Camera calibration and vehicle tracking: Highway traffic video analytics

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A B S T R A C T
We describe a real-time highway surveillance system (RHSS), which operates autonomously to collect statistics (speed and volume) and generates incident alerts (e.g., stopped vehicles). The system is designed to optimize long-term real-time performance accuracy. It also provides convenient integration to an existing surveillance infrastructure with different levels of service. Innovations include a novel 3-D Hungarian algorithm which is utilized for object tracking and a practical, hands-off mechanism for camera calibration. Speed is estimated based on trajectories after mapping/alignment with respect to dominant paths learned based on an evolutionary dynamics model. The system, RHSS, is intensively evaluated under different scenarios such as rain, low-contrast and high-contrast lightings. Performance is presented in comparison to a current commercial product. The contribution is innovation of new technologies that enable hands-off calibration (i.e., automatic detection of vanishing points) and improved accuracy (i.e., illumination balancing, tracking via a new 3-D Hungarian algorithm, and re-initialization of background detection on-the-fly). Results indicate the capability and applicability of the proposed system in real-time and real-world settings.

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1. Introduction

Intelligent traffic systems (ITS) have been expanding with incorporation of multiple technologies into vehicles, roadway, highway, tunnel and bridge surveillance. Such include image processing, pattern recognition, electronics and communication technologies. These have been employed for monitoring traffic conditions, reducing congestion, enhancing mobility, and increasing safety. Vision-based technology is a state-of-the-art approach with advantages of easy maintenance, real-time visualization and high flexibility compared with other existent technologies. This makes it one of the most popular techniques in ITS for traffic control. The most recent widely read description of vision-based highway surveillance is that of Coifman et al. (1998). The last one and a half decades have witnessed improvements in cameras, communications, and video analytics. This paper presents an update to the latter.

Modern commercial vision-based surveillance systems have improved considerably since the tripwire systems described by Coifman et al. (1998). Many commercial systems may be tailored to monitor either freeways, arterials, bridges, or tunnels (Econolite's Autoscope Solo Terra, Traficon's VIP/T, Citilog's XCam-I, Kapsch Trafficcom AG's VR-2). There are about two dozen products by approximately a dozen vendors that have a freeway option. In contrast to the earlier survey cited (Coifman et al., 1998), today's systems all incorporate vehicle tracking. Incidents reportable by the systems include wrong-way driver
Dynamic scene modelling and anomaly detection based on trajectory analysis

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Abstract: A real-time scene modelling approach is presented that recognises temporary and permanent road structure change resulting from construction, accident or lane expansion and other obstructions. The system defined utilises a two-phase approach to modelling the scene. In the transitional phase, a dominant set-based graphical clustering approach is applied to understand the current scene structure from trajectory groupings, whereas the operational phase analyses the trajectories in real-time to detect anomalies such as u-turns, wrong-way or erratic drivers based on the acquired model of the scene structure and normal traffic patterns. In addition, the concept of dynamic traffic flow analysis is utilised to identify and remember temporary additions and removals of paths due to construction and accidents, as well as permanent road structure changes. An intuitive equal-arc-length sampling is applied to extract only the spatial information from the trajectory comparisons, since the spatial characteristics alone are sufficient for road structure understanding. A distance metric is developed to measure spatial difference and directional change of the path with entrance and exit awareness. Results for a publicly available dataset are provided, demonstrating that the method can efficiently model the scene, detect anomalies and capture both temporary and permanent scene reconstructions.

1 Introduction

Societies around the globe have become accustomed to the ubiquitous presence of cameras in the public and corporate space for purposes of security, monitoring and safety. Applications include highway or intersection surveillance, security monitoring in sensitive areas such as airports, railway station, parking lots, shopping malls, retail spaces and office buildings, and many others. In these applications what is generally studied is scene modelling, behaviour prediction or anomaly detection of individual agents or groups of agents. Learning behaviours are also occasionally studied.

Trajectories are one of the most popular spatial and temporal representations for an object’s motion in these different scenes or scenarios. Our infrastructure assumptions may be visualised as surveillance video subjected to video analytics to extract the trajectories. However, other configurations might be acceptable. For example, on-board units which process and communicate features to a road-side station as envisioned in [1]. Although the examples given here feature intersections, the approach would be a suitable component of the intelligent vehicle system [2] as it expands. Through analysis of trajectories, the normal and abnormal behaviour of objects and the dynamic structure of the scene can be determined and monitored.

Based on the complexity of the representations, problems involving trajectories can be categorised into two types: structured and arbitrary trajectories. Structured trajectories are defined as descriptors for moving objects in specific scenes in which an object’s motion is constrained by the various structures in the environment. A good example of this would be the roads, curbing, turn lanes, traffic signals and other characteristic structures in an intersection between two roads. Arbitrary trajectories, on the other hand, are not typically heavily influenced or constrained by the environmental structures. Examples of arbitrary trajectories include the path of a storm, migratory tracks of wild animals or the movements of the hands and feet of a dancer. More complicated representation is required for the arbitrary trajectories since it incorporates a higher freedom of movement.

This effort addresses the analysis of structured trajectories in order to gain an understanding of an object’s typical and atypical behaviours, as well as to determine the dynamic characteristics of the environmental structures that affect the behaviour. In particular, we undertake the monitoring of a traffic environment such as an intersection with the goal of generating alerts when overall traffic patterns, as well as individual incidents, differ from the typical and expected behaviours.

The novelty of our approach lies in the dynamic and online techniques applied to the monitoring process and alert generation. As trajectories are observed they are classified based on the behaviour of the previous set of trajectories. One would expect, over time, to observe a finite, repeatable set of behaviours. When one or more trajectories differ from the expected set of behaviours, this creates an anomaly. This anomaly could be the result of a traffic...
A nonparametric approach to region-of-interest detection in wide-angle views

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ABSTRACT

We propose a tracking-free method to detect the regions of interest (ROI) in a wide-angle video stream. A region is defined as a statistical outlier among occurrences of motion patterns, and is detected in an unsupervised manner. Based on 3D structure tensors, the activity at any site is modeled by the probability distribution of distances between structure tensors. The distribution is estimated using a nonparametric kernel density estimator. The detection of regions is determined by observing a long period of low-probability motion occurrences. Experiments performed with real-world datasets indicate that the proposed algorithm can detect both spatial ROIs and spatio-temporal ROIs, and outperforms other nonparametric methods.

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1. Introduction

Efficient region of interest identification has been an active topic in computer vision fields such as visual attention in images and anomaly detection in video sequences. Currently the cameras record sufficient visual information for monitoring purposes. In fact, in most instances it is impractical for either human observers or automated systems to analyze each pixel in detail. Therefore selective operations are needed at different sites in a visual scene. Through region-of-interest (ROI) detection, non-interesting (e.g. normal) events can be excluded and further explicit event recognition methods can be applied to the remainder. This mimics the primates’ visual system. However, it is not a trivial problem for man-made systems to understand the scenes and perform such selective processing.

The localization of ROIs becomes more urgent when given wide-angle camera views with background motion clutter. Most surveillance videos are produced in this manner to obtain a large and efficient coverage of a monitored area. The challenge we address is that the greatest portion, both spatially and temporally, of the video is not of interest. Traditional approaches such as tracking-based methods are not efficient, especially in clustered scenarios. Tracking-based approaches perform well in narrow-angle views or sparse scenarios with limited objects. In wide-angle views much more information must be processed which lowers the efficiency. More importantly, because it is not goal-driven, much computation is needed to establish which are the “normal” trajectories or other representations. Therefore, some researchers have begun applying methods that first localize the regions of interest, followed by operations such as tracking and anomaly recognition. This work is also motivated by this framework. The focus is on identifying potential ROIs in videos for further analysis.

Region of interest detection is basically a classification problem for which visual information is assigned labels of “interesting” and “non-interesting”. For local feature representation, the description can be descriptive (such as common trajectory) or probabilistic (such as histogram). Correspondingly, the identification of local interest is based on the distance or probability of an observation compared with the canonical description. The relationships among information of different sites are also exploited in some probabilistic graphical models (e.g. conditional random fields). In order to model the information and detect the regions of interest, existing studies mainly use local information to model the activities [14,26,16]. Usually it is assumed that the statistical information follows a basic distribution (e.g. Gaussian) or a mixture of them. The training phase is designed to compute the parameters according to optimization criteria. It is not always straightforward to estimate the parameters and it is difficult to determine the form of the distribution or the number of the mixed models that should be applied to arbitrary videos. The innovations of the described method are given below.

- 3D structure tensors are used as the basis to extract tracking-free features to characterize the motion and spatial dimensions concurrently; bypassing object tracking avoids the computational expense and the errors it may induce.

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Abstract—In this paper we present an automatic vehicle ingress/egress counting method by clustering dense trajectories extracted from monitoring videos. Dense trajectories are extracted based on dense optical flow when passengers cross the door of the vehicle, and then clustered into different groups according to their descriptors with each legitimate group as a passenger. The contribution of the proposed method is twofold. First, we put forward an online passenger counting framework which is based on feature-points tracking and can be easily deployed to different scenarios. The method works even in low illumination conditions as demonstrated in experiments. Second, vehicle running information was combined to improve the accuracy of passenger counting. The transit vehicle settings are unconstrained and complex due to variations from illumination, movement and uncontrolled passenger behaviors. We tackle this by incorporating different modalities besides videos such as the status of the vehicle (e.g., in motion or not). The experimental results on multiple real bus videos show that the proposed system can count passengers with average accuracy of 94.9% at an average frame rate of 38 fps.

I. INTRODUCTION

Accurate ridership estimation is an essential step in intelligent transportation network evaluation and planning. Developing an automatic passenger counting (APC) system has both scientific and commercial interest. It requires an efficient solution to passenger detection and counting, and robust treatment to varying bus running states and lighting conditions. The application of APC can save time and labor for transportation agencies. In this work, we introduce an automated solution to automatic passenger counting problem by tabulating the number of vehicle ingress and egress.

There exist many people counting approaches and systems using different techniques and data sources. Attempts include contact-type counters and non-contact infrared beams and radio frequency sensors. While they can achieve high accuracy when applied properly, such equipment induces additional deployment and cost. Machine vision technologies provide an ideal potential for the passenger counting since video cameras have been widely mounted on buses and other transit vehicles. They use the same data sources (i.e., ordinary camera videos) as a human rider checker does. Therefore, the solution we present in this paper explores video analytics based on dense passenger trajectories, and it achieves sufficient accuracy for passenger counting (i.e. 95%).

Vision-based counting and flow estimation have attracted interest in computer vision and intelligent systems communities, such as Refs. [1], [2], [3] for general people counting and Refs. [4], [5], [6], [7], [8] for passenger counting on public transportation. Existing approaches for passenger counting can be divided into the following three categories: body-part-recognition-based, passenger-segmentation-based and feature-point-tracking-based. Body-part-recognition-based approaches detect (and probably track) the body parts of a passenger such as heads and shoulders [3], [5], and then count based on the detection results. A challenge with body-part-recognition-based approaches lies in the fact that most bus surveillance videos are recorded in low illumination with low resolution, which makes it difficult to extract distinctive features of the passenger body parts. A similar challenge exists for segmentation-based approaches.

The proposed method in this paper can be categorized as among the feature-point-tracking-based approaches. It tackles the problems under low lighting conditions where traditional body-part recognition fails. In addition, the proposed method is easily applied to scenarios where the cameras are not mounted overhead, a condition under which most existing papers reported their results. The proposed method provides a complete solution to detecting type (i.e. boarding or alighting) and counting occurrences. We evaluate our approach using real bus surveillance videos captured by Fort Worth Transportation Authority (FWTA) in the USA.

A. Related Work

Trajectories have been utilized for action detection and recognition for a long time as reviewed in [9], and are still explored for video analysis [10], [11], [12]. Feature-point-based trajectories have been used more widely than object-based trajectories in the context of passenger counting [4], [6], [7], [8]. In [4] the authors divide image frames into blocks and select moving pixels based on eigenvalues of structure tensors. The direction of the movement is determined by the usage of two virtual base-lines. [6] takes a clustering-based approach. The authors cluster the obtained trajectories into trajectory groups, each of which then corresponds to one passenger. In addition, it uses only one virtual tripwire. However, the paper only tackles “getting in” without consideration on the discriminating between boarding and alighting. A real-time dense stereo-matching procedure is proposed in [8] for estimation of passenger flows. It computes a disparity map by a stereo-matching for each pair of images, and gets

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Automated Two-dimensional-three-dimensional Registration using Intensity Gradients for Three-dimensional Reconstruction

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Yassine Belkhouche
Stephen Jackson
Bill P. Buckles
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ABSTRACT
We develop a robust framework for the registration of light detection and ranging (LiDAR) images with 2-D visual images using a method based on intensity gradients. Our proposed algorithm consists of two steps. In the first step, we extract lines from the digital surface model (DSM) given by the LiDAR image, then we use intensity gradients to register the extracted lines from the LiDAR image onto the visual image to roughly estimate the extrinsic parameters of the calibrated camera. In our approach, we overcome some of the limitations of 3-D reconstruction methods based on the matching of features between the two images. Our algorithm achieves an accuracy for the camera pose recovery of about 98% for the synthetic images tested, and an accuracy of about 95% for the real-world images we tested, which were from the downtown New Orleans area.
Video Stabilization Using Principal Component Analysis and Scale Invariant Feature Transform in Particle Filter Framework

Yao Shen
Partha Guturu
T. Damarla
Bill P. Buckles
Kamesh Namuduri

ABSTRACT
This paper presents a novel approach to digital video stabilization that uses adaptive particle filter for global motion estimation. In this approach, dimensionality of the feature space is first reduced by the principal component analysis (PCA) method using the features obtained from a scale invariant feature transform (SIFT), and hence the resultant features may be termed as the PCA-SIFT features. The trajectory of these features extracted from video frames is used to estimate undesirable motion between frames. A new cost function called SIFT-BMSE (SIFT Block Mean Square Error) is proposed in adaptive particle filter framework to disregard the foreground object pixels and reduce the computational cost. Frame compensation based on these estimates yields stabilized full-frame video sequences. Experimental results show that the proposed algorithm is both accurate and efficient.

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Iterative TIN-Based Automatic Filtering of Sparse LiDAR Data

M. Y. Belkhouche

Bill P. Buckles

ABSTRACT
A novel method for automatic separation of terrain points and object points using sparse LiDAR data is developed. The proposed method is based on iterative elimination of step edges connecting terrain points to object points. The first step is to detect these edges. Using a triangulated irregular network (TIN) interpolation of the LiDAR raw points, each triangle is assigned to one of two classes: edge triangle or non-edge triangle, using the slope as the discriminative function. Edge triangles are located at the boundary between terrain and non terrain points, therefore the vertices of each triangle consists of terrain and object points. Initially the lower points are considered as terrain points and the higher points are object points. The elevation of object points is adjusted using an interpolation method based on estimated local slope. The local slope is calculated using non-edge adjacent triangles to the step triangle. The slopes of modified triangles are recalculated using the new elevation. This process is repeated until no triangle is assigned to the edge triangle class. At the end of this process, all the adjusted points are classified as object points and the other points are considered terrain points. Validation is done by computing the type I (terrain points misclassified as object points) and type II (object points misclassified as terrain points) errors.

We used two large data sets containing many complex objects. We achieved an overall accuracy higher than 90%, and an average error less than 10%.

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Analysis, Modeling, and Rendering of Urban Flood Events

Bill P. Buckles
Laura Steinberg
Xiaohui Yuan
Xiaoping Liu
Liangmei Hu
Yassine Belkhouche
Bradley Cromwell

ABSTRACT

911 control centers wish to know the extent of flood given verbal eyewitness reports of depths at specific sites. First responders, given a flood extent map, might wish to know if a high-water vehicle can navigate a specific route. Before an event, FEMA needs accurate elevations in for issuing FIRMs (Flood Insurance Rate Maps). Many of these needs can be addressed via prior-collected data from a ranging sensor, LiDAR, in which an increasing number of municipalities are investing.

Working with organizations such as regional council of governments, FEMA, and the Army Corps of Engineers, we are integrating LiDAR with other data sources to obtain data products of higher value and accuracy. Specifically, we are determining terrain and building structure properties that lead to a better understanding of the potential risks of wind and flood damage as well as provide post-event assessment. This entails solving several problems in both the science domain and the application domain. In the application domain there are issues relevant to determining accurate breaklines, accurate roof topologies, and building heights and footprints. We address all of these.

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A WAVELET-BASED NOISE-AWARE METHOD FOR FUSING NOISY IMAGERY

Xiaohui Yuan
Bill P. Buckles

ABSTRACT
Fusion of images in the presence of noise is a challenging problem. Conventional fusion methods focus on aggregating prominent image features, which usually result in noise enhancement. To address this problem, we developed a wavelet-based, noise-aware fusion method that distinguishes signal and noise coefficients on-the-fly and fuses them with weighted averaging and majority voting respectively. Our method retains coefficients that reconstruct salient features, whereas noise components are discarded. The performance is evaluated in terms of noise removal and feature retention. The comparisons with five state-of-the-art fusion methods and a combination with denoising method demonstrated that our method significantly outperformed the existing techniques with noisy inputs.
A PREPROCESSING METHOD FOR AUTOMATIC BREAKLINES DETECTION

M. Yassine Belkhouche
Bill P. Buckles
Xiaohui Yuan
Laura Steinberg

In the recent years, digital terrain models (DTMs) have been used in many applications such as hydrology for flood modeling, forest fire prediction and placements of antennas. Developing an accurate DTM that reflects the exact behavior of the terrain surface is a very complicated task. Different methods have been developed for DTM generation from LIDAR cloud points using interpolation methods. These methods include inverse distance weighting, kriging, as well as rectangular or triangular based methods.

In some areas where the surface behavior (slope) changes rapidly, interpolation methods incur large errors. Different situations can be identified. For example, in the case of step edges, interpolation has to be done separately on the upper and lower surfaces. The same situation appears in case of buildings, bridges and other elevated structures. For this reason, introducing a line that separates the two sets of points is necessary. Such lines are called breaklines. After the detection of all the breaklines, interpolation methods can be used for each set of points independently. Since the manual determination of breaklines is time and labor consuming, developing an automatic method becomes very important.

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}
AN ADAPTIVE METHOD FOR THE CONSTRUCTION OF DIGITAL TERRAIN MODEL FROM LiDAR DATA

Xiaohui Yuan
Liangmei Hu
Bill Buckles
Laura Steinberg
Vaibhav Sarma

LiDAR (Light Detection And Ranging) is an active sensor now approved by FEMA for construction of digital terrain models (DTMs). A LiDAR acquisition device measures the distance to the target by calculating the time spent in signal reflection. Together with a Global Positioning System and an Inertial Navigation System, a three-dimensional (3-D) land surface topology is obtained via an airborne LiDAR. The applications of LiDAR began slowly but are gaining momentum as the instruments and support for them improve [1, 2]. Given elevations, urban landscapes can be accurately visualized in 3-D, damage from natural disasters can be assessed (based on pre- and post-disaster data) or predicted (given the water level), line-of-sight analysis for proposed transportatio n corridors can be performed, and fine-scale air contaminant models which rely on accurate depictions of the cityscape can be improved. An important step in many of these applications is to separate bare earth measurements and construct a DTM. In this paper, we present an adaptive method to remove above-ground LiDAR measurements and generate DTMs. LiDAR returns from New Orleans are used to test our algorithms.

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Video traffic surveillance is expensive because of the high cost of initial investment, long term maintenance, communication service fee, and the requirement of operator monitoring of the visuals. Low- and medium cost cameras are proliferating. Coupled with the advance of wireless communication technologies, it is timely for TxDOT to investigate how to bring the costs of traffic surveillance down to allow large coverage and safety. The objective of this project is to enable TxDOT districts to deploy video surveillance cameras with ease and low cost. Towards this objective, we will achieve four goals in the project. The first goal is to compile a list of low cost camera technologies appropriate for traffic monitoring and compare them. The second goal is to survey the current communication technologies applicable to traffic video surveillance and compare the installation and maintenance costs. The compatibility of the video cameras with the telemetry methods will be investigated as well. The third goal is to propose and prototype a system architecture that will allow the detection of vehicles and pedestrians and transmit the processed data to a TMC. The fourth goal is to investigate video analytics to allow autonomous monitoring of typical situations and generate alarms when necessary. This approach can free operators for other important duties and allow continuous monitoring thus improving safety.

The system will be prototyped and tested on a selected freeway site and integrated with an existing TMC. We will examine the Core Technology Architecture of TxDOT to produce implementation guidance on how the developed system can be integrated with existing TMCs.
LiDAR (a laser-based instrument that produces elevation maps when used from airborne platforms) is valuable for flood plain maps and approved by the Federal Emergency Management Agency (FEMA) as a source for digital flood insurance rate maps (dFIRMs). The vast majority of LiDAR is collected at low densities specifically for this purpose and, as a result, has little other value. Our ultimate goal is increasing the utility of low-density LiDAR. One way is to fuse the LiDAR data with visual images. The combination of LiDAR and visual imagery will be used to build large-scale 3D maps of the areas under observation which will be converted, in part, to GIS products.

LiDAR and optical imagery is presently used for urbanscape rendering, line-of-sight analysis, land-use classification, etc. Each of the application domains mentioned requires data density to be high and acquired at additional cost by flying missions at lower altitudes. The densities thus obtainable are 3-12 pts/sq m. The vast majority of LiDAR data will continue to be collected for flood plain maps. Since FEMA requires only 19ft. horizontal accuracy for contour maps, the density is typically 0.1-0.2 pts/sq m. As instruments improve, missions will be flown at higher altitudes to further reduce costs. It is the lower end of the density spectrum on which we concentrate.

The existing practice (previous paragraph) makes obvious two issues that must be addressed in creating new value from sparse LiDAR. **(1) Coregistration** - Coregistration of 2D images and 3D LiDAR is formulated as a correspondence problem, solved by matching techniques. This leads to derivative issues. For example, matching involves feature extraction, feature description, and search for correspondence across both modalities. Because we plan to build large-area maps (mosaiking), we must also address 2D to 2D and 3D to 3D registration. **(2) Rendering** - Rendering is the extraction of a 3D model for the purpose of visualization. In addition to the derived issues noted for registration, the issue of feature-level fusion exists. Underlying both coregistration and rendering is the problem of validation. This alone is rich in research opportunities and our work plan devotes adequate resources to it.

This research will lead to new technologies that increase the utility of sparse LiDAR in construction projects related to roadways, railways, oil and gas pipelines, electric transmission lines, communication networks, ports and harbors. LiDAR data has potential to be effective in disaster response planning, particularly during floods. In such projects, speedy collection of accurate topographic data is an important factor.
SGER: A New Tool for Economic and Environmental Planning – Expanding the Boundaries of LiDAR (NSF IIS-0722106)

Bill Buckles, PI
Laura Steinberg
Xiaohui Yuan

LiDAR (Light Detection And Ranging) is an active sensor now approved by FEMA for construction of digital terrain models (DTMs) and digital elevation models (DEMs). DTMs and DEMs, together with appropriate GIS layers, are key sources for the construction of digital flood insurance rate maps (DFIRMs). LiDAR use has not yet supplanted the USGS-generated DEMs and DTMs that have been available for decades. However, the momentum is in that direction. We wish to turn the attention of agencies at the state and local level to other possibilities for obtaining value from the LiDAR data they are already collecting.

To do so, we intend to show that LiDAR - combined with multispectral data - can (1) detect watersheds in urban areas that are at the scale of a neighborhood thus can be used for storm drainage management, and (2) collect sufficient detail of the urban structural landscape to be of real use in predicting property damage for given catastrophic events such as floods or earthquakes.

We employ a set of tasks that include selecting urban sites for study. We have both the LiDAR and IKONUS multispectral imagery for New Orleans, Louisiana. By a combination of new analytical techniques, field observation, and comparison to standard datasets, we will increase the value of LiDAR data now owned by many jurisdictions. Key to our approach is the development of a set of information-fusion related algorithms that answer each of the questions: (1) Can present USGS DEMs and DTMs be improved by automatic detection of break lines and neighborhood-scale watersheds gleaned from LiDAR elevation data fused with multi-spectral imagery? (2) Can the heights, geometries, and footprints of buildings be determined with an accuracy sufficient for disaster assessment? (3) Can the fusion product provide a modeling tool to predict, given factors such as water rising level, the potential damage and provide valuable information for pre- and post-disaster planning?

An interdisciplinary team from the University of North Texas and Southern Methodist University is in place. It includes an environmental engineer and two computer scientists. Each is supported by capable technical staff and laboratory associates.
This proposal extends a funded Digital Government project entitled “SGER: A New Tool for Economic and Environmental Planning - Expanding the Boundaries of LiDAR” (proposal ID: 0722106). LiDAR (Light Detection And Ranging) is an active sensor approved by FEMA for construction of digital terrain models (DTMs) and digital elevation models (DEMs). DTM s and DEMs, together with appropriate GIS layers, are key sources for the construction of digital flood insurance rate maps. FEMA-specified LiDAR products are primarily designed for terrestrial floodplain mapping applications. In our previous proposal, the key was to develop information fusion related image understanding algorithms that answer three questions: (1) Can present USGS DEMs and DTMs be improved by automatic detection of break lines and neighborhood-scale watersheds gleamed from LiDAR elevation data fused with multi-spectral imagery? (2) Can the heights, geometries, and footprints of buildings be determined with an accuracy sufficient for disaster assessment? (3) Can the fusion product provide a modeling tool to predict, given factors such as water level rise rate, the potential damage and provide valuable information for pre- and post-disaster planning?

In this project, this collaborative work focuses on multispectral data aggregation and 3D visualization. Our goal is to answer the following question: Can 3D model be generated and strategic planning questions, e.g. given a flood stage visualize the flooded area, possible breaching locations, and elevations of water around building footprints, be answered? The China/US team plan two tasks to achieve this goal. First, we will develop a method to render photogrammetric and processed images over the “surface” of the reconstructed 3-D model from LiDAR data. Second, develop an integrated visualization tool. The data needed is the building footprints, building heights, and structural form of the roofs. These are similar to specific data products from the previous project and, with some additional effort, they can be extracted from the disaster maps. The data support will be extended to include a km² region of Hefei, China.