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A system for the generation of synthetic Wide Area Aerial surveillance imagery

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ABSTRACT

The development, benchmarking and validation of aerial Persistent Surveillance (PS) algorithms requires access to specialist Wide Area Aerial Surveillance (WAAS) datasets. Such datasets are difficult to obtain and are often extremely large both in spatial resolution and temporal duration. This paper outlines an approach to the simulation of complex urban environments and demonstrates the viability of using this approach for the generation of simulated sensor data, corresponding to the use of wide area imaging systems for surveillance and reconnaissance applications. This provides a cost-effective method to generate datasets for vehicle tracking algorithms and anomaly detection methods. The system fuses the Simulation of Urban Mobility (SUMO) traffic simulator with a MATLAB controller and an image generator to create scenes containing uninterrupted door-to-door journeys across large areas of the urban environment. This 'pattern-of-life' approach provides three-dimensional visual information with natural movement and traffic flows. This can then be used to provide simulated sensor measurements (e.g. visual band and infrared video imagery) and automatic access to ground-truth data for the evaluation of multi-target tracking systems.

1. Introduction

Wide Area Persistent Surveillance is the use of a sensor or sensor network to monitor a very large area, continuously and over long periods of time [1]. This surveillance can provide a variety of information; to allow a forensic analysis of a significant incident (good or bad), or a general analysis of the pattern of life in order to optimize the flow of people or other traffic through a city [2]. In principle, given continuous coverage, it can allow persons of interest to be tracked from one location to the next [1,3] or track stolen vehicles traveling through a road network [4]. Although some data could be provided by ground-based sensors, such as Closed Circuit Television (CCTV) cameras, the simplest way to provide continuous coverage of a city-sized area is to use airborne sensors, such as a Wide Area Aerial Surveillance (WAAS) system [1] incorporating a very high resolution, wide field of view camera system; capable of producing images of the order of a hundred megapixels [5] to several gigapixels [6] in size and at a relatively high frame rate.

The data produced by these devices is of considerable interest to Big Data analysts. The data rate of the sensor will often far exceed the capacity of the communications networks used to transfer the data to the ground for processing [7], and it can easily exceed the ability and availability of human analysts to interpret the data once it has been transferred [1]. This is

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particularly true when the area being surveiled is a complex urban environment, with different types of road traffic (local traffic, arterial flow, and public transport) and a huge variety of behavior exhibited by the individuals. This means that useful or relevant information normally needs to be extracted from the raw sensor imagery automatically, before being forwarded to the next level of processing. The development of automated systems to do this data selection and prioritization is made difficult by a lack of available data on which to optimize the processing. Public datasets monitoring different activities across very large urban areas are not readily available, and benchmark data are not as common as in some other standard image processing applications. Generating the data requires specialized and expensive sensors (which may be restricted to military users), and the use of co-ordinated flights over heavily populated, urban areas. Even when these issues have been resolved, recording large amounts of surveillance data over a city could give rise to legal concerns over the privacy of the individuals being monitored. It can be difficult to anonymize such data, because people and vehicles may be traced to known housing or other locations. Once recorded, there are further problems associated with distributing the large quantities of data involved and with the security of the final data set. In spite of these difficulties, some relevant data sets do exist. Examples of existing WAAS datasets include the Columbia Large Image Format (CLIF 2006, CLIF 2007), the Greene Town Centre (Greene 07), the Wright Patterson Air Force Base (WPAFB 2009), and the Minor Area Motion Imagery (MAMI 2013) datasets, all available from the SDMS website [8].

The data sets that are available for academic study are important for the validation of automated WAAS data processing methods, but they will never offer the flexibility required for the design and optimization of specialist tools and rapid prototyping of new algorithms. In these areas, synthetic image generation has several advantages over pre-recorded datasets, and research into WAAS sensor development could benefit hugely from developments in modelling and simulation methods. In addition to solving many of the problems described in the previous paragraph, synthetic data allows an exploration of unusual camera angles, configurations and parameters, the insertion of special behaviors and events, and (importantly) access to the exact truth data used to generate the imagery. The simulation of wide area video sequences has specific requirements: (i) Consistency – the same quality and level of detail must exist across the simulated area and throughout the video; (ii) Coherency – interactions between people and between vehicles can have far reaching influence and extend throughout the city area; and (iii) Big Data – smaller simulations can choose between simulating a smaller area or duration, whereas wide area persistent surveillance requires both large areas and long periods of time.

This paper proposes a framework for the generation of simulated city-wide image/video data; incorporating the three-dimensional terrain, buildings and road data, modeling the movement of people and vehicles, pattern of life information for individuals and locations, and a high resolution visualization tool that can be used to generate long duration high resolution video data across the city area. The proposed framework is outlined in Fig. 1. It adopts a similar approach to the wide area image generation as the US Army PerSEval project [9] but it takes a person-centric approach, with an individual's route planning, interactions and individual intent being modeled explicitly to provide a more natural representation of the pattern of life. The paper is organized as follows: Section 2 describes how objects traverse the city simulation, switching seamlessly between different simulation engines; Section 3 describes the image generation and configurations of wide field of view cameras; Section 4 covers associated querying and playback tools for city metadata and the large video dataset; Section 5 concludes the paper with a discussion on future expansion of the system.

2. Related work

Most work in the area of traffic modeling and the simulation of pattern of life is aimed at producing an environment where entities or agents can move and interact in a realistic manner and that demonstrate emergent properties that can be studied and related to behaviors in the real world. In particular, with the rapid growth of computing power, there has been a significant improvement in the fidelity of simulations of traffic [10–14] and pedestrians [15]. In addition, the ability to model vehicles in a complex traffic network allows for the improvement of other vehicle simulations, such as driving simulations with realistic vehicle controls and good graphical rendering of the three-dimensional scene for the human operator or driver [16]. The aim of the current paper is to use some of these approaches to populate a large urban or city environment that contains three-dimensional terrain features, real background imagery of the ground, three dimensional buildings, a realistic road network and traffic simulation, and individual people (pedestrians) who are associated with a series of tasks as part of a simulated pattern of life. Although there has been a lot of previous work on developing algorithms to track the movement of vehicles and individuals through such a complex environment, progress in this area has tended to rely on the availability of real image data and a small number of large scale trials involving real sensors. the current work provides an alternative means to generate realistic looking surveillance and reconnaissance data, and the ground truth to be used to evaluate the performance of the algorithms.

The data used in the present work (three-dimensional terrain, background features, road layout and building information) are all derived from open source data sets, whilst the traffic and pedestrian modelling uses a standard and a widely-used open-source simulator. There are a number of established open-source vehicle simulation tools available which operate at different levels of detail and abstraction, divided into the following classifications [17]: Macroscopic simulation - examples of which tend to consider roads load solving as a form of conservation of a quantity entering and leaving the road "pipe", these simulations are applied to strategic planning applications [12]; Mesoscopic simulation - a hybrid approach where microsimulation may be used within the road "pipe" but detailed behaviors such as waiting at junctions to turn etc, may not be present; Microscopic simulation - involves the simulation of individual vehicles traversing the road network and