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Camera-Based Wireless Sensor Networks for E-Health

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Abstract: Wireless sensor networks (WSN) are widely applied in many fields such as e-health, military, surveillance and industrial applications. In e-health field, WSN is commonly used for monitoring elderly people, babies , and patients The progress of WSN technologies allowed the connection of a camera to WSN node to transfer images and video. This technology improves the monitoring of patients and gives more information which is not available with traditional WSN nodes. The problem with image and video transmission is the high demand of bandwidth and the requirements of human monitoring at the sever side. In this research , images captured by WSN nodes are analysed at the node side and only special images are transferred indicating special patient activities. This reduces the required bandwidth and reduce the human effort the server side. Image processing algorithm are optimized to be suitable for the low computation power and memory resources in the WSN camera node.

Keywords: WSN – E-Health – Motion detection- Image processing

I. INTRODUCTION

WSN are collections of large number of small nodes communicating together. The WSN node is a tiny device has the capabilities of sensing , communication and computation. These nodes are deployed in a special structure to allow communication together based on the range of communication for each node. Usually data are transferred to a server side to monitor the environment or the required phenomena. Sometimes, WSN are used to make actions or execute commands sent from server to nodes. Sensor networks can be found in a wide variety of areas such as disaster area, near active area, inside potentially dangerous chemical plant, or in with a nuclear reactor[9].For E-Health field, WSN are becoming increasingly important for monitoring patients both in the clinical setting and at home. They provide more comfort for patients, with the absence of wires reducing costs and providing more flexibility[4]. WSN are getting a special place in the development of e-Health application, due to its characteristics such as: not intrusive design, low energy consumption, low price and its flexibility to integrate into health care environments[7]. Camera-based wireless sensor networks (WSN) are an emerging research area with many promising applications. Potential applications include remote video surveillance, monitoring and assisting elderly and health patients, and habitat monitoring[13]. Using camera-based WSN in E-health applications can give more and more information about the patient. Traditional WSN nodes have many shortages in many situations which can be compensated by transferring the full situation of the patient, infants, or elderly people using images and videos. The main problem with camera WSN nodes are the bandwidth. Usually WSN nodes are used to transfer very low rate data while the source of the data is a temperature ,pressure or flow sensors these sensors has a rate of few bytes per second or per minute. Hence, most WSN are designed for low rate data transmission. Usually they depend on Zigbee or IEEE802.15.4 standard. A single camera may require a transmission rate of 13.8 Mbps, for a video of 15 frames/s and resolution of 640*480. Multi camera nodes can increase the traffic of the network dramatically. Although many compression techniques can be used, the traffic still considered very high compared to traditional WSN nodes. The large transmission rate doesn't affect the network traffic only but also the battery of sensor nodes, while communications are very hungry to power. In this research, special events are detected and images or video describing these events are only sent over the network. These events may represents the motion of the patient, environment changes , waking up , baby crying,...etc. This technique reduces the required network bandwidth and also gives alerts to the server which reduces the human efforts. The required image processing techniques and algorithms are optimized to be suitable for the small memory and computation power of WSN nodes. This paper is organized as follows: section 2 introduces the camera node system, section 3 discusses the event driven monitoring, section 4 illustrates the motion detection techniques and the proposed methods, section 5 gives the results , and the conclusion is given in section 6.

II. CAMERA NODE SYSTEM

A traditional sensor node is mainly composed of four units, sensor unit, processing unit, wireless communication unit and power supply unit. Some other optional units can be

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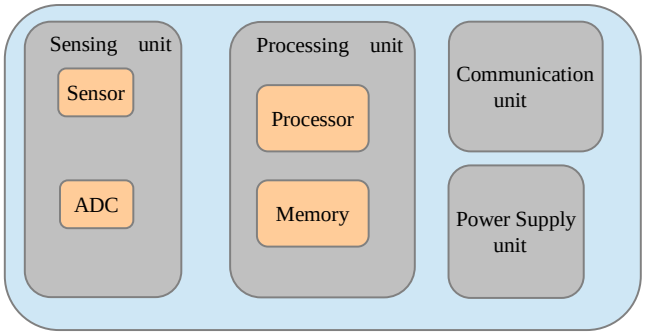
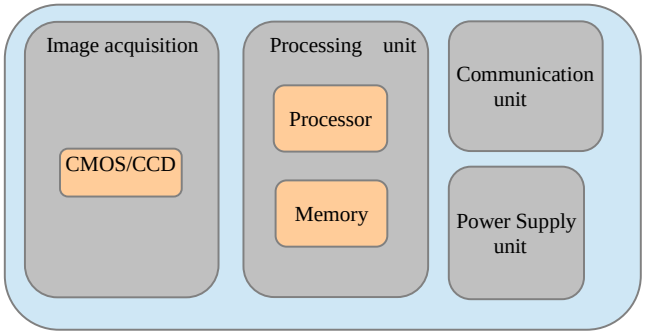
found in sensor nodes. In camera sensor node, the sensor unit is replaced with an image acquisition system. Figure 1 shows the architectures of a traditional sensor node and camera sensor node.



a) Traditional Sensor Node



b) Camera Sensor Node

Figure 1. Traditional Sensor Node and camera sensor node

While the both structures seems to be similar , but there are many big differences between the two nodes. The employed sensors, such as temperature and pressure sensors, typically generate a limited amount of data at quite low rates. Thus, there is no need for high processing capabilities within the node and an ultra-low-power device is able to control the entire process (involving acquisition, processing and wireless communication)[6]. Extra computational capabilities are required for camera sensor nodes. Memory sizes of tens or hundered Kbytes are not suitable for image and video storage. Camera nodes are equipped with larger memory and sometimes they contain different types of memory such as SRAM and DRAM. The node should be equipped with a fast and high efficient processor. DSPs , FPGAs , and advanced fast RISC processors are commonly used for this purposes. Leonardo .et al designed a people counting system based on camera sensor node equipped with ultra power FPGA chip. The developed code has been integrated on the prototype of a WCN node that consumes as little as 5mW[6]. Qin et al. reduced the required network bandwidth using image compression. They developed a low-power JPEG2000 compression technique on DSP-based camera node[10]. Many systems are designed using ready camera based node such as IMB400 and CMUCam2 [5][11]. Figure 2 shows the IMB400 Camera Board combined with The IPR2400 communication board and some other accessories to construct the camera node system[11].

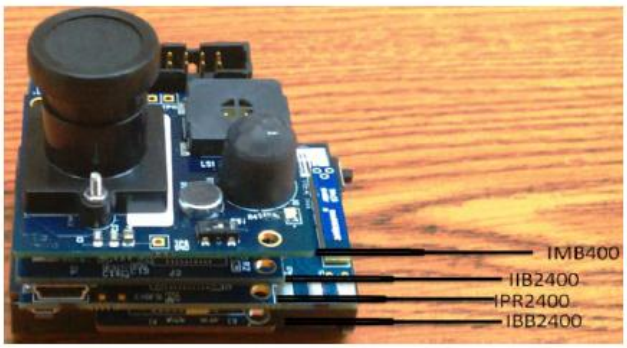


Figure 2. IMB 400 camera node [11]

IV. EVENT DRIVEN MONITORING

To reduce required network bandwidth and the human work, an automatic event detection is developed. Automatic intelligent monitoring can provide video and audio analysis that may generate auto alarms which can strengthen a human's response time and efficiency, while greatly reducing laborious human work The problem is how to bridge the gap between the raw media data and semantic annotation and descriptions[2]. In this research some important events for patient, elderly people and infant monitoring are designed and automatically detected. The following are samples of these events:

1- wake up 2-leave bed
3- move 4- enter room
5- exit room 6- close to object (oven -electricity ...etc)

Automatic detection of events can support the human observer with alerts to attract his attention. In addition to that it can be used to adjust transmission rate, so it can be used to reduce the data transmission in the case of no activities and increase it at the start of an event. The event detection and understanding depends on the motion states. Complex object detection and tracking are avoided for the computation and memory shortage provided by camera sensor nodes. Instead of that motion detection algorithms are used to detect and understand events. A simple user view initialization is needed before running the system. So, after deploying the camera sensor node, the user defines different object locations using simple GUI. The location of these objects are fixed in the capture image as the camera position and orientation are not changed. The motion detection in different zones has different meanings. The states transition of motion detection represent a special scenario and hence a special event. Fig.3 illustrates some zones in the images. For example the event "exit room" consists of motion detection

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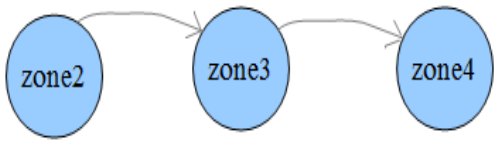
in zone 2 followed by motion in zone 3 ,followed by motion zone 4.

a)



b)

Figure 3. a) zones specification b) state transition for exit event

V. MOTION DETECTION

Motion detection deals with object tracking , classification , and analysis. It depends on the difference between two frames in the video sequence. In this application, we are not interested in the object classification or analysis while the motion detection is only used to attract the attention of some events and the remaining analysis and evaluation of the situation is the responsibility of the human part. there are three commonly used types of moving object detection methods: frame differencing, optical flow and background subtraction[1].

1)Frame Differencing: Frame differencing is to compute difference of a pixel's values in two or three adjacent frames and detect an object pixel using a threshold of the difference[1][12].

2) Optical Flow: Optical-flow-based motion detection uses characteristics of flow vectors of moving objects over time to detect moving regions in an image sequence [12].

3) Background subtraction : Also known as background differencing method, it is the mostly used moving objects detection method. It selects a reference image as the background and uses the difference of the current image and background image to detect moving objects[1].

To reduce the complexity of motion detection, hierarchical structures can be used. Elham et al. used an adaptive deinterlacing method based on variable block-size for motion detection[3]. A combined method of background subtraction and frame differencing is used. The combination of the two methods seems as an adaptive background subtraction. In addition to that, hierarchical structures is used to increase the speed of the system. Noise is found in the motion detection process due many reasons such as lighting , camera orientation deviation , ...etc. These noise appear as small spots or as lines near edges, and they are removed easily using image filters. Fig.4 shows the motion detection for the exit event.

VI. EXPERIMENTS AND RESULTS

The most important factor for the performance and hardware requirements of the system is the image size. The motion detection system is implemented on a PC and tested using different parameters. The memory requirements are calculated for the system. The time and computational complexity are measured on PC which reflects the performance of the system when it is implemented on a camera sensor node.

Table1. Two frames differences (RGB)

Image Size	Time	Memory Requirements
640 * 480	50 ms	1.8 MB
320 * 240	19 ms	456 KB
160 * 120	9 ms	114 KB
Hierarchical	32 ms	1.8 MB

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Figure . 4 motion detection and states for exit event

Table2. Three frames differences (RGB)

Image Size	Time	Memory Requirements
640 * 480	70 ms	2.7 MB
320 * 240	28 ms	684 KB
160 * 120	12 ms	171 KB
Hierarchical	44ms	2.7 MB

Table3. Four frames differences (RGB)

Image Size	Time	Memory Requirements
640 * 480	100 ms	3.6 MB
320 * 240	35 ms	912 KB
160 * 120	15 ms	228 KB
Hierarchical	60 ms	3.6 MB

Table4. Two frame differences (Gray)

Image Size	Time	Memory Requirements
640 * 480	45 ms	614 KB
320 * 240	17 ms	152KB
160 * 120	8 ms	38 KB
Hierarchical	28 ms	614 KB

The result tables illustrate the effects of different parameters on the performance of the system. The motion detection based on hierarchical structure starts with the detection on small scale images then diffuse to larger images. The largest image size only is stored in the memory while the other scales are extracted from it. The hierarchical structure improves the speed while motion zones only are analyzed for large scale images.

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VII. CONCLUSION

The camera based wireless sensor network supplies rich information about the state of patients in e-health applications. The data transmission rate of camera sensor nodes can be dramatically reduced by applying image analysis and processing at the sensor node side. Hierarchical structures for representing images are used to reduce both of required memory and computational complexity for motion detection algorithms, which make it feasible to run these algorithms in tiny sensor nodes. Events detection supply us with a meaningful description of the raw video data, which reduces the human required works and efforts.

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