Optimized Energy-Aware Algorithm for Collaboration in Visual Sensor Networks

[1]Harish.H.Kenchannavar, [2]Umakant.P.Kulkarni

[1]Department of Computer Science & Engineering,
Gogte Institute of Technology, Belgaum

[2]Department of Computer Science & Engineering,
SDM College of Engineering and
Technology, Dharwad

Abstract

Network lifetime is one of the critical performance parameters in Visual Sensor Networks. In order to avoid transmission of redundant information to the base station, it becomes necessary to select among the nodes in the neighboring region having the same area of coverage for data transfer. This work presents an efficient approach aimed at reducing the extra amount of information to the controlling station. The proposed algorithm is based on the concept of image overlapping and energy conservation technique which increases the network lifetime.

Key words: *visual sensor network, overlapping based energy aware, horizontal collaboration, network lifetime, redundant*

1. Introduction

In wireless sensor networks, a sensor node comprises of sensing computing, communication, actuation and power components. A typical WSN incorporates around tens to thousands of such nodes, which share information and perform tasks in a co-operative manner using the wireless medium. Wireless sensor networks can be utilized at a global level for monitoring the environment and habitat study, in the battle field for military surveillance and scrutinizing the battle field for useful military information, for search and rescue operations during natural calamities and mishaps, for maintenance in industries, for infrastructure health monitoring, to realize smart homes and in human bodies for monitoring the patient's health conditions. In WSNs, the sensor nodes have the self – organizing ability that allows them to get arranged in an appropriate network infrastructure which results in ad-hoc nature of WSNs. Also the WSNs behave as a distributed database networks where users can retrieve information from a WSN by sending queries to and retrieving information from the base stations.Recent progress in imaging technologies, prove that the design of small low power and low cost image/video capturing devices is achievable in near future.

For most of the above listed applications, the QoS plays a major role while designing the sensor networks responsible for delivering the multimedia content for critical applications such as health monitoring, military surveillance etc. Research carried out in the field of sensor networks concentrates on curtailing the energy consumed by the sensor nodes for processing, problems associated with preserving the coverage area etc. The primary goal in the coverage optimization algorithm is to retain the coverage area when a sensor node fails and hence conserve the energy by making a sensor node active and the other nodes in the neighboring area having same field of view to go into the sleep mode. This feature helps to prolong the lifetime of the network [4]. Remaining part of this paper contains the following sections. Related work is presented in Section 2. Section 3 describes the network model and problem definition. Section 4 and Section 5 discuss the flowchart for the novel approach and the simulation setup. Section 6 presents the result analysis.

2. Related Work

Research carried out in the field of cluster–based WSN is massive focusing on the issues of energy efficiency and scalability related to clustering protocols. In statistical techniques, for selecting the cluster head [5, 6], all the sensor nodes in the network share equally the role of cluster head which adds to the life span of the sensor node. HEED Clustering algorithm [7] implements a hybrid model to select the cluster head based on the residual energy of the node and the node's proximity to its neighbors- an additional parameter involved the selection process. The issues related to the power of balanced energy consumption among the cluster head nodes has been discussed in [8, 9]. The ACE clustering algorithm [10] partitions a network into uniformly dispersed clusters. Another clustering technique known as autonomous clustering makes use of coverage estimation parameter which is presented in [11].

One of the basic problems faced in sensor network is the network coverage, as it critically affects the performance of the network sensing task. Therefore in recent years, strong research is being done on the coverage aspect in the sensor management area [12, 13]. A scheduling scheme for activating the sensor nodes depending on the data collected from the nodes in the neighboring region without compromising on the coverage area has been proposed by the authors in [14]. Authors Wu and Chen in their work [15] have suggested a collaborative processing technique which exploits the spatial correlation among the different images captured by the adjacent cameras in the neighborhood. Applications of fundamentals of projective geometry for detection and tracking have been proposed by the authors in [17, 18, 19] and include the discussion on image mapping technique using the sample Euclidean co-ordinate transformation.

3. Network Model and Problem Description

Let a multi-hop wireless VSN be represented by a graph G, in which set N consists of visual sensor nodes given by N= $\{n_1, n_2, n_3 \ldots n_k\}$ situated at random positions within the specified network boundary. The network area can be bifurcated into various regions, represented by the set R= $\{R_1, R_2, R_3 \ldots R_m\}$ where regions $R_1, R_2, R_3 \ldots R_m$ comprise of a group of visual sensor nodes covering the region.

Each sensor node in the VSN is defined by its sensing area and the energy component specified by N_{si} and N_{ei} respectively. Let N_{s1}, N_{s2}, $N_{s3} \ldots N_{si}$ specify the node sensing areas, $N_{e1}, N_{e2}, N_{e3} \ldots N_{ei}$ present the energy levels and $N_{I1}, N_{I2}, \ldots\ldots N_{Ii}$ denote the images captured at all the nodes respectively. Thus a node N_i in the VSN network be characterized by (N_{si}, N_{ei}, N_{Ii}).

This work focuses on node collaboration where the coverage area is overlapped among a group of sensor nodes in the surrounding area and only one node from the cluster is activated for transmitting the captured image to the controlling station. The other nodes go into standby/sleep mode- which is a low power energy state thus preserving its energy which increases the network lifespan. Decision as to which nodes will be activated for transmission is based on the overlapping data provided by the sensor nodes in the specified region. This paper presents an analysis carried out using the 2 approaches which affect network lifetime.

3.1 Without using overlapping information from the sensor nodes

This case considers that all the nodes in the network are active at any given instance. As stated, every sensor node n_i in the network has the energy component associated with it denoted by E_i , where i= 1, 2, 3…n

Total energy at all nodes is given by

$$E_{total} = E_1+E_2+E_3\ldots E_n=\sum^{n}_{i=0}E_i \qquad (1)$$

where, every node has up to E_{max} threshold energy.

Considering the scenario where all the sensor nodes in the network are in active mode, the total energy dissipated in the network by all the nodes after time 't' secs is given by equation (1).

Energy dissipated at each node = E_{total}/n Joules/sec – (2)

where n = number of sensor nodes

Since all the nodes are active simultaneously and each node dissipates a quantum of energy after processing all the energy in the nodes gets exhausted after a time interval of 't' secs. Therefore the network life time can be calculated to be 't'secs as shown in Figure 2(a).

3.2 Issue of Data Redundancy and Energy Conservation

In a sensor network, sensor nodes are closely placed to each other for a given application. This leads to data duplication (i.e. sensors capturing and sending the same information since they have same field of view) at the computing center which results in more energy dissipation at the nodes. The approach presented here mainly addresses the data redundancy and energy preservation aspects in the visual sensor networks which affect the lifetime of the network.

3.3 Activating the nodes based on overlapping scheme

This case considers the situation where the sensor nodes in the network have the same field of view for capturing the image information. Then based on the amount of overlapping, the sensor nodes forming the cluster in the region are selected and made active for image transmission to the base station. This approach helps in conservation of energy dissipated by the nodes and increases the network lifetime.

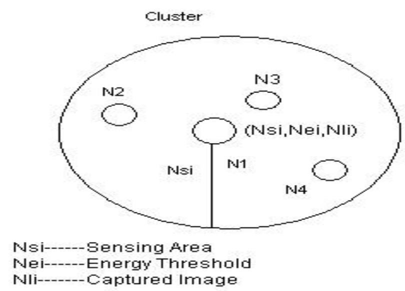

Figure 1. Cluster Formation

Cluster formation in the network occurs based on the fact that sensor nodes n_i and n_j have the same sensing area such that the distance D_{ij} between the nodes n_i and n_j should be less than the sensing area of node n_i given by N_{si} , as shown in Figure 1.

3.3.1 Calculation of Overlapping Factor

Consider a digital image f be represented by a 2 dimensional array of M x N pixels represented by {0,1,2,…..M-1} x {0,1,2,……N-1} having gray levels mentioned in the set {0,1,2…….L-1}. Let X = {X_i / i=1, 2, 3 …N} denote the reference image and Y= {Y_i/ i=1, 2, 3 …N} denote the captured image by the sensor nodes.

In VSN networks, the sensor nodes capturing the images are located at very short distances from each other. Hence the image magnifications and view points with respect to images taken from the neighboring sensor nodes are assumed to be similar. From the work presented in [15], it is considered that the overlapping content among the captured pictures can be carried out geometrically and also the energy information present in the overlapping portions is less in comparison to the other tasks in the sensor network.

3.3.2 Node Selection and Activation

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Consider the nodes $\{N_1, N_2, N_3 \ldots\ldots\ldots. N_n\}$ forming the cluster C_i in the VSN. A sensor node N_i from the cluster characterized by the following properties N_{si}, N_{ei} and N_{Ii} overrides another sensor node N_j with characteristics N_{sj}, N_{ej}, N_{Ij}, iff the following conditions are fulfilled. **Condition 1**: The Overlapping factor of the Image calculated should be greater for node N_i than for node N_j.

Condition 2: Energy at node N_i is greater than node N_j.

Employing the image overlapping technique to the nodes in the cluster, the network lifetime can be calculated as follows:

Best Case:

For a VSN consisting of n nodes } n/2 nodes are activated for transmission. n/2 nodes are in low power/standby mode.

At clock interval 1 unit, energy at the nodes reduces by amount E_i energy

At clock interval 2 units, energy at the nodes reduces by amount E_{i+1} energy

At clock interval t1 units, energy at the nodes reduces by amount $| E|/n \text{ X } n/2$ active nodes = $| E|/ 2$ energy units.

At clock interval t2 units, energy at the nodes reduces by |E|. Total life time of visual sensor network can be given by energy at intervals 1…t1 and t1…t2.

$$= | E|/2 + | E|/2 \qquad (3)$$

$= | E|$Same energy is utilized for two intervals 1…t1 and t1…t2 as shown in Figure 2(b).

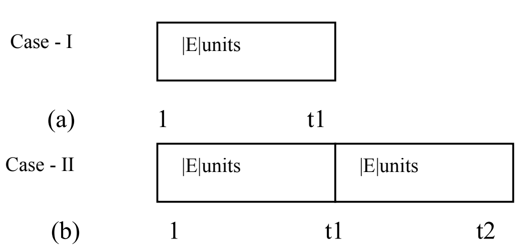


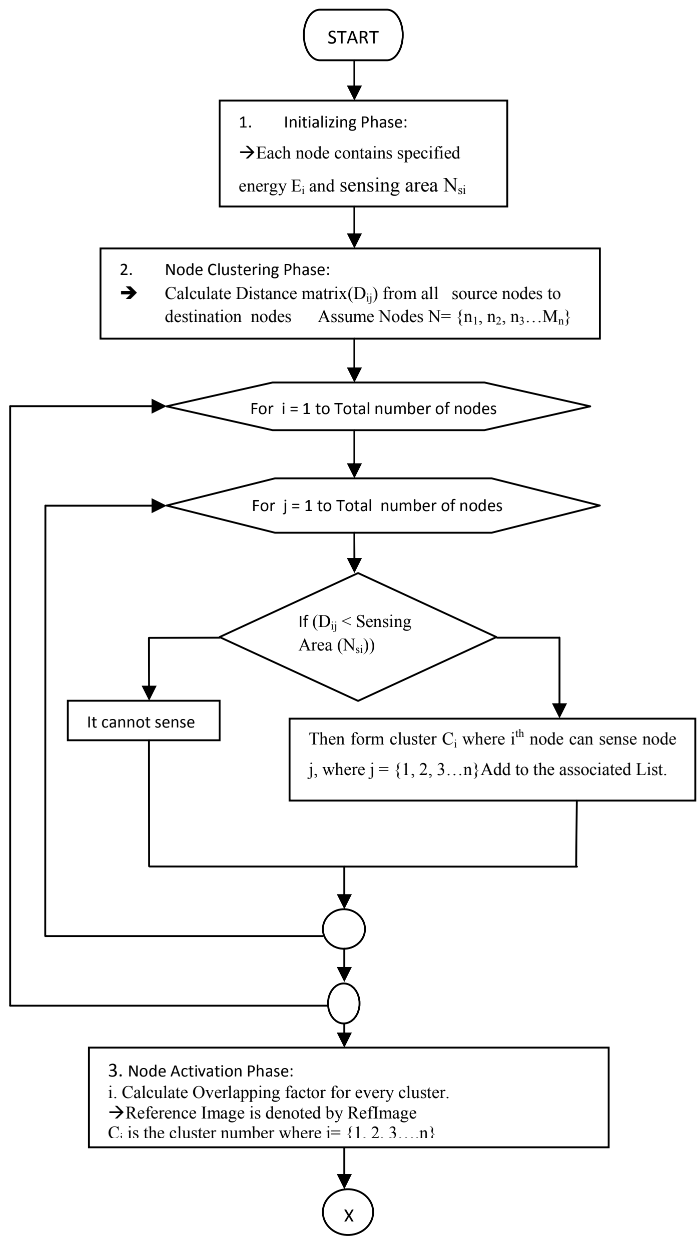
Figure 2 . Time Slot Diagram

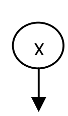
4. Flowchart and System Model

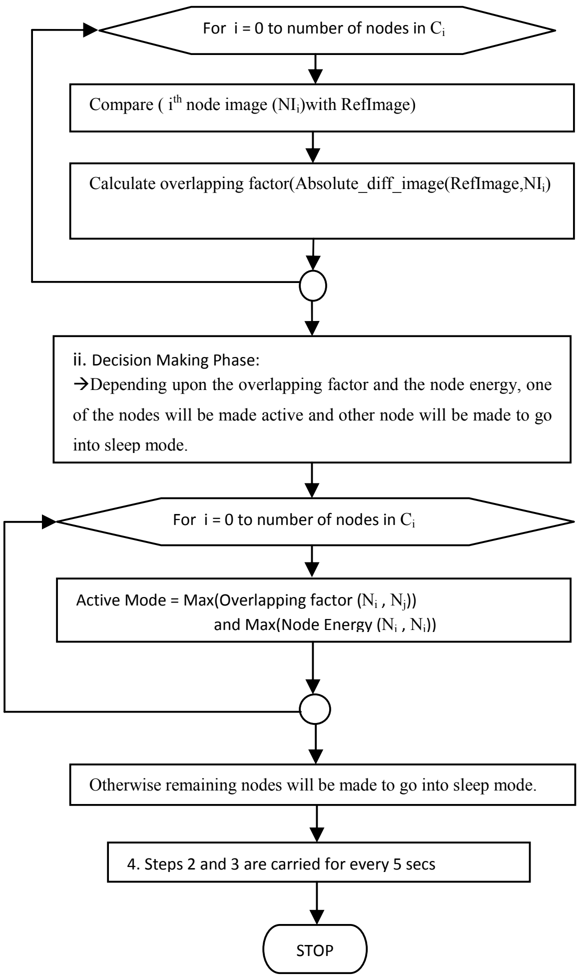
The sensor network lifetime can be increased by forming the sensor node clusters, based on quality metrics (Energy, distance and Overlapping factor) that is applied to spatially close visual sensor nodes in order to find correlation between the images to get rid of information redundancy that exists between the nodes.

4.1 Flowchart Using Overlapping Based Energy-Aware Technique

Consider in a visual sensor network,







4.2. ADVANTAGES:

1. Redundant information capturing and transmission of image can be avoided which helps in saving energy.
2. It increases the life time of the network.

4.3. LIMITATIONS:

1. Some amount of energy is dissipated while calculating the overlapping factor between the images from the nodes.
2. There is a small overhead of image transmission along with NodeID.

Following are the information formats used in the visual sensor network:

Packet format used for image transmission to the co-ordinator

NodeID	Image	Energythreshold	Timestamp

Packet format used to instruct the node to be active or to sleep

NodeID	Control Signal Active/Sleep

5. Simulation Set-Up

In this section, we discuss the set-up for VB .Net simulations performed with Image overlapping based energy aware approach and without overlapping of image.

5.1 Network Scenarios

We carried out simulations with 100 visual sensor nodes deployed over an area of size 640 X 480 pixels**,** which is programmed using VB .net. The nodes are deployed either randomly or non-uniformly in the network using a graphical interface as shown in figure 3. In case of the random deployment, the (x, y) locations of sensor nodes in the network are randomly chosen. The non-uniform deployment corresponds to the case where user manually places nodes within a certain area of network.

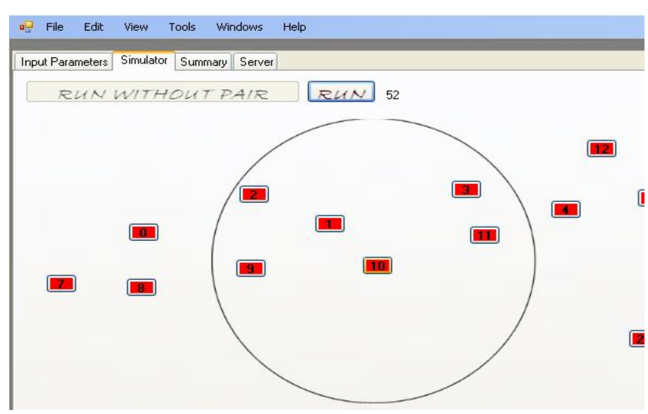


Figure 3. GUI For Visual Sensor Arrangement In The Network

Parameters	Value
Tx/Rx electronics Constant	50 nJ/bit
Amplifier Constant	10pJ/bit/m^2
Path Loss Exponent	2
Energy Threshold	10^{-4} J
Packet Size	30 bytes
Packet Rate	1 Packet/Sec
Sensing Range	15mts
Cluster Range	30mts

Table 1. Simulation Parameters

The input parameters considered for simulation is as given in Table 1.

5.2 Energy Model

We have used the free-space energy model defined in [13], where the energy required to transmit a *p*-bit packet is equal to

$$E_{tx} = p.(E_{amp} + \varepsilon_{fs} .d^n) \quad (4)$$

The energy required to receive a *p*-bit packet is

$$E_{rx}= p.E_{amp} \quad (5)$$

The parameters E_{amp} and ε_{fs} are the parameters of the transmission / reception circuitry and n is the path-loss exponent as listed in Table 1.

6. Result Analysis

Here, we have compared performance parameters such as network life time, number of dead nodes, active nodes and sleep nodes in the analysis.

6.1. Comparison of Network Life Time

Overlapping based energy aware algorithm is compared with normal simulation without overlapping and it is observed that network lifetime approximately doubles in case of overlapping based energy aware approach as seen from figure 4. Figure 5 and figure 6 show the comparative analysis of as to at what instance of time the sensor nodes become dead in both cases - with overlapping based energy aware algorithm and without overlapping.

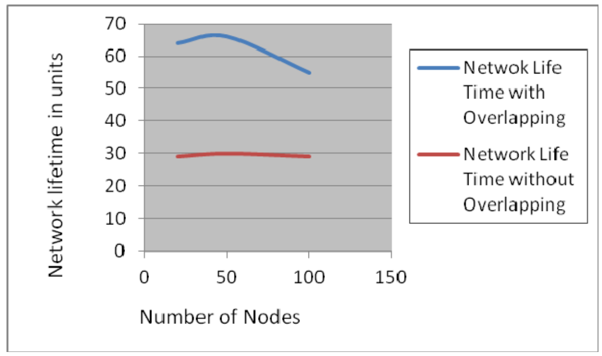


Figure 4. Comparison of Network Life Time (Overlapping Based Energy Aware Algorithm Vs Without Overlapping)

6.2 Analysis of Dead Nodes

Consider different sets of total number of nodes such as 20, 30, 60 and 100 present within the visual sensor network. For these sets the observation is made as to when the sensor node loses its energy and the time interval at which the sensor node becomes a dead node. From figure 8, in case of without overlapping, it is seen for total of 20 nodes in the network, at approximately 27 units of time, 4 nodes become dead and gradually all the sensor nodes go dead at 29th time unit, i.e. the network life ends at 29 time units. From figure 7, in case of overlapping based energy aware algorithm, for total of 20 nodes in the network, approximately at 27 units of time none of the nodes dissipate their energy. The situation starts changing approximately from the 30th time units where dead nodes begin to occur and gradually increase in number. And finally at 50th time units all the nodes in the network are dead, i.e. life time of sensor network is 50 units of time, which is nearly double the value as compared to without overlapping.

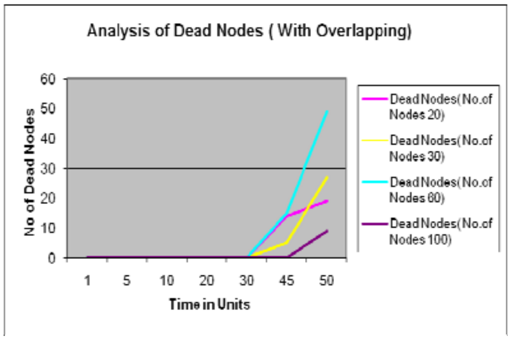


Figure 5. Shows The Analysis Of When The Sensor Nodes Will Become Dead Using Overlapping Based Energy Aware Approach For Different Sets Of VSNNodes.

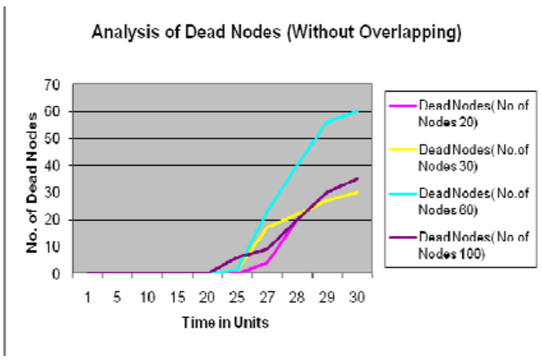


Figure6. Analysis Of When VSN Nodes Will Become Dead.

6.3 Analysis of Active Nodes

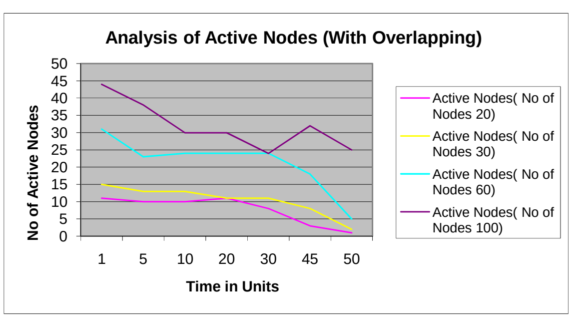


Figure 7. Analysis of Active Nodes with Overlapping

Figure 7 gives the analysis of the number of active nodes in case with overlapping. In case of overlapping based energy aware algorithm the number of active nodes is almost half the total nodes while the other half are in sleep mode at the initial stage and then gradually decrease in number as the time progresses due to the overlapping concept thus increasing the lifetime of the network to almost double the value achieved for without overlapping case. For example consider the total sets of nodes as 100 within the network. At time unit 1, the number of active nodes is nearly 40, which drops down to 35 at 5 time units. At 7^{th} time unit the active node number drops to 30 and remains constant at this value from this time unit till 17 time units and then at 20^{th} time unit the number of active nodes decreases to 27 and then finally at 50^{th} time unit the number of active nodes is 25. Similar observations can be made for other sets of total nodes as shown in figure 9. In this case it is seen that the lifetime of the network is 50 time units for all the sets of total nodes which shows an increase in network life time.

6.4. Analysis of Sleep Nodes

Figure 8 gives the analysis of sleep nodes in case of overlapping based energy aware algorithm. Consider the scenario when there are 100 total nodes in the network. Observe from the graph at 1 time unit the number of sleep nodes is 56 i.e. the rest 44 nodes are active and are engaged in image capturing. At time unit 10 the number of sleep nodes is 70 and the remaining 30 nodes are active. And finally at 50^{th} time unit the number of sleep nodes is 46.

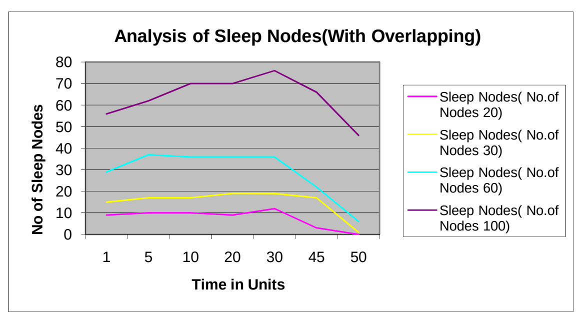


Figure 8. Analysis of Sleep Nodes

7. CONCLUSION

We propose algorithm with overlapping based energy aware concept for selection of visual sensor node from cluster whose aim is to increase network life time. This can be done based on calculating overlapping factor of image between visual sensor node within their sensing area and node energy. Thus the sensor nodes with maximum overlapping factor and energy in the network are made active and other nodes are made to go into sleep mode. Using this approach, simulations and analysis carried out show increase in the network life time and reduction in data redundancy when compared with non-overlapping based energy aware technique.

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Asst. Prof. Harish H. Kenchannavar received his Masters degree (M.E) from Shivaji University, Walchand College of Engineering & Tech, Sangli, Maharashtra. He has registered for Phd degree under Visvesvaraya Technological University, Belgaum. Research Center:- SDMCET, Dharwad, Karnataka under the guidance of Prof. Umakant P. Kulkarni. He is currently working as Assistant Professor in Computer Science Department, Gogte Institute of Technology, Belgaum, Karnataka. He has presented and published papers at national and IEEE International conferences. His research interests include computer networking, simulation and modeling, visual sensor networks and queuing algorithms.

Prof. Umakant P. Kulkarni received his PhD degree from Shivaji University, Kolhapur. Research Center Walchand College of Engineering & Tech, Sangli, Maharashtra in Nov 2007 . He has completed his Masters degree (M.E) from PSG, Coimbatore. He is currently working as Professor in Computer Science Department, SDMCET, Dharwad, Karnataka. He has published and presented a number of papers in many reputed journals and at International IEEE conferences as well. This apart he also has presented technical talks and tutorials on various aspects of Mobile Agents. His research interests include mobile agents, computer networking, and distributed networking.