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Practical design and implementation of recognition assisted dynamic surveillance system ☆

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ABSTRACT

Open Service Gateway Initiative (OSGi) and Open-source Computer Vision (OpenCV) are widely used for developing applications. OSGi is constructed to provide a service platform with high application interoperability while OpenCV is used to provide many application programming interfaces (APIs) about image processing. In this paper, we design a recognition assisted surveillance system based on OSGi and OpenCV platforms. The system features dynamic monitoring by a camera carried by a robot and a Java 2 Micro-Edition (J2ME) viewer on a mobile phone. With the assistance of image recognition techniques, the captured frames are adaptively reproduced for handheld phones in a limited bandwidth environment. The proposed adaptive pause time control mechanism can efficiently improve the synchronization relationship between captured and viewed frames across heterogeneous networks. The evaluation results show that the proposed scheme can save power for the moveable camera and have a shorter time delay between the captured and viewed frames.

1. Introduction

The surveillance system makes a big progress with the assistance of Internet. The revolutionized system can make surveillance users monitor distant events by an Internet browser. Thus the remote live events can easily be seized at anywhere users can access Internet. If the monitoring application can be extended to a handheld device such as a cellular phone, surveillance users can acquire remote events at anytime and anywhere via any available mobile wireless network, such as the General Packet Radio Service (GPRS), Wireless Fidelity (Wi-Fi), and Universal Mobile Telecommunications System (UMTS) to the implementing Worldwide Interoperability for Microwave Access (WiMAX) or 3rd Generation Partnership Project Long Term Evolution (3GPP-LTE). On the other hand, the pre-installed cameras at fixed locations might have less flexibility. If the camera can be mounted on a movable device, a surveillance user may view more unseen corners which may not be caught by the fixed cameras. Furthermore, if the mobile camera and the mobile viewer/commander on cellular phone can be integrated on a common service platform, the service expandability can be achieved. However, the limited screen of mobile phones may hinder the user from clear recognizing the objects. In this article, we aim to implement a recognition assisted dynamic surveillance system by integrating the Open Services Gateway Initiative (OSGi) [1] open service platform and adding in the recognition function supported by the Open-source Computer Vision (OpenCV) [2] development platform. The system also includes a movable camera attached on an embedded system carried by a robot [3] and a viewing Java 2 Micro-Edition (J2ME) [4] application on a cellular phone.

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The OSGi alliance was formed to conduct open specifications for delivering services to local networks and devices [5]. Recently, many developments relating middleware construction are based on the OSGi standard [6–8]. The OSGi service platform, a general-purpose, secure, managed Java software framework, expands Internet services to homes [9–11], automotive [12], health care [13] and so on. OSGi can play a good broker role to aggregate applications. On the other hand, the OpenCV development platform has been used to realize the common image processing and computer vision algorithms including face detection, object segmentation and recognition and so on. The OpenCV APIs facilitate developing recognition assisted functions in our surveillance system with a low development cost. Meanwhile, Lego MindStorms series products have been developed by LEGO Company for years to enable developers to have an inexpensive robotic environment. One of its major contributions is to build simple, portable, and inexpensive experiments for proving the concept of a mobile robot service in the development beginning by not having extensive lab facilities [14,15]. We use Lego MindStorms NXT to carry the movable camera in our system. Thanks to the wireless technology revolution, a wireless user can access Internet services at anytime, anywhere via ubiquitous networks by a multi-mode device. J2ME is a typical mobile based development technologies [16,17]. A J2ME based wireless intelligent video surveillance system was implemented to make a useful supplement of a traditional monitoring system with its good mobility [18].

Our work for implementing the dynamic surveillance system includes building Java based bundles on the OSGi service platform, invoking the OpenCV APIs for frame recognition, controlling Lego MindStorms NXT via a Bluetooth connection by the iCommand Java package and the RXTX library [19], delivering the captured frames to OSGi through a Java based socket, and using J2ME to develop a remote viewer on a multi-mode mobile phone. In such a dynamic surveillance system, captured frames are normally obtained through a higher speed network in a building and then delivered to the remote mobile users through a lower speed network outside the building. The mismatch of transmission capabilities in different networks would affect the viewing continuity and playback liveness. Hence, adaptively pausing some time for frame capturing based on the network quality can save power consumed by the mobile camera. Such a mechanism can efficiently make use of the limited energy on the mobile robot and also can make the remote viewer obtain the captured frames with live event information.

The rest of this paper is organized as follows. Section 2 illustrates some related works about surveillance systems. Section 3 describes the system architecture of the proposed system. Section 4 depicts the operation flow on the system. In Section 5, we practically evaluate the performance of the proposed system in different capturing–viewing schemes and conduct a simple comparison with other surveillance systems. A brief conclusion is presented in Section 6.

2. Related work

In a traditional surveillance system [20,21], many fixed cameras are pinned at fixed locations to capture events. Users then keep a close watch on the videos sent from these cameras via a monitor at a fixed location.

Internet indeed facilitates the remote monitoring but it still lacks some flexibility. In the past, many efforts are put on improving the inflexibility in a traditional surveillance system. A web-based surveillance system in [22] was proposed for surveillance viewers to perform monitoring and controlling remotely by cellular phones. However, if the both sides – cameras and monitors can become movable, the monitoring area can become wider and the viewer can obtain the events remotely anytime and anywhere.

A network camera equipped on a mobile robot [23,24] can help capture events in wider and more dynamic angles. As hardware costs are coming down dramatically and capabilities of robot are increasing fast, robotics is becoming more important in everyday life. A robotic dual-camera vision system [25] is built by composing a telephoto camera whose field of view can be moved within a larger view field of a wide-angle camera. Meanwhile, movable robots can be a good facility to broaden the monitoring vision by carrying the event capturing camera. An autonomous mobile robotic system [26] developed on a multisensory mobile platform can autonomously navigate in the environment and perform surveillance activities. With the integration of current wireless network technology, a robotic surveillance system can extend the security sensing within a home or building environment. The surveillance robot in [27] adopts the ZigBee protocol for wireless communication to become a mobile video sensor node in a ZigBee-based home control network. The 802.11 b-enabled RISCBOT [28] can support online users to easily navigate the environment with assistance of a visual recognition algorithm by a web-based interface. Robotics solutions adapted to the conditions of unstructured and unknown environment can improve safety and security of personnel [29]. However, most of the robotic techniques mentioned above are specially designed for some purpose. A more flexible solution is expected for future extension. Meanwhile, if the surveillance system can be constructed over an extensible platform, the system can be easily integrated with future applications.

On the other hand, the unmatched bandwidth at both ends which are located in different network environments may incur a deferred playback at the viewer side, the transmitted frame rates should be adapted to the heterogeneous network conditions. Adaptive wireless multi-level ECN (AWMECN) in [30] is proposed to conduct rate adaptation and quality adaptation in the application layer for a better quality of service (QoS) on delivering multimedia over heterogeneous wireless networks. A more simple and intuitive way for the rate adaptation is adjusting the capturing period by a adaptive pause time control mechanism at the video input end. Following the above design issues, our work presented in this paper aims to design a recognition assisted dynamic surveillance system by fully integrating wireless, robotics, image processing, and mobile phone techniques.