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Sensors Lifetime Enhancement Techniques in Wireless Visual Sensor Networks - A Survey

Mr.K.Thangaraj, Prof.M.Chitra

Abstract: With the development of more powerful sensors compared with traditional data sensors, Visual sensor networks are emerging to deliver more demanding applications such as video streaming. Video sensor networks continue to gain increase interest due to their ability to collect video information for a wide range of applications in recent years. However, knowledge about these types of networks is mostly related to visual algorithms, leaving the issues such as the coverage of video sensor network and the transmission of video data aside. In this paper, we first concentrate on the issues of visual sensor network and surveyed the state of the art of this particular issue, regarding strategies, algorithms and general computational solutions also discussed, envisaging promising investigation and considering coverage in video-based wireless sensor networks. Then we discussed key research issues on visual sensor network, specifically camera coverage problem and low-power video data processing and communication problem.

Index Terms - *Visual Sensor Network, key issue, Camera coverage, Energy consumption.*

I.INTRODUCTION

In the last decade, Video Wireless sensor networks (VWSN) were one of the main research topics in computer communications. Composed of low-cost powered-restricted devices with sensing and computing capabilities which cooperatively communicate in a wireless manner, Video Sensors allowed a variety of innovative applications for sensing in wide, hostile or even hard access areas, as in battlefield surveillance, environmental monitoring, rescue operations, home entertainment and pollution detection, among others. To achieve such applicability, many aspects of these networks, ranging from energy efficiency to sensor deployment and mobile communications, have been addressed in numerous research projects.

K.Thangaraj – Research Scholar, Anna University of Technology,Coimbatore.
Dr.M.Chitra, Professor/IT, Sona College of Technology, Salem.

A crucial point in Visual Sensors is the coverage problem. The coverage concept is subject to a wide range of interpretations. Coverage can be formulated based on the subject to be covered, the sensor deployment mechanism, the network connectivity and energy consumption. All these issues will be surveyed in this paper, particularly considering VWSNs In traditional WSNs, different aspects of the coverage problem have been addressed by many works.

Fig.1. Visual Sensor Network

For example, in polynomial time algorithms are presented to determine if a set of wireless nodes can properly cover a target area. This problem is expanded, which regards a three-dimensional sensing model. The 3D sensing range of the nodes is calculated by a low-complexity algorithm, in polynomial time. The protocol proposed preserves nodes with higher importance for the sensing application, electing them for sensing instead of routing in sparsely covered areas. Several papers can be found in the literature surveying wireless sensor networks and visual sensor networks as their main research areas. In a different way, in this survey we present the recent developments, challenging issues and open research areas of the coverage problem in video based wireless sensor networks. This crucial part of Visual Sensors is surveyed in a structured way, comprising directional sensing, node deployment, coverage metrics and energy efficient solutions, besides complementary issues related to directional coverage.

Visual sensor networking is an emerging technology. Adequate sensing capabilities are the key issue in a system working autonomously or semi-autonomously in unstructured, unfamiliar environments. Networks of sensing devices are one of the emerging technologies for providing such systems with information about status and conditions in a large fragment of the environment. In such networks, a huge amount of sensed data that should be acquired and processed in real time requires both hardware-implemented processing algorithms and intelligent data selection mechanisms in order to prevent informational saturation.

II. SEQUENCE OF ISSUES AND RESEARCH

A. VISUAL SENSOR NETWORKS

Visual Sensors are an emerging *ad-hoc* network technology that employs autonomous wireless sensors equipped with low-power cameras to wirelessly retrieve visual data from the monitored field. In the last years, the demand for VWSN applications has significantly increased, fostered by vision-based applications as traffic monitoring, wildlife observation and surveillance. For an increasing group of applications, scalar data collected from traditional wireless sensor networks are insufficient, even if a large number of sensors are deployed.
Others relevant issues emerge when the wireless sensors are equipped with cameras. Given the large amount of data generated by camera nodes, data transmission requires more bandwidth and energy in Visual Sensors. To reduce the amount of data transmitted, many works suggest and propose algorithms for local processing of visual data. In fact, video-based wireless sensor networks may expect more energy consumption in local processing than in data transmission, contrary to traditional wireless sensor networks.

In addition, the nature of visual data imposes time constraints to the multi-hop communication among wireless nodes. Therefore, new protocols and network topologies were created or adapted to couple with the transmission of such data type. Moreover, QoS has been pointed as a valuable resource for video-based wireless sensor networks. Multimedia in-network processing is another key design requirement of Visual Sensors, addressed by many works. It is expected cooperative processing of multimedia data by intermediate nodes, potentially reducing the amount of data transmitted throughout the network and prolonging the overall network lifetime by saving energy, since the communication latency is kept in an acceptable level.

B.COVERAGE ALGORITHMS

Visual Sensor works have investigated the optimization of positioning of cameras and sensors considering deterministic deployment, as presented in the last subsection. When sensors are randomly deployed, the coverage can be also optimized, based on the positions, orientations and numbers of the sensors. The algorithms for optimal camera/sensor placement following deterministic deployment are a reasonable basis for coverage optimization in randomly deployed video-based wireless sensor networks, with some adaptations. When video-based sensors that cannot change their current orientations are randomly deployed in a monitored area, the covered area will be defined by the current positions and orientations of the sensors just after the deployment.

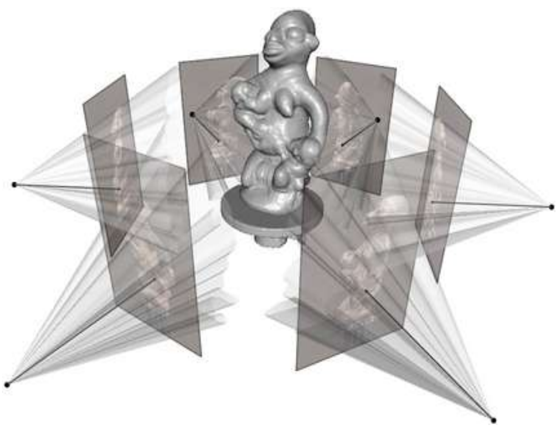

Figure 2. Visual Coverage –Multi perspective geometry

In this case, an algorithm can only compute redundant nodes in order to try to prolong the network lifetime, since the covered area cannot be changed (but can become depleted over time). The authors also noticed that increasing the number of deployed sensors linearly increase the coverage ratio and the number of active nodes, until the deployed sensors reach a threshold. Upon this value, the number of activated nodes increases slowly or even decrease, whereas the coverage ratios continuously increase.

This threshold is a function of the number of targets in the modeled experimental environment, but attests that the deployment of many nodes can potentially produce redundant nodes. Cameras with angular mobility are also investigated; Visual sensor networks with sensor nodes equipped with cameras having angular mobility can dynamically manage a covered area, avoiding blanket spaces and undesired overlapping. The proposed distributed algorithm proposed by the authors also aims to find the direction of least density of neighbors.

C. ENERGY BY SAVING REDUNDANT NODES

In a wireless sensor network, a node can be sensing, relaying messages or be in an idle state. Since even an idle communication-receiving circuit can consume almost as much energy as an active transmitter, idle nodes should be sleeping.

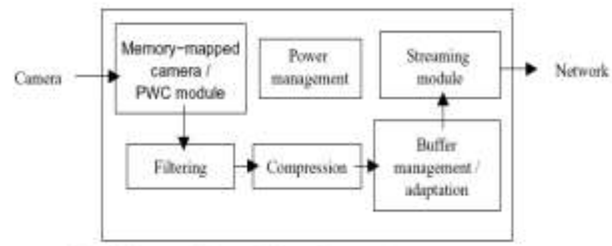

Fig.3. Panoptes model for Low Energy Consumption

However, a certain amount of active nodes should exist to ensure a desired level of coverage at all times. A survey on the routing techniques and protocols for wireless sensor networks, including energy aware routing, can be found. Connectivity preservation, coverage maximization and energy saving can be performed in different ways. When dealing with real-world environments, however, some of these aspects can be prioritized over the others. It impacts the election of nodes to routing or sensing functions. For example, if a region of the monitored field can only be viewed by a unique sensor node. It is particularly relevant for sparsely covered areas, which can be created after deployment or after many nodes deaths or failures. On the other hand, some approaches can prejudice the coverage on behalf of the prolonging of the network lifetime. It could be performed by reducing the number of active sensors even if uncovered areas appears, increasing the number of redundant nodes.

D. OTHER RELEVANT ISSUES

As each video-based sensor has a direction and different field of views can overlap, images from distinct viewpoints can be obtained from the network by combining the retrieved visual data from the monitored field, just selecting the appropriated cameras. Soro *et al.* presents a method to reduce energy consumption and data redundancy by selecting which parts of retrieved images from each camera should be sent to the sink in order to reconstruct a desired viewpoint, considering 3D field of view. For the proposed solution, two distinct methods are evaluated. The first one is based on the minimum angle between the direction of the desired view and the direction of the camera.

In the second approach, cost metrics are applied to measure the camera's importance in the monitored area. This approach also considers the remaining energy of the sensor nodes. The proposed solution is an extension of the work presented, which regards 2D viewing and uses no metric to evaluate the camera importance for scene viewing. The sensor cameras can be moving or have movement capability, give rise to new challenges for the coverage. McCurdy, *et al.* proposes a system for continuous and probably wide coverage by employing head-mounted cameras in personnel who (typically) moves across an area of interest.

An algorithm for switching viewed images in a soft way is also presented. The drawback of this solution is that coverage cannot be predicted, and blank areas can be created along the time. Lee *et al* designed a VWSN with a mobile sink. Authors argue that such configuration can improve coverage, with reduced energy consumption. The work presented in also expects the using of solar rechargeable energy batteries, as an option to prolong the network lifetime. According to the authors, this particular type of communication imposes new challenges for the prolonging of network lifetime and connectivity maintenance.

E. OPEN RESEARCH AREAS

Most experiments related to the coverage problem only contemplate the deployment of dozens of sensors. However, real-world implementation can require hundreds or even thousands of sensors. Such demand should be properly investigated, since the performance of many proposed algorithms could be affected by a large number of deployed sensors. Other interesting research area employs audio and video sensors to retrieve multimedia data from the monitored field.

Few works investigate heterogeneous multimedia sensors, and many details related to audio and video coverage are still open. Therefore, we need to study methods of coverage control and cooperative processing. They are the two key methods to guarantee performance of network system monitoring. The principal standard to measure video sensor network coverage control algorithm is the coverage degree of net to monitoring area and targets, which can influence the probability of targets we can monitor.

As to different monitoring goals (target discovery/ target tracking) and monitoring objects (monitoring area! target path), designed coverage control algorithms are not all the same. We can discuss the researches on coverage control from regional coverage and path coverage. Cooperative processing is one of the important approaches of realizing the monitoring goal of sensor network, whose implementation method is closely related with its application. As for the target monitoring application based on video sensor network whose resources are limited, cooperative processing makes use of related visual information among many video sensor nodes, and can efficiently realize full monitoring of targets.

IV. EXPERIMENTS AND RESULTS

There is a tremendous number of sensor networking technologies being developed for sensor networking applications. From the hardware perspective there are two important sensor developed. One is Berkeley Mote and the other one is PC-104-based sensor developed at UCLA.

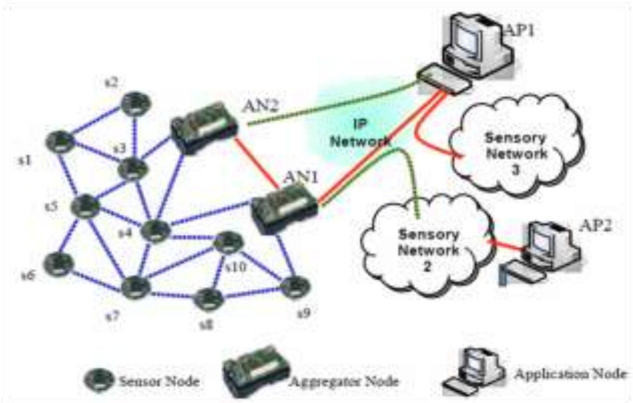

Fig.4. Sensor Network Model

For our survey we took Panoptes platform the next logical platform within the hierarchy of sensor network platforms. Normally hybrid technologies, where motes and the PC-104-baed sensors can be used to trigger higher-powered sensors would allow the sensor network's power consumption to be minimized. These technologies also have ad hoc routing, location discovery, resource discovery and naming capabilities.

To test the ability of the sensor to deal with disconnected operation, they run experiments to show how the video rate is adapted over time. For these experiments they first turned on the sensor and had it capture, compress and stream data. The experiment then turned the network card on and off for the times. The buffer reaches values resulting in the saw tooth graph shown in figure. 4.

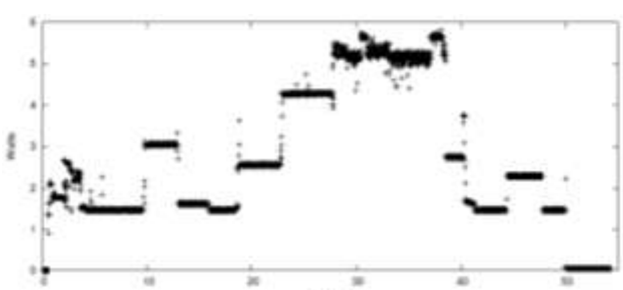

Fig.5. Power Consumption of Video Sensors

Their experiments show that it is able to capture fairly high quality video running on low amounts of power, approximately the same amount of power required to run a standard night light. And it showed how the buffering and adaptation manage to deal with being disconnected from the network. Here they not yet directly implemented power management routines within the video platform. But they used to control the frame rate of the video being captured which will be useful to turn on and off to save the power.

III. CONCLUSION

Visual sensor networking is an emerging technology that promises a wide range of potential applications in both civilian and military areas, and has therefore received tremendous attention from both academia and industry in recent years. Depending on the application, the large amount of correlated synchronized impulses of data sends to a small number of nodes. This high generation of data packets is usually uncontrolled and results in network congestion.

In this paper, many works comprising the coverage problem in Visual Sensors have been surveyed, considering deterministic and random deployment, coverage metrics and energy efficiency, among other topics indirectly related to the coverage problem. Some promising open research areas have been also presented, indicating a possible direction for future works. The main goal of my work is to understand the energy consumption trade-offs between computation and communication in sensor networks in general, and Wireless Visual Sensor Networks, in particular. In order to do so, I need to evaluate and model: energy spent to process data by Visual Sensors (e.g., how much energy vision algorithms require, etc.) as well as energy required for communications. Through my work, I plan to find out the solutions on energy consumption issues.

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