5th International Conference on
Structural Health Monitoring of Intelligent Infrastructure (SHMII-5) 2011
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COMMERCIAL REMOTE SENSING AND SPATIAL INFORMATION TECHNOLOGIES IN TRANSPORTATION

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Abstract:
Recent developments in remote sensing technologies have paved the way to numerous potential planning and engineering applications; This paper outlines the efforts of US Department of Transportation to leverage the most current remote sensing and spatial information technologies, methodologies and practices for specific applications targeted towards development of transportation infrastructure planning, development, construction and condition assessment processes. The paper highlights various areas of applied research from the context of infrastructure condition assessment/health monitoring to include highways, bridges, ports and other transportation modal applications. The paper illustrates specific project applications of various remote sensing technologies and present key findings, uses, challenges and recommendations for future potential application.

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ABSTRACT: Recent developments in remote sensing technologies have paved the way for numerous potential planning and engineering applications; This paper outlines the efforts of US Department of Transportation to leverage the most current remote sensing and spatial information technologies, methodologies and practices for specific applications targeted towards development of transportation infrastructure planning, development, construction and condition assessment processes. The paper highlights various areas of applied research from the context of infrastructure condition assessment/health monitoring to include highways, bridges, ports and other transportation modal applications. The paper illustrates specific project applications of various remote sensing technologies and presents key findings, uses, challenges and recommendations for future potential application.

1 INTRODUCTION

The concept of remote sensing generally refers to instrument –based techniques adopted in the acquisition and measurement of spatially based information of specific attributes of target subjects that are related to classes, features, objects and/or materials. Various civil engineering applications of remote sensing and spatial information technologies include disciplines such as regional planning, site investigations, topographical studies, terrain mapping and analysis, water resources engineering, infrastructure development and planning, transportation network analysis and operations, landside analysis etc.

The US Department of Transportation initiated a program in 2006 to conduct applied research investigation of commercial remote sensing and spatial information technologies for use in infrastructure planning, development and construction, operations and maintenance inspections by applying emerging advances in products and systems. The objective of the Program is to validate new applications that offer smarter, safer, efficient and cost competitive transportation services, methods, and processes to enhance conventional approaches and trends.

2 PROGRAM INITIATIVES

The intent of the program was to explore remote sensing applications throughout the various modes of operations – ranging from highways and waterways to transit. With the aim to target modal application several initiatives were formulated and developed to cover areas such as:

2.1 Infrastructure Development Planning

The infrastructure development, planning and decision making process is burdened with challenges of collecting data, adopting innovative methods and timely implementation of new technologies for efficient movement of people and freight. The purpose of the initiative was to apply remote sensing technologies to collect data and develop innovative frameworks and methodologies for analysis in studies and projects in infrastructure development and to reduce congestion and improve safety within the infrastructure systems such as ports, urban corridors and gateways. The results would lead to application of space-based technologies to improve existing planning procedures and/or to develop new procedures to aid and enhance current practices in infrastructure development planning.

2.2 Infrastructure Construction, Condition Assessment and Asset Management

This initiative focused on validating new methods, tools and systems for cost effectively monitoring the quality of construction and condition of the physical infrastructure. The purpose of the initiative was to implement remote sensing technologies and products for achieving smarter, automated and non-intrusive methods for quality control of infrastructure construction and also to develop capabilities for asset management and condition assessment for maintaining performance and continued serviceability, after construction. The results would lead to longer performing physical infrastructure and significant savings of construction, repair and rehabilitation cost for transportation agencies. The application tools would also contribute to reducing the cost for inventorying and inspecting physical infrastructure systems for asset management.

3 SENSING PLATFORMS

The application of new sensing technologies can be potentially applied from a variety of spatially distributed platforms such as satellite based medium to high resolution imageries, above ground aerial platforms and unmanned aerial vehicles that can operate under predetermined trajectories over selected areas of transportation systems and infrastructures such as bridges, rail lines, highways, airports, marine terminals and

transit operations. In addition, to compliment the data collection effort, spatial information technology methodologies and products such as geographic information systems, global positioning systems and other intelligent transportation systems are essential to the overall remote sensing process.

4 PROJECTS

A competitive process was adopted to solicit proposals and select projects for the conduct of applied research in various areas of transportation applications from pavement structures, bridges to freight movement and corridor planning. A few representative projects are illustrated below to highlight examples of remote sensing applications in transportation:

- *Integrated Remote Sensing and Visualization (IRSV) System for Transportation Infrastructure Operations and Management (University of North Carolina, Charlotte)*

The project explored and developed innovative remote sensing methods for bridge management systems; the project targeted: 1) application and validation of new remote sensing technologies for use in applications in bridge management systems at the state and local levels, and 2) application of remote sensing methods and technologies to existing structure condition assessment. The system (Figure 1) was built on a large Geographic Information System based platform and utilizes Light Detetction and Ranging scans, visual inspection and large-scale data visualization methods. It assisted the process of validation of remote sensing applications for infrastructure asset management and construction delivery by providing meaningful structural information including post construction deliverables and real-time structural loss estimation from daily operations (Boyle et al. 2010 and Chang et al. 2010).

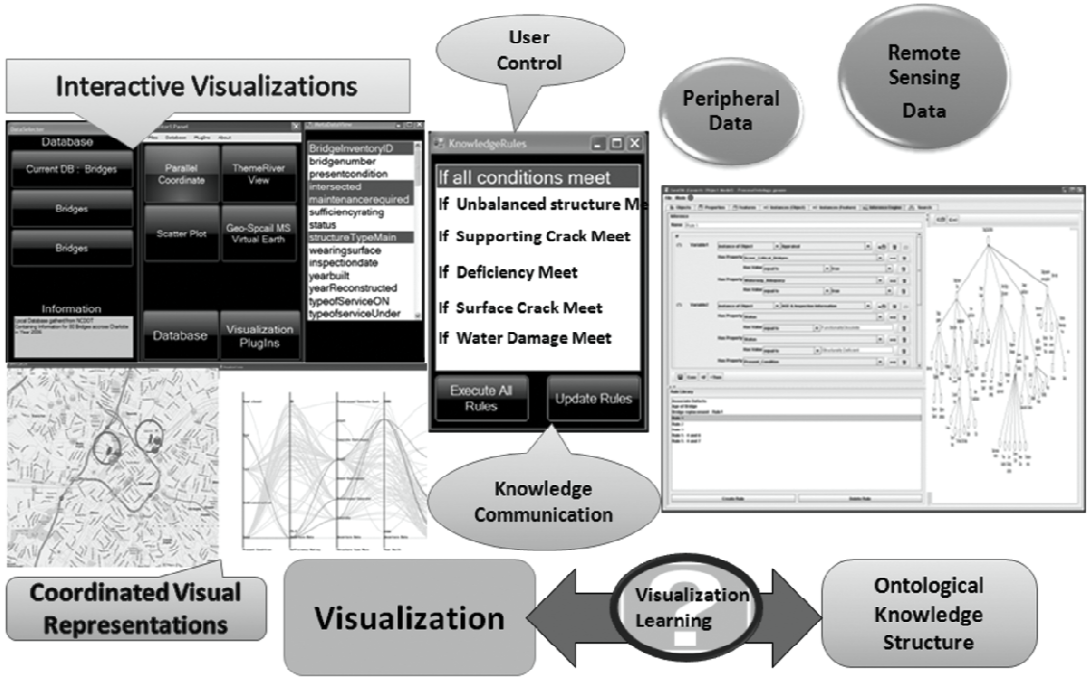

Figure 1. IRSV System Architecture Overview.

- *Bridge Condition Assessment Using Remote Sensors (Michigan Technological University)*

The project explored the correlations among in-situ, stand-off and remote sensor systems. A decision support system (Figure 2) was developed to combine inputs from various data sources to create a unique bridge signature, which could be tracked over time to assess changes in bridge condition and provide the bridge engineer an up-to-date status on the health of bridges (Ahlborn et al. 2010).

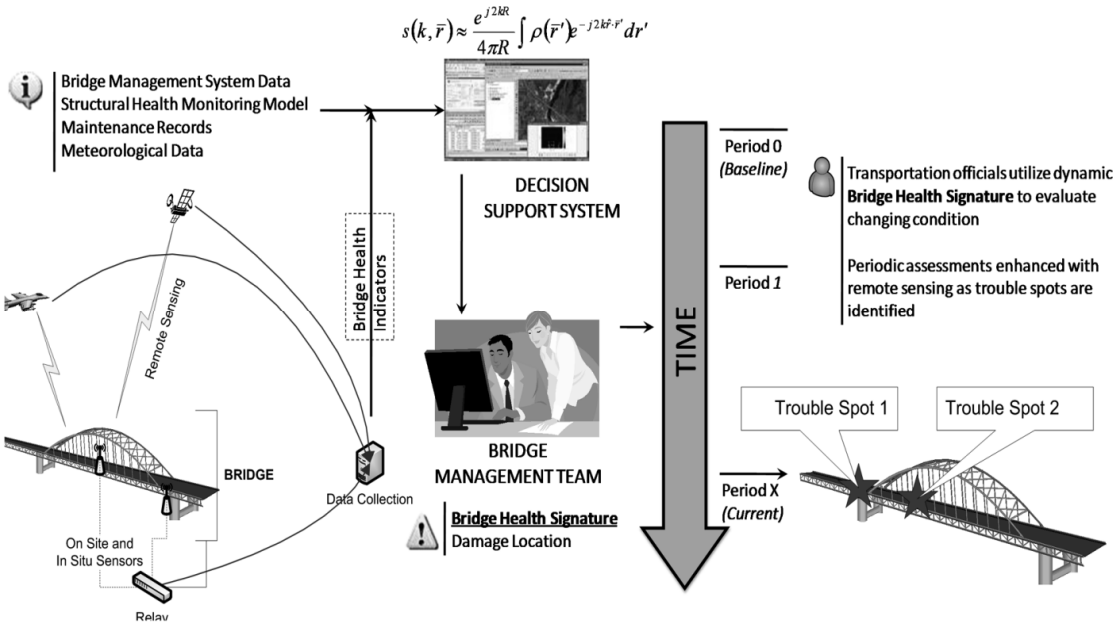

Figure 2. Bridge Health Monitoring Concept.

- *Enhancing Monitoring and Planning of Network Infrastructure with Remote Data Collection (University of Arizona)*

The project was an investigation of enhanced use of traffic flow data from remote sensors for better monitoring of traffic and transportation infrastructure with a focus on: (1) data infusion of simultaneous data collected from airborne and ground sensors for infrastructure monitoring; (2) use of remotely collected data for developing better models for network planning; and (3) emergency operation, and developing tools and enhancing "enabling" technologies for airborne data collections.

- *Multimodal Short Sea Freight Shipping System (George Mason University)*

This project is focused on development of systems concepts for increasing freight mobility by diverting freight from highways onto alternate transportation routes through inland and coastal waterways. The project will deliver an innovative, systematic and scalable methodology for evaluating and implementing short sea freight shipping routes by applying remote sensing and spatial information technologies.

- *A Remote Sensing and GIS-enabled Asset Management Systems (Georgia Institute of Technology)*

This project integrated emerging 3D scanning laser technology, image processing algorithms, and GPS/GIS technologies into an intelligent sensing system that improves roadway asset management (Hu et al. 2010). Pavement and sign assets are being used to validate the developed sensing system with a special focus on automatic detection of pavement distresses and automatic sign inventory data collection (Kim et al. 2009).

- *Metropolitan Transportation Information System Applying Space Based Technologies for Freight Congestion Mitigation (University of California, Santa Barbara)*

The project adopted a metropolitan network of sensors and support systems that integrated tracking of vehicles by multiple technologies with container manifest data for drayage truck movements in and around the Port of Los Angeles/Long Beach. The information generated by the system informs strategic decisions on regional goods movement and freight infrastructure planning, congestion pricing and truck-only lanes. It enables tactical efficiencies such as synchronization of port operations with vehicle arrivals, deadhead trip reduction and efficient facility layout.

- *Streamlining Transportation Corridors Planning Processes and Validating the Application of Remote Sensing Technologies for Environmental Impact Assessments (EIA) (Mississippi State University)*

New and innovative approaches to streamlining transportation infrastructure planning and related environmental impact assessments was researched through the application of commercial remote sensing data and spatial information technologies. A consortium led by Mississippi State University collaborated with partner DOT agencies to estimate and quantify benefits of new and innovative approaches versus traditional methods for completing planning tasks in the EIA process.

- *Integrative Freight Demand Management in the New York City Metropolitan Area (Rensselaer Polytechnic University)*

The project developed a self-sustaining urban freight traffic management system for the New York metro area that integrates state-of-the-art remote sensing technologies, cutting-edge freight demand management, traffic simulation, and policy. The project combined the concept of revenue generation, power of time of day pricing, with tax deductions to receivers willing to accept off-hour deliveries, and GPS based traffic monitoring, to induce a shift of truck traffic to off-hours of the day.

5 OPPORTUNITES AND CHALLENGES

5.1 Opportunities

Advancements in information technology systems and platforms in both, software and hardware environments, have revolutionized the way we collect, analyze and display information. Computing speeds have improved tremendously to allow for efficient processing of large data sets resulting in advanced automated data interpretation

capabilities. Similarly, from the context of data visualization, advances in graphical software and hardware components have assisted various user communities such as planning and engineering professionals to view and analyze data and its associated attributes under multiple spatial environments and for various temporal conditions.

Integration of remote sensing with spatial information technologies can therefore provide a wealth of informaton for transportation professionals to efficiently measure, monitor and assess condtions of interested infrastructure systems. This provides a basis and framework for design and establishment of decision support systems for use in operational and maintenance cycles of infrastructure management. User-defined criterion can be incorporated into such systems to collect, interpret information and provide useful results for decision makers/managers/ maintenance professionals to support and add value to their individual professional capacities.

5.2 Challenges

Legacy automated data systems have existed for quite some time in our respective commuties and have served us with varying capacities – ranging from semi-automated to fully automated systems. Remote sensing technologies offer new data and attributes which may require an existing infrastructure data management system to be updated, in size and structure, to accomodate new system requirements. Legacy systems were developed under conditions of the most current technologies at that time and may not be sustainable under today's suite of technology landscapes. Therefore, approaches like the most logical solution of "additive" functionality in a specific application may not be as simple as it may seem to appear. Incompatibility and portability issues of software/hardware components are examples of such challenges to enhance existing system capabilities. The ultimate alternative is to build an entirely new mangement system as a replacement.

New automated systems may require significant capital investments to fund development of software suites and acquisition of necessary hardware to house and support the system. State and local agencies have limited capital resources to fund major information technology projects to include software development and aquisition of new hardware. It may therefore be a challenge for some agencies to adopt new technologies under a finite operating funding mechanism to fully leverage and use innovative and state-of the-art technologies for infrastructure management.

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