Demo Abstract: NOMAD – Networked-Observation and Mobile-agent-based scene Abstraction and Determination

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1 Introduction

With the advancement of the sensor network technology and cyber physical systems [2], the merging between the virtual cyber space and the real physical world is bound to happen, which will impact the lifestyle of the human being. The metropolitan area sensor networks, composed of millions of heterogeneous sensors and penetrating every aspect of the city life, provide gigantic amount of real-time information of the city, which makes it possible to reconstruct the real world in an on-line cyber space.

According to neuroscience study, approximately 80% of the information perceived is from one's vision. Similarly, the majority of the current city sensing tasks are accomplished through video surveillance networks. Big cities have been equipped with networked video cameras for traffic monitoring, criminal prevention and forensic collection. Taking London as an example, there are more than 500 thousand cameras deployed currently, and developing city like Beijing is catching up quickly by installing 400 thousand cameras in the past few years.

However, the current video surveillance networks have shortcomings. All the ethic and privacy problems aside, fixed video surveillance networks are limited in performances. First, the fixed installation of cameras restricts the coverage, and improving by installing more cameras are slow and expensive. Second, in current video surveillance systems, video information streams back to a central station to be archived in a storage pool or monitored by people, but the geographic locations and the spatial orientations of the video are not explicit to users. With gigantic amount of video information, retrieving meaningful information requires great efforts and sophisticated skills, which will be undoubtedly infeasible as the system grows bigger. Third, a fixed video surveillance camera acts like a warning sign to people who will possibly commit a crime, but it merely repels the crimes out of its coverage area instead of eliminating them. Crimes still happen in the dead spots of the *big brothers*.

We wish to demonstrate the prototype of the NOMAD system, an enhanced and distributed system for future smart city surveillance. The NOMAD system addresses all the three problems of the fixed video surveillance system, and aims at merging the cyber 3D space and real city in a distributed manner. By networking static and mobile cameras in the city, the NOMAD system provides multi-view observation of the city. By taking the advantage of the mobile agents, scenes in the city can be abstracted and reconstructed, and semantic level information can be determined.

Technically, NOMAD system is composed of car-mounted NOMAD units and information collecting points. Every car-mounted unit includes a camera, a positioning module, a short-range wireless transceiver and an embedded processor. Collecting points are sparsely deployed at roadside, each equipped with an antenna tower and the backbone network access. When the cars traverse across the city, the NOMAD units constantly take snapshots and video clips of their surroundings and buffered them with space and time stamps in the local memory. When they encounter with each other or move into the coverage zone of the information collecting points, buffered information is disseminated between the peers, or uploaded to a surveillance center through the data collecting points. In such a delay tolerant manner, the NOMAD system avoids generating excessive traffic load to the current wireless cellular networks [1].

At the surveillance center, the snapshots, together with their location and time information, can be aligned to the predefined 3D city model. Fig.1 shows the predefined model of an ancient gate on the Tsinghua campus, and its appearances from different angles. The snapshots will be fit into the model and reflect the real appearance of the scene as dynamic textures. In this way, video information from different angles will be merged to reconstruct the real world in the cyber space.

2 On-site Demo

The on-site demo is a prototype of the NOMAD system, and will show our ideas of the future NOMAD deployment in the city. It consists of about 10 NOMAD dollies, one data collecting point, a GUI computer and an indoor positioning system.

We will call for volunteers in the exhibition hall, give out NOMAD dollies and ask them to walk the dollies around. On the dollies are the modules of the NOMAD units, including processors, positioning modules, battery packs, and wireless communicators. Stretching up from the dolly is a light bracket with a stabilized platform on the top, holding the camera and the antenna.

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i) Close-by fixed video surveillance camera view ii) NOMAD view from behind

iii) Remote surveillance camera view iv) NOMAD view from front

Figure 1. Predefined 3D module of a building

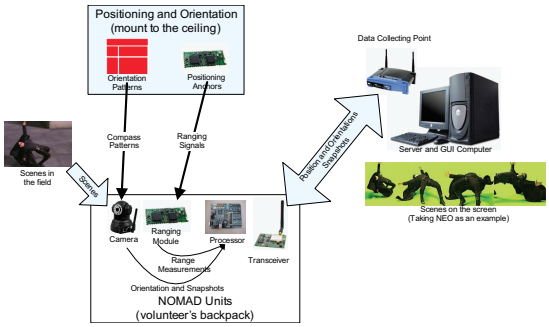

Figure 2. Block diagram of the NOMAD demo system

On the ceiling of the exhibition hall, we will place multiple wireless anchors and color patterns to help the NOMAD units locate themselves. A data collecting point will work on 2.4GHz 802.11a/b/g Wi-Fi channel to acquire snapshots from the NOMAD units.

The GUI computer plays an important role in demonstrating the scene abstraction and determination functions of the NOMAD system. On the screen, audience will be able to read the current and historical locations of all NOMAD units and their camera's orientations. The coverage of the exhibition hall will be calculated and represented in the thermal map style.

The NOMAD's scene abstraction and determination capability will be presented in the following way. When there is a special event happening, people, including the volunteers, will gather around the spot, resulting in a zone with good coverage. The NOMAD system will identify such events by coverage analysis and highlight the zone on GUI. If a user requests to see the scene, multi-angle views of the zone will be abstracted from the NOMAD units and displayed on the screen. The block-diagram of the NOMAD demo system and an example of the scene abstraction is also shown in Fig.2.

3 Key Algorithms

Indoor localization is critical for the functioning of the system. However, the satellite based positioning system such like GPS is not working for most indoor scenarios. Therefore, we have to develop a positioning system for the demo. The system is based on chirp-modulated radio ranging and triangulation algorithms. Plural anchor nodes will be installed on the ceiling to respond to the ranging requests periodically emitted by the NOMAD units. By collecting the ranging packets, the system is able to estimate the distance between the tags and the anchor nodes. Through multiple ranging measurements, the location of the NOMAD units can be calculated.

Besides location, the orientation in NOMAD system is also critical to decide the view of the observation. Visual pattern recognition is adopted to decide the orientation of the camera. Color patterns will be hung on the ceiling of the hall to help camera decide its direction. The patterns are designed in such a way that is immune to the distortion caused by view point changing, and they will be printed in red, which is most sensitive to CMOS sensors. Based on the video pattern recognition and compensated by position, the NOMAD unit could estimate the orientation of its camera. An electronic compass will also be equipped as a supplementary method for the direction detection.

When a user is interested in the situation at a determined location or around a specific person, related snapshots will be abstracted from distributed NOMAD units or the archived data, and comprehensive scene reconstruction based on multiple view angle snapshots can be done on the GUI computer.

On the other hand, if a user sets up a criterion for the scene of interest in terms of popularity (people density in the adjacent area). The NOMAD system can autonomously determine whether such a scene emerged, and abstracts the snapshots from the NOMAD units or the archived data for display when such an event emerges.

4 Conclusions and Future Work

The NOMAD system is an enhancement to current video surveillance system. By taking advantages of the mobile agents and networked observation, it provides rich and comprehensive information of the physical world, and reconstruct them in cyber space. This will help the mergence between the peers.

The NOMAD system will undoubtedly stimulate research efforts in the related areas, for instance, routing algorithms in delay tolerant networks, pattern recognition algorithms to eliminate privacy issues, three dimensional modelling from multiple views, abnormal activity analysis through video sources, etc.

5 Ackowledgements

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6 References

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