

UTC Project Information	
Project Title	MPC 445 – A Sensor Fusion Approach to Assess Pavement Condition and Maintenance Effectiveness
University	North Dakota State University
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Project Cost	\$150,000
Start and End Dates	January 1, 2014 - January 31, 2016
Project Duration	2 Years
Brief Description of Research Project	<p>Transportation agencies in rural and cold regions face enormous challenges keeping up with demands to repair roads quickly. They must assure consistent repair quality assessment during the short construction season, particularly for roads that must support intense industrial activities in oilfields and rural freight corridors. Maintaining a state-of-good repair in these regions requires continuous performance measures, without disrupting traffic flows. To evaluate repair and maintenance effectiveness, infrastructure sensors such as electrical strain gauges and magnetic capacity sensors are widely deployed. Unfortunately, they provide performance measures only in the longitudinal direction. Furthermore, their installation requires waterproofing and even so, they are susceptible to electromagnetic interference and have relatively short lifecycles. To mitigate these and other performance issues, the Co-PI's research team developed more rugged and reliable devices in 2012 by packaging optical fiber sensors in three dimensions using fiber-reinforced polymer (FRP) to withstand the harsh environments within pavements. Testing shows that these devices operate robustly within pavements, and provides reliable and real-time road performance assessment. The Minnesota Department of</p>

	<p>Transportation (MnDOT) is using the new sensor system to evaluate the feasibility of installing thin (3 inches) concrete overlay with fiber reinforced concrete materials at the MnROAD facility as shown in Fig. 1</p> <p>To provide accurate and uniform repair assessment across all installation types, material variances, and different environmental conditions, optical sensors require calibration. Therefore, this proposal aims to develop an automatic sensor calibration approach that utilizes ride-quality performance measures. The Federal Highway Administration (FHWA) requires annual reporting of the International Roughness Index (IRI), which is the most common ride quality measure for the National Highway System. However, transportation agencies do not regularly monitor the ride quality of repaired and local roads because of the high complexity and cost of measuring and reporting the IRI. To provide continuous, network-wide, and lower-cost ride quality measures, the PI developed and validated a new approach using micro-electro-mechanical system (MEMS) inertial sensors. The emerging dominance of smartphone apps, social media, and connected vehicles presents significant opportunities for the ubiquitous deployment of wireless inertial sensors to monitor and report ride quality through data mining techniques and cloud computing. The fusion of dynamic ride-quality and static in-pavement performance measures, therefore, will enable rapid scalability of a low-cost solution for continuous, network-wide assessment of repair and maintenance practices, especially for cold, rural regions.</p> <p>Research Objectives: This goal of this study is to develop a sensor fusion approach to improve road repair and maintenance effectiveness assessment using embedded road sensors. To achieve this goal, the team will execute the following four specific objectives:</p> <ol style="list-style-type: none"> 1) Optimize the design of the optical sensor network and its data acquisition to assess the performance of repaired roads. 2) Develop a theoretical understanding of the correlation between ride-quality measures and the output from embedded optical fiber sensors. 3) Characterize the ride quality accuracy and precision with respect to traversal volume, MEMS output quality, and GPS performance. 4) Synthesize a model that is capable of automatically calibrating the sensors using ride quality data. 5) Evaluate the effectiveness of the developed sensor fusion approach.
<p>Implementation of Research Outcomes</p>	<p>Field experiments validated the theory of using connected vehicles to measure pavement roughness, and in turn the ability to use those results as a means of calibrating the embedded sensors so that they will maintain long-term accuracy of measuring and reporting a variety of parameters. Through continuous calibration, the embedded sensors will measure and report parameters that allow agencies to characterize traffic conditions and to assess many aspects of pavement structural health. Numerical simulations further revealed that a sensor placement</p>

	<p>interval of approximately one meter will provide agencies with roughness measurement levels that are most significant in making maintenance decisions. Therefore, agencies can monitor roughness even when connected vehicles are not providing similar information.</p>
<p>Impacts/Benefits of Implementation (actual, not anticipated)</p>	<p>Embedded sensors that remain operational throughout the lifecycle of pavement assets will provide agencies with a remote means of monitoring the usage characteristics, health conditions, and service level of pavements, without deploying expensive instrumented vehicles that can potentially disrupt traffic. When smart cities design and construct new pavements with the sensors already embedded in the materials, those pavements will save agencies tens of billions of dollars by eliminating the need to regularly deploy expensive probing equipment and personnel.</p>
<p>Web Links</p> <ul style="list-style-type: none"> • Reports • Project Website 	<p>http://www.ugpti.org/resources/reports/details.php?id=843</p>