Intelligent Software Agent based Image Fusion in Wireless Multimedia Sensor Network

Prof.Dr.P.K.Srimani,
Former Chairman, Dept. of Computer Science and Mathematics, Bangalore University,
Bengaluru, Karnataka, India
Email: profsrimanipk@gmail.com
Bhanu K. N.
Dept. of MCA, Rajarajeswari College of Engineering, Bengaluru, Karnataka, India
Email: bhanu.kn@gmail.com

---ABSTRACT---

Wireless Multimedia sensor networks (WMSNs) can be used in monitoring disaster management, military operations, agriculture, building structures, etc. Multi sensor image fusion has been of great interest and challenge in WMSNs. This paper proposes an Intelligent agent based context aware image fusion scheme for Wireless Multimedia Sensor Networks . The proposed scheme operates as follows: Every sensor node and sink node deployed is running with agent platform. Sensor node agency resides in each of the sensor node and sink agency in sink node. The proposed scheme uses BDI (Belief, desire intention) model for innetwork image fusion in WMSN. Sensor node agency performs context sensing and context interpretation by using BDI model and the interpreted context is sent to the sink node. Sink node agency receives the context information and generates the fusing agents(mobile), which are responsible for fusion of images from active sensor nodes. Mobile agent roams around the network, visits all the active sensor nodes and fuses the image. Mobile agent returns the fused image to sink node. The scheme is simulated to test the operation effectiveness.

Keywords - **Wireless Multimedia Sensor Networks, Context-Aware computing, Software Agents, Cognitive Agents, BDI-architecture, Image Fusion.**

Paper submitted: 16/04/2016 Accepted: 16/04/2016

I. INTRODUCTION

Wireless Multimedia Sensor Networks (WMSNs) comprises of tiny sensor nodes that have capability of sensing, computation, and wireless communications which are camera enabled. Recent development in the sensor technology has led to the development of low cost tiny sensor nodes enabled with CMOS cameras, which are combined with distributed signal processing and multimedia source coding techniques that are economically feasible. A tiny sensor node communicates within a short distance and collaboratively works to fulfill the application specific objectives of WMSNs [1] and [2]. Large number of sensors can be deployed for many applications that require unattended operations. These sensors are capable to communicate either to their neighboring nodes or directly to an external Base Station (BS), called as sink. The deployment of more number of sensors allows sensing over larger geo-graphical regions with greater accuracy. Using conventional methods of data gathering and processing of multimedia data in WMSNs could lead to some of the problems like energy consumption, redundant data transmission, increased latency, bandwidth overheads, etc. The inclusion of context-awareness in WMSNs can solve these problems to a greater extent. Con-text can be identity, activity, location or time. Context is usually used to represent the information type in a system. To conserve the network life time of the WMSN, context aware computing and software agent technology paradigm together can give optimal solutions.

Usage of context-aware computing [3] in various applications helps to retrieve the information quickly. According to [4], a system is context-aware if it uses context to facilitate the relevant information and service to the user. Context aware information gathering in WMSNs needs to have suitable information and measure of the context, which used to represent the system. Context-Aware computing mainly helps to get the relevant information from the environment, which in turn saves the energy consumption. WMSNs can be used for monitoring in various applications such as agriculture, disaster areas, health care, military, buildings, forests, animals, industrial control, etc. From recent literature it is found that WMSN have great challenge to monitor the militant activities in the battle field. WMSN's can be used for various applications in military such as, army movement monitoring, ammunition monitoring, regulating friendly troops, etc. The sensors must be equipped with various visual aids, so that they can generate some really interesting and very useful data.

Intelligent Software agents can be employed for informa-tion fusion to prolong the network life time by eliminating the redundant information. Agents can be static or mobile. Static agents reside at particular location and perform tasks autonomously either by interacting with user or other agents at environment in the network and perform autonomous tasks by collaborating with other mobile/static agents or users. Mobile Agent based applications mainly fall in the areas like: network management, electronic commerce, wireless multimedia sensors, grid computing and grid services, distributed data mining, multimedia, human tracking, security, etc.

Some of the related works are as follows. The military requirements for flexible wireless sensor networks have been provided in [5]. It describes the evolution of military sensor networking devices by identifying three generations of sensors along with their capabilities and also presents some of the existing developer solutions. The work presented in [6] investigates the design trade-offs for using WSN for implementing a system, which is capable of detecting and tracking military targets such as tanks and vehicles. The system estimates and tracks the target based on the spatial differences of the target object signal strength detected by the sensors at different locations. In [7] [8] a survey of mobile agent based applications is presented.

The work presented in [9] considers the tradeoff between the increase in the data aggregation required to reduce the energy consumption and the need to maximize the information integrity. A position-based aggregation node election protocol for wireless sensor networks, where aggregation node election is done to support asynchronous sensor network applications [10]. A load balancing data gathering algorithm that forms different groups of sensor nodes is described in [11]. A technique to extend the WSN operational time by organizing the sensors into a maximal number of disjoint set covers that are activated successively is presented in [12]. Active sensors are responsible for monitoring events and for transmitting the collected data, while nodes from all other sets are in a low-energy sleep mode.

The work given in [13] presents a method for fusing of the sequences of images obtained from multimodal surveillance cameras and subjected to distortions typically for WSNs. The scheme uses the Structural Similarity Measure (SSM) to measure a level of noise in regions of a received image in order to optimize the selection of regions in the fused image. Dual-Tree Complex Wavelet transform (DT-CWT) is used in the algorithm for region-based image fusion to fuse the selected regions. SOAR [14] is an excellent example for automated flight control and battlefield simulation which is developed by using cognitive agent based systems. The work mainly describes the military application scenario, where there is no predefined knowledge.

Our contributions are as follows: (1) Employing software agents at the sensor nodes to facilitate the cognition capabilities, which interpret and deliver context aware information in reliable way, (2) Intelligent decision making based on context, (3) Wavelet based image fusion code is embedded in mobile agent for image fusion, and (4) Fused image transmission reduces bandwidth requirement.

The rest of the paper is organized as follows. Proposed cognitive agent based image fusion in military sensor networks is discussed in section II. Simulation model is presented in section III. Results are analyzed in section IV. Finally, section V concludes the paper.

II. SOFTWARE AGENT BASED IMAGE FUSION

This section provides the preliminaries, network environment, and complete description of the proposed work.

A. Preliminaries

This section provides definitions of some terms used in describing the proposed work.

- Sink Node: Sink node is responsible for collecting information and coordinating overall processing of the information, It has its own knowledge base which is called as Sink Black Board (SBB). SBB has all the information about the sensor node such as, node id, geographical location, communication range, bandwidth required etc. It mainly generates the fusion agent, which is required for fusion.
- Critical information: An image sensed by the sensor node which is a critical object (such as gun, enemy movement, enemy vehicles, etc. in military). Based on the sensed image importance, context will be interpreted as critical and the sink node is informed.
- Non-critical information: This relates to the less critical information such as, lighting conditions, fog, temperature, etc. Such information may be fused on-demand by the sink node.
- Emergency context (critical context): Whenever the sensed image matches with any one of the critical images in the database of a sensor node, then we define it as an emergency context. This information will be sent to the sink node, which triggers fusion process with a single level wavelet fusion code.
- Simple context: If the sensed image does not match with any one of the critical images in the knowledge base of sensor, then it is considered as simple context. Once simple context has been interpreted; information will be sent to sink node which triggers fusion process with two level wavelet fusion code.
- Belief set: It is the belief set generated by sensor node based on the sensed parameters $\psi_1, \psi_2 \ldots \psi_N$ and actions taken.
- Beliefs: It is the database comprising of belief sets generated by sensor node.
- Image signal strength: It is entropy difference between the two considered images.
- Image correlation: It is the degree of similarity between the images.

B. Network environment

Network environment is shown in figure 1. It comprises of heterogeneous sensor nodes and a sink node. Sensor nodes are geographically distributed over the network area, which collects the data periodically. Sensor node comprises of an agent platform with static and mobile agents, camera and other sensory devices such as light condition, temperature, humidity, etc. The nodes sense data and send the sensed information to the sink node using wireless multihop communication. We assume that all the nodes in the network (sensor nodes and sink node) are static and have some initial energy. During deployment phase, all senor nodes have same energy. It is assumed that sensor nodes have capability to reconfigure the transmission power. All the sensor nodes are equipped with Global Positioning System (GPS), processor and transceiver for communication. Each sensor node communicates with neighboring sensor nodes within its communication range. Senor nodes participate in aggregation (active nodes) only if the sensed values in a particular time window drift by a given threshold.

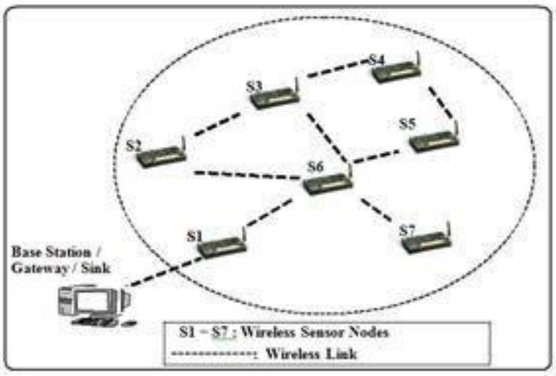

Fig.1. Network environment

C. Proposed work

Each agency employs a set of static and mobile agents to perform dedicated tasks. Sensor node agency performs context sensing and context interpretation based on the sensed image and sensing time. It comprises of node manager agent and context agent. Sink node agency initiates fusion process and it comprises of sink manager agent and fusing agent.

Agents use the Belief, Desire and Intention (BDI) architecture, which facilitate the cognition capabilities to make the intelligent decisions.

The usage of BDI architecture for agents presents the following benefits: WSN's exhibit dynamic changes in the environment and their parameters too. BDI agents have the capability of quickly adapting to such environment; the sensing capabilities and the sensing parameters may be many and can keep changing, therefore the beliefs regarding the environment can be regularly updated by using BDI architecture; autonomous decisions can be made based on the criticalness of sensed parameter.

The belief generation and action selection is done as follows:

• In the context of the BDI-frame work for the proposed work, here we will use AgentSpeak (L) to model the BDI system [15]. We will follow all the notations and expressions of the AgentSpeak (L) agent. An AgentSpeak (L) agent consists of the belief set and plan clause.

• In general the belief set {BN} can be formalized as BN = {ψS1N, ψS2N,......,ψSNN , CN}. Where CN is criticalness of information which is either 1 or 0. NMA calculates the image signal strength of the sensed image out of all other sensed parameters. Agent that monitors the sensor node takes the decision CN. CN =1 indicates change in the entropy (critical) whereas CN=0 means no change in the entropy (non-critical).

• Based on these belief sets B1, B2 ...BN, the Node Manager Agent's (NMA) plan clause can be given as:

$$goal : \{B1 \quad B2, \ldots\ldots, \quad BN \leftarrow C_1 \ldots C_N\} \quad (1)$$

where B_N is the belief and C_N is an action.

Basically, AgentSpeak model works in the following steps.

1) The agent selects an event that has occurred based on sensor status and images.

2) The agent generates the plans with matching conditions, where the matching factor is defined by the monitoring agent that resides in node or the user.

3) Among all the plans, agent identifies the plan with satisfying preconditions.

4) The plan is then added to the intention stack. This intention stack is executed by popping out topmost plan and performing the first C_I, if C_I is event.

Let us say, Ψ = MA plan set, Ψ_I = i^{th} plan clause, C = goal which triggerss Ψ_I, BS= the belief set { B1^B2…….^Bn}

We use Ψ(BS, C) to denote the body of ψI and also assume that the plan consists of number of action plans.

$$\Psi I(BS , C) = \begin{cases} \{(C1(P), C2(P)), head(\Psi I(BS , C)) \\ (C1(P))), tail(\Psi I(BS , C)(C2(P)))\} \end{cases} \quad (2)$$

Where each action plan (CI (P)) is a well-defined action performed by the MA i.e, if action selected is C1 = critical information then MA generates Critical Context Interpreter Agent (CCIA) and if action selected is C2 = non-critical information then NMA generates Non-Critical Context Interpreter Agent (NCCIA). Both CCIA and NCCIA perform the actions as mentioned in below subsections.

Critical Context Interpretation Agent (CCIA): It is a static agent generated by NMA for interpreting the context. CCIA gets the sensed image from NMA and compares the sensed image with the images in the NBB. A histogram is used for the comparison of the images as given in context interpretation mediate value between high and low histogram value for a gray scale image) by the NMA. If the value after comparison of the images is below the threshold, then, the context is emergency type (i.e., image sensed is nearly same as that in the data base), else if the value is above threshold, then the context is interpreted as simple context (i.e., image sensed is nearly same as that in the data base). In case, where emergency context is detected, the corresponding information will be sent to the sink node. Sink node initiates fusion process using 1 level wavelet fusion code embedded in a mobile agent (called fusing agent). If simple context is detected sink node initiates fusion process with 2 level wavelet fusion code embedded in a mobile agent.

Non-Critical Context Interpretation Agent (NCCIA): It is a mobile agent which is meant for storage and fusion of the non-critical information. If NMA decides in favor of the non-critical information, which mainly relates to fog, temp and other environmental conditions. Then this information will be stored by the agent itself and updates NBB. If suppose user at the sink node requires the non-critical information, user communicates to NMA of sensor node for this information. NMA triggers NCCIA. Once the agent is triggered, it visits all other active nodes (collects the information present in the KB/NBB) and fuses only the non-critical information from active nodes and returns to sensor node. The information will be communicated to sink node. This helps in conserving the energy as it will deliver the non-critical information only as and when user wants it. It also helps the user to have overall aggregated information about the environment.

Fusing Agent (FA): It is a mobile agent equipped with image fusion code (1 level and 2 level wavelet fusion code) that migrates from one active node to another active node (we assume the agent itinerary to be given by SMA) depending on the routing information provided by the SMA. The agent visits an active node, fuses the image, and moves to another active node along with the fused image. The agent will use correlation model, which is kept inside the sensor node to fin d the correlation of data/images. If the value is high it means that the data between the two nodes is highly correlated, then it will classify it as the fusion node and fuses the data, else it will classify it as non-fusion node and moves on to the next node until it visits all active nodes.

D. Agent interactions

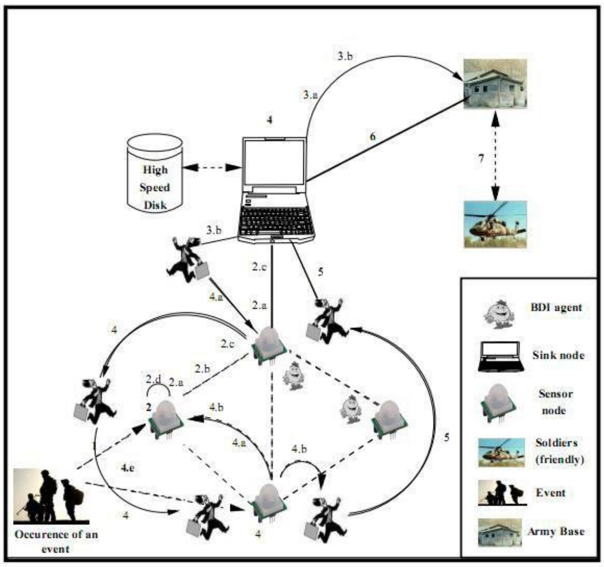

Fig. 2. Agent interaction

Figure 2 presents the agent interaction sequence of the proposed scheme:

1) Upon occurrence of an event in an environment. Sensing agent gathers the information through sensors about the target in the environment.

2) It updates the Knowledge Base (KB) and Belief sets of NMA. NMA decides that the sensed parameters are critical information; hence it generates CCIA, which in-turn starts interpreting the context, viz., emergency context and simple context.

   a) Histogram is used to interpret the context by fixing some threshold level, if the histogram level is below the threshold, then the context is considered as the emergency context and the node will send this information to the sink node.

   b) On the other hand if the value of the histogram is above the threshold, then the context is considered as simple context and this information is sent to the sink node.

   c) if NMA decides that the sensed parameters are non-critical information, then it will generate NC-CIA, which stores this information and also in-turn updates the KB/NBB. if user wants the information, then NCCIA visits all active nodes and fuses non-critical information.

   d) if the sensed parameter is of the environmental conditions, then the BDI agent configures the camera lens of the node accordingly as per lighting conditions.

3) After getting the context information or the image directly from the sensor node, the sink node will perform two functions:
   a) If the sink node receives emergency context information, then it generates FA with 1 level wavelet fusion code and sends it for information fusion.
   b) If the context is simple context, then the sink node generates FA with 2 level wavelet fusion code and sends it for fusion of information

4) FA visits the sensor node and collects the data and fuses the data. Then it will move on to next node (as per the routing table). When FA reaches the second node, it classifies the nodes as fusion and non-fusion nodes by triggering a process called as the correlation calculation process, again we divide this into two steps:
   a) FA when in the second node, calculates the correlation of the data with the first node.
   b) if the correlation value is high, then the FA will consider it as the fusing node and fuses the data else it will go to next active node.

5) FA will migrate to the sink carrying the fused information and updates the SBB (Sink Black Board).

6) Finally, the sink node will send the fused information to the control room for further actions.

III. SIMULATION

We have simulated proposed scheme for various network scenarios using C programming language with a confidence interval of 95%. In this section simulation model, performance parameters and result analysis are presented.

A. Network model

Wireless senor network is generated in an area of l × b square meters. It consists of N number of static nodes, placed randomly. Each node is associated with energy E_F joules, transmission range R meters. The communication environment is assumed to be contention-free. 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 non-active state. We assumed the channel as error free. Sensor MAC protocol (S-MAC) [16] is used for media access. Free space propagation model is used with propagation constant β.

Propagation model: Free space propagation model is used with propagation constant β. Transmission range of WMSN node communication radius is r for a single hop distance d meters. It is assumed that at any given time, the value of transmitted power is NP ow milliwatts for every node.

Battery model: Image sensor nodes are deployed in the battle field, recharging of the nodes at the target is difficult. So, we have considered a solar cell recharging model [Xiaoming Fan et al., 2004] and a layered clustering model to deal with the restrict energy consumption under the consideration of visual quality. The system lifetime can be prolonged by rechargeable solar cell that can be recharged by solar panel in daytime. Image sensor nodes consumes node – batt in millivolts to sense an image.

B. Simulation Procedure

To illustrate some results of the simulation, we have taken A = 100, B =200 meters and N=1 to 5, num=5 to 15, node − batt=90 millivolts, Th= 50%, 60 %, 70 %). Gray scale image of varying size rows × columns= (32 × 32, 64 × 64, 128 × 128, 256 × 256, (8, 12, 16, 24) bits/pixel, Present Signal strength= (30%,50%, 60%,70%, netBW = 4MBP S, Propagation Constant β =3.5, and F code = (4 , 8, 12) Kbytes.

Begin

- Generate the WMSN for the given radius and number nodes.
- Sense the parameters and generate the active nodes
- Apply the proposed context aware fusion model.
- Compute the performance of the system.

End

The following performance parameters are assessed:

Fig.3. Sensed image 1

Fig.4. Sensed image 2

Fig. 5. Fused image

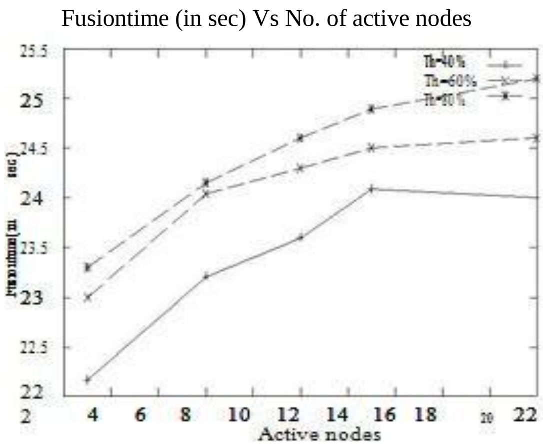

Fig. 6. Fusion time Vs. Active nodes

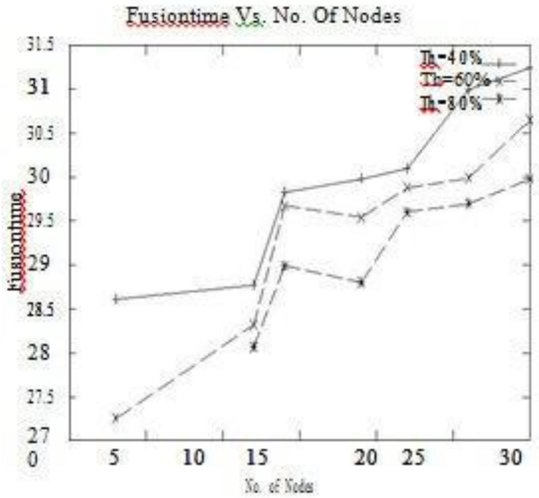

Fig. 7. Fusion time Vs. Number of Nodes

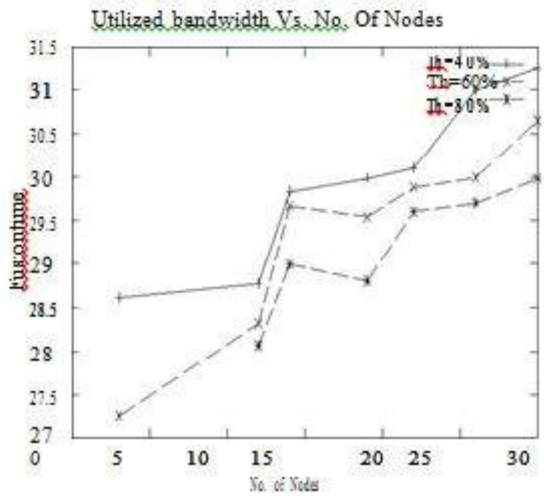

Fig. 8. Utilized bandwidth Vs. Active nodes

Figure 6 depicts the analysis of fusion time. It shows that as the number of active nodes increase, the fusion time increases, but there is no abrupt increase in the fusion time even if there is increase in number of active nodes. Figure 7 shows that as number of deployed nodes increase along with increase in threshold, number of active nodes decrease and thus fusion time decreases accordingly.

In figure 8, different gray scale images are taken and their used bandwidth against number of active nodes has been analyzed. Bandwidth used increases as there is increase in the number of active nodes for each gray scale image.

IV. CONCLUSION

This paper presented an intelligent software agent based con-text aware image fusion in WMSNs to form an infrastructure for image fusion. In an environment where source nodes are close to each other, and considerable redundancy exists in the sensed data, the source nodes generate a large amount of data, which not only wastes the scarce wireless bandwidth, but also consumes a lot of battery energy. BDI based intelligent agent has been used to interpret the context, and the given frame-work can be extended for various sensor input parameters.

REFERENCES

[1] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam and E. Cayirci, "Wireless Sensor Networks: A Survey", Journal of Computer Networks, vo l. 38, no. 4, 2002.

[2] I.F. Akyildiz, Melodia. T.and Chowddhury K.R, "A Survey on Wireless Multimedia Sensor Networks", Journal of Computer Networks, v ol. 51, no. 921-960, 2009.

[3] Kirankumar B. Balavalad, S. S. Manvi and A. V. Sutagundar, "Context Aware Computing in Wireless Sensor Networks", In proceeding s of International Conference on Advances in Recent Technologies in Com-munication and computing, 2009.

[4] A. K. Dey, and G. A Bowd, "Towards A Better Understanding of Context and Context Awareness", In proceedings of 1st internationa l symposium on handled and ubiquitous computing, Karlsruhe, Germany, pp. 304-307, 2002.

[5] Michael Winkler, Graeme Barclay, "Theoretical and pract ical aspects of military wireless sensor networks", Journal of Telecommunica tions and Information Technology (JTIT), February, 2008.

[6] Tatiana Bokareva, Wen Hu, Salil Kanhere, " Wireless Sens or Networks for Battlefield Surveillance", Land Warfare Conference, Br isbane, 2006.

[7] Abdelkader Outtagarts, "Mobile Agent based applicatio ns: a survey", International Journal of Computer Science and Network Security, vol.9 no.11, 2009.

[8] Laura, G, Sergio, P., Andrew, T., "Efficient data aggrega tion in wireless sensor networks: an entropy-driven analysis", In Proceedi ngs of IEEE 19th International Symposium on Personal Indoor and Mobile Radio Communications, PIMRC 2008, pp. 1-6,15 - 18 Sept. 2008.

[9] Levente, B., Pter, S.," Position-Based Aggregator Node Election in Wireless Sensor Networks", International Journal of Distr ibuted Sensor Networks, Hindawi Publishing Corporation, 2010.

[10] Mihalela, C., Ding-Zho,D., "Improving Wireless Sensor Network Life-time through Power Aware Organization", Springer Journal of Wireless Networks, 11, pp. 333-340, 2005.

[11] Jianming, Z., Xiaodong, HU.," Improved Algorithm for Min imum Data Aggregation Time Problem in Wireless Sensor Networks", Jour nal of Systems Science and Complexity vol. 21, no. 4, pp. 626-636, 2008.

[12] Xin, G., Lin, G., Xin, G., Wang, Tomoaki, O., "A new load balancing and data collection algorithm for energy saving in wireless sensor networks", Springer Journal of Telecommunication Systems (JT S), pp. 313-322, 2010.

[13] Dejan Drajic, Nedeljko Cvejic, "Adaptive Fusion of Mul timodal Surveil-lance Image Sequences in Visual Sensor Networks", IEEE Trans actions on Consumer Electronics, vol. 53, no. 4, 2007.

[14] J Ones, R. M., L Aird, J. E., N Ielsen, P. E., C Oulter, K. J., K Enny, P., AND Koss, F. V. "Automated intelligent pilots for co mbat flight simulation", AI Magazine vol. 20, no. 1, pp. 2741, 1999.

[15] A. S. Rao. "AgentSpeak(L): BDI agents speak out in a logi cal com-putable language", Technical Note 64, Australian Artificia l Intelligence Institute, pp. 42 - 55, 1996, Also appeared in Agents Breaking Away (LNAI 1038).

[16] W. Ye, J. Heidemann, D. Estrin, "Medium Access Control Wi th Coor-dinated Adaptive Sleeping for Wireless Sensor Networks", I EEE/ACM Transactions on Networking, Vol. 12, No. 3, pp.493 - 506, 2004.

Dr. P.K. Srimani, F.N.A. Sc., is a Former Chairman, Dept. of Computer Science and Mathematics, Bangalore University, Bengaluru. She has more than thirty years of teaching and research experience in the field and has successfully guided more than a dozen Ph.D. students.

Bhanu K N is currently working as Associate Professor in the Department of Computer Applications, Rajarajeswari College of Engineering. She obtained her MCA, from IGNOU, NewDelhi, M.Phil., in Computer Science from VMU, Salem & presently pursuing Ph.D., in Computer Science from Rayalaseema University, AP.