SENSORS AND SENSOR NETWORKS

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Abstract

Recently, sensing technology has been experiencing quantum leaps in price reduction and in performance. This has occurred because of simultaneous advances in new materials, cheap computing power, micro to nano-level integrated fabrication, wireless networking, and sophisticated information technology. At the same time, the pace of business and the pace of change have been accelerating and driving the need to be constantly and immediately aware in projects and business ventures of risks, threats, opportunities, and physical state. This need to be aware of the state of a project and the emerging capability to sense the state have come together to create a wealth of opportunities. Simply put, getting better information faster results in better decisions and competitive advantage. This paper explores how sensors, networked sensing systems, and tools to use sensor data in decision making will radically improve construction project performance over the next decade.

Introduction

- Background
  - Sensing technology advances
  - Industry challenges
  - Understanding that while sensors deliver objectivity, quantification, constant attention, ability to deploy anywhere, and save costs, human judgment is indispensable for targeting, deploying effectively, interpreting, and learning from sensor data
- Need
  - Complete awareness of project state to clear the fog
  - Learning from experience
  - Decision support; go to fact based, leadership driven
  - Data to calibrate life cycle economic models of facilities for investment portfolio planning and for asset management
- Opportunity to get better information faster so better decisions can be made at planning, management, and control levels
- Objectives of lecture to explore how sensors, networked sensing systems, and tools to use sensor data in decision making will radically improve construction project performance over the next decade, so that we can realize their potential impact and direct our advances
- Scope of lecture: primarily physical sensors; focus on procurement and construction phases but consider impact on all others; not exhaustive; no rigorous ontology or taxonomy
- Structure of lecture follows:

Project Data Needs

- All phases: planning, design, procurement, construction, start-up, operation, and decommissioning
- Types:
  - Business risk data: commodities, markets, financials, etc.
  - Control data: cost, schedule, and productivity
  - Location and position data: of people, materials, machines, etc.
  - Process transitional states: of curing, compaction, etc.
  - Test results: (e.g. welds)
  - Facility condition data: erection state, as-built geometry, distress, deterioration, etc.
  - Facility performance data: over operating life

- Forms:
    - Numeric, textual, image, 2D and 3D temporal and spatial streams, CAD formats, etc.

Sensing Capabilities

- Modes:
    - LADAR
    - RFID
    - GPS
    - 2D digital imaging
    - single axis laser ranging
    - internal encoders
    - ultrasonic, inductive loops, heat, biological, web based, etc.
- Enabling technologies:
    - Micro-fabrication and integration, e.g. motes
    - Cheap computing power
    - Wireless communications
    - Ad hoc networks
    - Internet
    - Off-the-shelf signal processing tools
    - Sensor stream databases
    - Knowledge management and data mining methods

High Potential Sensing Applications in Construction

- Concrete corrosion, maturity, strain, etc.
- RFID and GPS for materials management
- Laser positioning and GPS for machine control
- Internal encoders, RFID, and GPS for effortless productivity tracking
- Laser ranging, flash LADAR, and RFID for safety
- LADAR for as-builts

Research Issues

- Manufacture of cheap, robust, site deployable, standardized, “plug and play” sensors
- Error modeling
- Design of wireless sensor networks for fault tolerance
- Sensor data fusion and integration methods and applications
- Sensor database system design
- Automated data mining and learning algorithms
- Project process redesign due to sensor data frequency, volume, etc.
- Integration of sensing systems into construction project management systems

Business Issues

- business models for shared new technology investment or use risk
- corporate data security risks associated with wireless transmission of data
- impact of detailed data records on disputes, claims, litigation, etc.

Conclusions

- potential to reduce project duration by 50%, to reduce costs substantially, to improve safety, and to improve quality
- potential to improve predictability of life cycle performance
- some sensing technologies are ready for use
- more research in this area will pay off substantially