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This abstract is intended for public release.

Title: **Velocity Sensor Assisted Micro Inertial Measurement for GPS Denied Personal Navigation**

The Defense Advanced Research Projects Agency/Microsystems Technology Office (DARPA/MTO) is sponsoring research and development in Micro Inertial Navigation Technology (MINT). The MINT program goal is to create navigation sensors that use secondary inertial variables, such as velocity, to enable long term precise navigation that a traditional IMU equipped only with accelerometers and gyros cannot accomplish. This program seeks the creation of micro and nano scale low-power navigation sensors that allow long term (hours to days) GPS-denied precision navigation. The sensors should be small enough to be placed in small compartments, such as the shoe sole or small UAVs, where zero relative velocity measurement may be accomplished with high accuracy. The power consumption of the sensors should be small, ideally compatible with energy harvested during locomotion, so that the weight load due to batteries powering the sensors is minimized. The sensor technology should work over wide temperature range and shock environment that is typical in DOD applications.

The Carnegie Mellon University (CMU) MINT effort began in Mar 2008 and is called the Velocity Sensor Assisted Micro Inertial Measurement (VSAMIM) project. It consists of three well-integrated one-year phases aimed at implementing high-accuracy shoe-based personal navigation for long-term GPS-denied environments. Tasks in Phase I focus on terrain-relative velocity (TRV) sensors for bias identification and resetting velocity error from the inertial sensors, as well as in integrated complementary metal oxide semiconductor (CMOS)-MEMS process development and component designs for low-bias and low-noise accelerometers. Tasks in Optional Phase II will initiate chip-scale integration of the TRV sensors as well as in the development of bench-top transponders for use in shoe-relative sensors (SRS) to measure the range between shoes. The accelerometer designs from Phase I will be fabricated and characterized in Phase II, and low-bias and low-noise gyroscopes and magnetometers design effort will be initiated. The Optional Phase III will assemble the bench-top SRS transponders into a multi-sensor system for range estimation and complete chip-scale TRV integration as well as chip-scale accelerometer/ gyroscope/magnetometer integration.

Sensor fusion algorithms will be developed initially based on COTS (commercial off-the-shelf) hardware which will gradually be replaced by sensors developed on the program as they become available. Sensor prototypes will be integrated into a wearable personal navigation system comprising sensors and embedded computing and characterized for their capacity to meet system level performance metrics. Research directions in sensor design and sensor fusion algorithm formulation will be informed by performance models based on human motion capture data which encode the relationship between sensor level signal characteristics and system level accuracy.

Initial experimental results verify the importance of the unique capacity of a shoe mounted system to provide regular zero velocity updates (ZUPTs) during the stance phase of walking. Such updates reduce the time dependence of computed position error from cubic to linear - leading to substantial improvement in position error under GPS-denied conditions. Initial simulation results verify the capacity of inter-shoe ranging, based on the SRS, to provide further substantial improvements in performance.

The presentation will include an overview of the program, and a brief description of the approach, technical status and test results.

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