This project addresses the challenges posed by the deployment and use of networks of fixed and mobile heterogeneous smart sensing devices to monitor geographic areas containing possibly moving objects. These sensors capture information on a plethora of composite spatio-temporal events of interest, which when fused and analyzed in a specific application, may trigger the execution of pre-defined continuous queries and responsive actions. Current technology cannot deliver the responsiveness demanded by the envisioned monitoring and surveillance systems that require activity orchestration to support real-world application-related decisions and/or triggering of context-driven query generation to for refining the quality of information about the monitored phenomenon. An effective overall system must factor in competing demands on sensor network resources and their best allocation to sensing the environment and analyzing the sensed data. Current state of the art in sensor networking technologies, query processing, and information fusion, falls short in facilitating the management and integration of such evolving heterogeneous information in WSNs. In particular, query processing algorithms and associated linguistics constructs are not comprehensive enough to support context-driven spatio-temporal activity specification and query processing. Routing and MAC layer techniques are similarly inadequate in realizing query-specific information dissemination in a mobile activity oriented sensor network with QoS support. Current indexing structures and techniques lack sufficient flexibility to adapt naturally to the changing topologies in mobile environments and to the spatio-temporal requirements of tasks. To meet these multiple research challenges in networking, data management, control, and signal analysis, it is imperative to develop an integrated approach to realize effective sensor net applications.

Intellectual Merit: In the proposed project we will:

1. Design and implement distributed algorithms for processing spatio-temporal queries with uncertainty in WSN, as a foundation for novel, dynamics-aware similarity queries under rigid transformation. Mining tools such as maximal association rules will be used to reduce the computation cost of frequent queries.
2. Develop new linguistic techniques to support reactive behavior. We will use the evolving triggers as a formal foundation, and devise distributed algorithms for detection of novel spatio-temporal composite events.
3. Design novel spatio-temporal multidimensional index structures that adapt to topology changes and support efficient routing and query processing. Self-organizing partitioning schemes will be used to enable robust global structure emergence from local interactions of possibly mobile sensors. Systems dynamics techniques will be used to allocate sensors, or their functions, based on the dynamic distribution of activity requirements. Updatable lattice query structures will be developed to support query reuse.
4. Develop efficient context-aware application layer routing primitives and medium access control protocols that facilitate mobility and dynamic quality of service for time sensitive messages, while aiming for energy, delay, and throughput efficiency. Network coding and cross-layer optimization will be explored for this purpose.
5. Develop distributed resource allocation and mobility control algorithms that balance event localization, event response, exploration, and routing, and are robust to sensor noise and communication failures.
6. Design context-aware resource and power-efficient data processing algorithms that dynamically react to triggers based on activity detection at lower levels or query specifications and data interpretation at higher levels.

The outcomes of this project will allow the realization of efficient software systems for sensor networks for robust tracking of mobile objects, surveillance of regions of interest, and detection of complex events of interest based on spatio-temporal queries. The algorithms and techniques developed in this project will be evaluated using an experimental test bed consisting of a network of over 200 heterogeneous sensors. In addition, the networking related protocols will be simulated using OpNet and OMNET++ based simulators, the information and query processing related work will be developed over TinyOs and TinyDB platforms, and evaluated using sensor datasets available in the public domain.

Broader Impacts: This research effort aims to contribute to the rapid development of national and local capacity to respond to critical events and to develop technology to advance the ability and scope of sensors networks to detect and monitor events in applications of high priority, such as surveillance, habitat monitoring, and ground troop management. The proposed research activity is a multidisciplinary effort involving researchers with expertise in distributed mobile databases; signal processing, robotics/control, networks, and information management. The research will facilitate advancement of the state the art in energy efficient database and networking technologies. This work will contribute to and complement efforts under way for the design and management of reliable smart facilities. Leveraging on the existing cooperation between UIC and Northwestern Univ. through the Committee on Institutional Cooperation (CIC), the curriculum at the participating institutions will be enhanced with new courses on Sensor Networks and Its Applications offered jointly by the PIs. The PIs have a history of working on collaborative research projects and have extensively involved undergraduate and minority students and women in their research projects.

Keywords: wireless sensor networks; heterogeneous nodes; query processing; spatio-temporal multidimensional indexing; context-aware routing; distributed resource allocation; distributed mobility management.