Key Issues in Video Sensor Network

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ABSTRACT
The introduction of video sensors into a sensor network allows existing sensor network applications to be enhanced as well as providing for new applications which cannot be supported by typical scalar sensor networks. This is due to the vast amount of information which can be obtained from an image. Scalar data is insufficient for many applications such as video surveillance and traffic monitoring. Whereas, camera sensors collect video data, which are rich in information and offer tremendous potential when used in wireless sensor networks. 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 highlight the issues and opportunities of video sensor network. And then we discuss key research issue on video sensor network, specifically camera coverage problem, network architecture, and low-power video data processing and communication. Finally, we identify enabling approaches in this area.

Keywords
Wireless sensor network; video sensor network; key issue; camera coverage

I. INTRODUCTION
Wireless sensor networks (WSNs) are widely applicable to many sophisticated military or industrial applications, including environmental monitoring, surveillance, object tracking or health monitoring. In many practical applications, sensor nodes can be equipped with very tiny video cameras to facilitate the task of tracing a particular object of interest, or the continuous/periodic monitoring of any change in the environment. However, each sensor typically has a very limited battery and processing power. In addition, due to the high costs involved, most sensors are not equipped with the Global Positioning System (GPS) and thus do not have precise knowledge about their own locations during actual deployment. Hence, the challenging issues that need to be addressed in many advanced image, video, and multimedia applications on WSNs include, but are not limited to, the following topics:
• effective image and video capturing;
• object view-angle coverage with visual sensor networks;
• sensor image processing for object tracking;
• in-network pre-processing such as image and video compression;
• collaborative visual information processing;
• distributed vision processing;
• image aggregation in sensor nodes;
• image processing with computational and energy constraints;
• image and video processing with network security;
• image-based localization of sensors;
• Image processing and editing, taking into account domain knowledge such as location and angle information.

An illustrative information-rich video sensor network is illustrated in Fig. 1. In this network, rich information will be captured by randomly deployed sensors as visual images, which will be backhauled through multiple relaying nodes to the sink. Gathered data will then be analyzed to reconstruct the scene of interest and commands and control will be disseminated back.

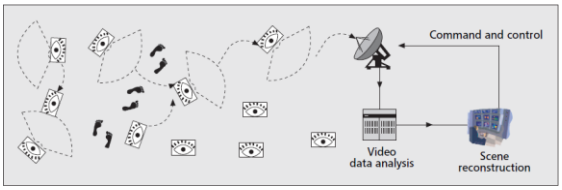

Figure 1: An illustration of video sensor networks:

low-resolution and yet information-rich video streams captured and delivered by resource constrained sensors empowers central servers to perform scene reconstruction and in-depth analysis.

At present, an important aspect of sensor network research is how to realize the collection, transfer and processing of simple environmental data (such as temperature, humidity, intensity etc.) on micro nodes whose energy is greatly limited[2]. However, the monitoring environment is becoming more and more complicated. The simple data which are acquired by traditional sensor network cannot satisfy people's whole demand to environmental monitoring. There is a pressing need to introduce media like images and videos of rich information to environmental monitoring activity based on sensor network, so as to realize fine-grained, exact information environmental monitoring. Video sensor network thus emerges [3]. In this paper, firstly, the concept and characteristic of video sensor network are proposed. Secondly, the key issue in video sensor network such as coverage problem, network architecture, and low power video data processing are analyzed. Finally, the applications of video sensor network are discussed according to the classification of area. The reminder of this paper is organized as follows: the next section discusses the concept and characteristic of video sensor network. In section 3, we present the key issue in video sensor network. In section 4, the applications of video sensor network is given. Finally, we draw our conclusion on section 5.

II. THE CONCEPT AND CHARACTERISTIC OF VIDEO SENSOR NETWORK

In recent years, the research of video sensor network technology has already attracted scientific researchers' close attention.

Concept and Characteristic of Sensor Network
Sensor network is a network **formed** by a lot of miniature low-cost low-power sensor nodes existing monitoring environment by means of Multi-hop communication. Sensor nodes have the ability of data collection, processing, wireless communication and self organization [8]. They can collaboratively accomplish large and complex monitoring tasks. In the network, only a few cluster nodes are responsible for order issue and data collection, thus to realize the communication with internet. Compared with other traditional network, sensor network has the following features:
(1). Resource-constrained: Because of limited cost, size and power consumption, the computing power, program space and memory space of nodes are much weaker and smaller than common computer.
(2).Large-scale use: In order to finish regional monitoring missions, usually there are thousands of sensor nodes are densely deployed in the target area, so as to make use of the high degree of connectivity among nodes to assure the fault tolerance and invulnerability of system.
(3).Self-organization structure: Network deployment and launch don't depend on any prepositioned network facility.
(4).Multi-hop communications: In wireless network, communication distance between nodes is limited. Each node can only communicate with its neighbour. If the communication with nodes outside its radio frequency range is expected, information must be transferred through intermediate nodes by means of routing.
(5).Strong dynamic: In network, nodes may quit from net operation because battery power runs out or other faults. Some nodes may be moved or new nodes can be added to the net because of mission requirements. All these can lead to changes of network topology.
(6).Safe and reliable: Sensor network is applied to monitoring missions in harsh environment or security sensitive areas. Thus sensor network is required to have the ability to prevent monitoring data from being stolen and identify counterfeit monitoring information.

A. Definition and Feature of Video Sensor Network

Video sensor network is a distributed sensor network formed by a group of video sensor nodes that have computing, storage and communication capacity [9]. It can realize full-scale and effective monitoring with the help of the video sensor on nodes to apperceive video information of surrounding environment, then transfer the data to information gathering center by means of multi-hop relay, and finally the monitoring data are analyzed by the information gathering center. As one kind of sensor, video sensor has its distinct features apart from common points. They are concretely manifested in the following aspects [10][11]:
(l).Increased network capacity. Because of the introduction of a lot of media such as video and images, node and network capacity of video sensor (collecting, processing, storage, transceiver, energy supply, etc.) has been significantly enhanced.
(2).Complex processing tasks. Data collected by traditional sensor network has a single form and are of less information. Thus the processing is simple. Only calculation of add, subtract, multiply, divide, sum, average are needed. It is difficult to form a comprehensive understanding of monitoring environment based on these information. However, videos and images collected by video sensor network are of rich information and of complicated forms. We can process them by means of compression, recognition, integration, etc. to meet diverse application requirements.

III. THE KEY ISSIUE IN VIDEO SENSOR NETWORK

A. Emergency Saving Control Strategy

Because the environment and condition of video sensor application is complicated and mostly doesn't allow a battery change, and its energy consumption is also larger than traditional sensor, how to save the limited battery energy on each node and try to extend the life of the whole net become an important performance standard of video sensor network.

B. Deployment and Coverage of Video Senor Nodes

Deployment and coverage are two fundamental problems of sensor network, which reflect sensor network's perceptual range and quality of physical world. Traditional deployment and coverage optimization of sensor network that based on directional perception model is not applicable to video sensor nodes which have directional perception. Based on whole-new directional perception model, design rational and efficient video sensor network deployment method and node dispatch strategy, study video sensor network coverage optimization that consider both energy efficiency and reliable monitoring, so as to extend the work life of network and provide sufficiently high monitoring coverage.
Network Architecture of Video Sensor Nodes
Existed simple sensor network structure based on cluster cannot perfectly process large data media services including images and video information. And the in-network processing and retransmission of these large data media information need to consume a lot of net resources. Only based on a single video sensor node, it is difficult to offer monitoring quality required by users. As we consider performance such as deployment, energy consumption, expansibility, flexibility and fault tolerance, it is also an important research issue to make use of isomorphic or heterogeneous video sensor nodes to build network system structure of powerful functions, structural optimization and excellent performance.

C. Real- Time Transmission

Video information has high requirements for the delay and synchronization of transmission. Video sensor network should have stronger media transmission ability. At present, the broadband resources and processing ability of video sensor network are rather limited. How to efficiently solve the real-time transmission of images and video information is the key point of video sensor network's practicality. We should research and design real-time, reliable transport protocol and strategy that are applicable to video sensor network, so as to save net energy and extend work life of net.
Collaborative Processing Technology of Video Sensor Nodes
In sensor network, the fundamental purpose of collaborative processing is to coordinate the act of man sensor nodes, keeping their high consistency, so as to realize the functional goal of sensor network. However, as to a single sensor, its perception and communication range, energy and computing ability are limited. A single node cannot separately process large-scale scene monitoring tasks. In order to give full play to sensor network's monitoring ability, we must coordinate lots of sensor nodes in the net with limited resources so as to efficiently solve the problem of complex media data's collecting, processing, transmission and exhibition. Besides, compared with centralized processing, collaborative

processing has distinct advantages in increasing system robustness and improving network performance.

D. Storage and Search of Video Information

Widespread video sensor nodes constantly percept and collect visual information in the environment. Its data amount is extremely large. How to efficiently store the massive data that reflect environment state of different times in video sensor network and how to quickly search interested information from it are hot issues in current research.

IV. THE APPLICATION AND CLASSFICATION OF VIDEO SENSOR NETWORK

A. Application of Video Sensor Network

Video sensor network is mainly applied to environment monitoring. Because of its intuition, convenience and rich information, it is widely applied to many fields such as the military, the civil and commercial field. It has a bright future. The main featured applications are the following [12]:

(1).Battlefield monitoring: Video sensor network can realize many functions such as the monitoring of enemy troops and equipment, real-time monitoring of the battlefield, target locating, battle field assessment, etc .

(2). Traffic monitoring: Video sensor network can monitor the traffic of traffic hub, ring road and highway, so as to count vehicles passing by, whether there is illegal target parking and whether there are fault vehicles. It can also provide the latest situation about road congestion, recommend the best route, and remind the drivers to avoid accidents, etc.

(3).Security-sensitive area monitoring: Monitor security-sensitive working environments such as mines, power stations, coal mines, watch towers, etc.

(4).Intelligent home and target tracking: Building intelligent kindergarten to monitor children's early education environment and track children's activities can allow parents and teachers to make a comprehensive study of students' study and life process. And it can also be used to monitor people's (especially old people living alone and the disabled) behaviours.

(5) Public safety monitoring: Video sensor network can also be widely applied to security monitoring of public places like airports, railway stations, customs, stadiums, parking lots, business places, etc. It is also used for real-time monitoring and forecast of emergent environments (like fire, earthquake, etc.).

B.Classfication of Video Sensor Network:

According to different tasks, application of video sensor network can also be classified as the following five categories:

(1) Target monitoring: Monitor overall movement (such as speed, direction, sport features, etc.) of a single target or multi-target (such as a crowd) to avoid congestion or discover unusual situations in time. Typical applied scenes include discovering targets in complicated weather environment (such as rain, snow, heavy fog, night, etc.), and monitoring of gathering places like railway stations, traffic arteries, supermarkets and tourist attractions.

(2) Target recognition: Recognize targets that satisfy premade features (such as movement, shape, colour, appearing frequency, etc.) from the video sequence, so as to discover unusual situations in the monitoring scene as early as possible. Send out alerts and provide valuable information in the fastest and best way. This kind of application plays an important role in the security-monitoring of customs, airports, railway stations.

(3) Target tracking: Use recognized results to track targets, especially moving targets or targets that satisfy designated features. By means of target tracking, we can not only acquire more detailed and reliable monitoring data of targets, also can we realize the forecast of targets' trajectory.

(4) Target classification: Classify the results of target recognition. And make a statistic of information of some targets (passersby/vehicles, etc.) in the monitoring scene such as appearing frequency and location.

(5) Scene reconstruction: Use multi-source video sensor nodes to monitor a same scene, then processing canter reproduce the scene information according to redundant visual information and reconstruct tree-dimensional monitor scene. This kind of application can be used for scene simulation or augmented reality of areas that it's difficult for people to arrive (such as polluted areas, protected areas or hostile regions). Among all the applications mentioned above, target monitoring is the most widely used. Its purpose is to explore and monitor interested zones and targets in the monitoring area by means of the cooperation of many video sensor nodes in the net. We can classify the target monitoring based on video sensor network into three major stages:

• Target Discovery Stage

In order to efficiently discover targets in time, we hope that video sensor network can cover the whole monitoring area to maximum extent. That's under the condition of certain net resource, reduce network coverage overlap and blind areas as much as possible.

• Target Tracking Stage

When discover a target appearing in the monitoring area, we hope that video sensor network can offer full monitoring of the target (usually moving targets). That means video sensor nodes around the target moving route automatically adjust to higher degree of coverage matching the tracking.

• Target Information Processing Stage

Considering the limited resources of a single video sensor node and the redundant information of neighbouring nodes, we hope to realize common monitoring of a same target through coordination of many video sensor nodes. On the foundation of guaranteeing certain monitoring image quality, reduce the in-net transmission of large data redundant visual information, save net energy, so as to extend work life of the whole target monitoring system. 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. Coverage control and cooperative processing are the two key points to guarantee target monitoring performance of video sensor network, which directly influence the probability of being

monitored and the extent of monitoring information. Meanwhile, one of the important standards of target monitoring system based on video sensor network is long-term and efficient monitoring of environment. Coverage control and cooperative processing are two efficient approaches for sensor network even video sensor network to improve net resources utilization ratio and save net energy consumption. They can realize the maximization of network monitoring life under the precondition of performing guaranteed target monitoring tasks.

V. CONCLUSION

In this paper, we highlighted the potential applications of visual sensor networks and discussed the challenges that should be met to enable these applications. Research on video sensor network is just at its beginning. Optimizing camera coverage, designing scalable network architectures, building cooperation processing strategy, and optimizing the trade-off between data transmission and energy cost are key research issues for video sensor network. Also, due to the different elements that enter into the design of visual sensor networks, multidisciplinary research is highly needed to design future video sensor network.

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