New Progress on Research into Cyber-Physical Networks: Integration of Information and Sensor Networks

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Our project, NSF CNS-0931975 "CPS: Small: Collaborative Research: Foundations of Cyber-Physical Networks", represents a joint effort of two active and experienced research groups in the fields of (i) data mining and information network analysis, and (ii) physical/sensor networking and medical care network applications, respectively for building up solid foundations for cyber-physical networks. Combining our expertise and joining our research efforts, we take *care-net*, *i.e.*, *medical care cyber-physical network*, and *military intelligence networks*, as its key application scenarios and investigate the foundations, methodologies, algorithms and implementations of *cyber-physical networks*. In the second year, both UIUC and UVA groups have been dedicated to the proposed research and generated fruitful results. These results have been published in and/or submitted to major venues in the field as research papers, demonstrated in major international conferences as research system prototypes, and delivered at international conferences as conference tutorials or keynote speeches. The new technical materials are also integrated into our educational programs. Our project introduction, conference tutorials, and research papers can be found at our project Web sites: www.cs.uiuc.edu/homes/hanj/projs/cps.htm and www.cs.virginia.edu/~stankovic/cps.html respectively, for broad dissemination.

The UIUC group has investigated the following research issues: (1) *spatiotemporal data analysis in cyber-physical networks*, including spatiotemporal trajectory cluster analysis [TIST 2011] and movement pattern mining in cyber-physical networks, including new algorithms on mining smarm patterns [VLDB'10] and periodic patterns [KDD'10] for moving objects, with a system prototype, MoveMine, demonstrated in ACM SIGMOD'10 conference; (2) enhanced power of information network analysis, including information-network rank-based classification [KDD'11], constraint-based role discovery [ICDM'11 sub], diversity analysis and outlier analysis [KDD'10], with an ACM SIGKDD'10 tutorial on mining knowledge from data using an information network analysis approach and several keynote speeches in major conferences such as SDM'11 and ASONAM'11; and (3) *reliable and trusted data analysis with cyber-physical networks*, including trustworthiness analysis of error-prone sensor networks in cyber-physical systems [ICDM'10, ICDM'11 submission]. These studies have helped us understanding the principles of spatiotemporal data and moving object data mining, information network analysis, and cyber-physical network analysis, which has paved the way for our further study of the foundations of cyber-physical networks .

The UVA group is investigating two areas: (i) CPS infrastructure for application development, and (ii) data mining in conjunction with UIUC. We are building the CPS infrastructure and application requirements (as originally proposed) to be able to understand new data mining requirements and test new data mining solutions in a home health care application. This includes improving data mining to handle human behavior patterns, time durations of activities, real-time sensor streams, and rare events that might indicate medical problems. We evaluated the use of height for biometric identification of residents, by mounting ultrasonic distance sensors above the doorways in a home, and evaluated this approach using 20 people in a controlled laboratory environment and by installing in 3 natural, home environments [Pervasive2010]. We also developed a sleep monitoring system based on the WISP platform - active RFID-based sensors equipped with accelerometers. We showed how our system accurately infers fine-grained body positions from accelerometer data collected from the WISPs attached to the bed mattress. We evaluated the accuracy of the movement detection and body position inference for 6 nights and compared these results with two baseline systems: one that uses bed pressure sensors and the other is an iPhone-based application [WirelessHealth2010]. We also performed a comprehensive empirical study to investigate important factors that affect link qualities in terms of Packet Reception Ratio (PRR) in BSNs. Both the body shadowing effect and the interference within one BSN and between multiple BSNs are examined by changing various factors such as the transmission power, the sensor placement, and the distance between two BSNs, etc. Based on the study, we proposed several approaches to guarantee reliable communication for BSNs [RTSS2010].