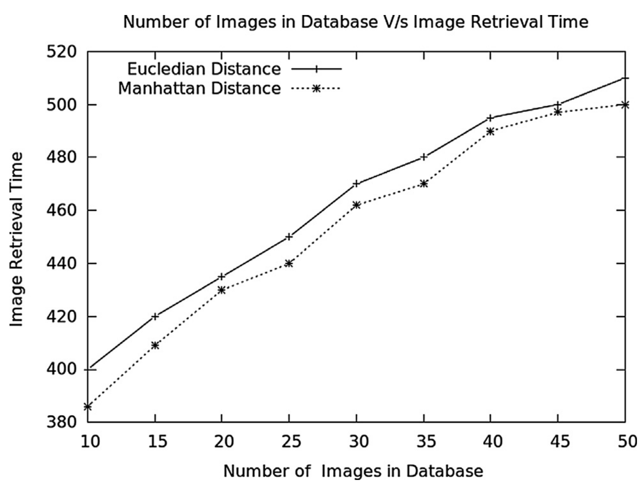

Fig. 14. Number of Images in Database vs. Image Retrieval Time in milli seconds.

mitted for disease and weeds detection, the energy consumed for disease detection and weeds detection is more.

6.9. Image retrieval time in CBIR

The image retrieval time for similarity measurement using Manhattan distance and Euclidean distance is plotted in Fig. 14. According to the results, Manhattan distance has better retrieval time and hence it is considered in the proposed work. As the number of images in database increases, the image retrieval time also increases gradually.

7. Conclusion

A multi-agent based context-aware information gathering for monitoring agriculture using WMSN is proposed in this article. The sensor node senses the data and updates the knowledge base. Sensor node comprises of an agent platform with static and mobile agents, camera and other sensory devices such as soil pH, moisture, temperature, smoke, etc. The sensor node forms a cluster on its own based on the communication range. Once the information is sensed by the sensor node, it compares the information with the threshold value; if it is not in range, a message is sent to sink node via cluster head using the multi-hop technique. Information from different active nodes is fused and sent to the sink node using mobile agents. The end user can access the reliable information at the sink node whenever required. As compared to CAWIS, the proposed agent-based context-aware system for agriculture (ACAA) to gather information using WMSN, performed better in terms of context detection time, delay, fusion time and energy consumption. The work can be extended by considering video sensors for intrusion detection along with the other sensing parameters considered in this work. For bigger crop fields the work can be extended by incorporating multiple sink nodes to perform better.

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