DATA-LOGGING AND SUPERVISORY CONTROL IN WIRELESS SENSOR NETWORKS

By

Aditya N. Das, Dan O. Popa & Frank L. Lewis

Automation & Robotics Research Institute,

University of Texas at Arlington, TX

OUTLINE

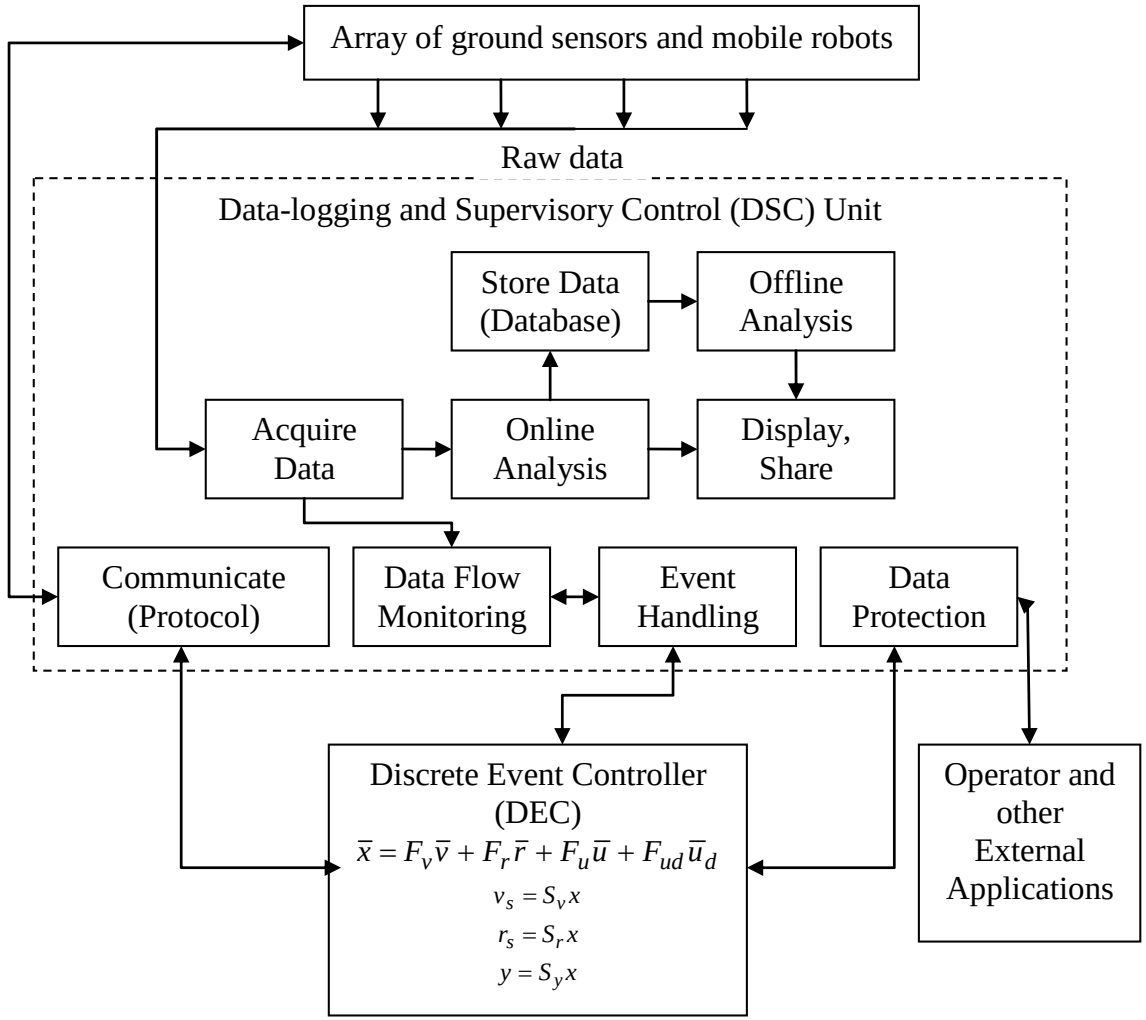
- Motivation
- Background
- Application & Set Up
- Implementation
- Conclusion

MOTIVATION

To design a WSN environment which would has the following features:

- *Data Centric*
  - More stress on information rather than on network
- *Zero Admin Deployment*
  - Minimal human intervention
- *Faster*
  - Efficient algorithms which would run faster
- *Secure*
  - Protection from unauthorized access to data/system
- *Information-Based Event Handling*
  - Efficient ways to detect and address events
- *Low Cost*
  - For mass deployment and easy-to-build applications
- *Compatibility to Different Deployment Scenarios*
  - Land, water, under-water or aerial monitoring

SUPERVISORY ARCHITECTURE FOR WSN



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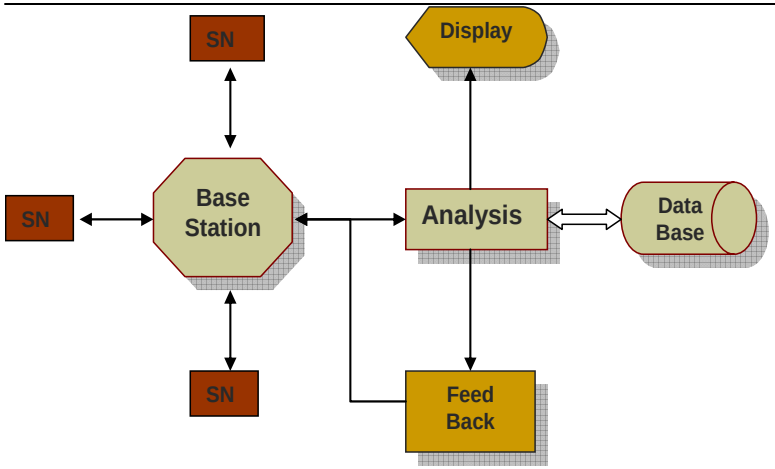
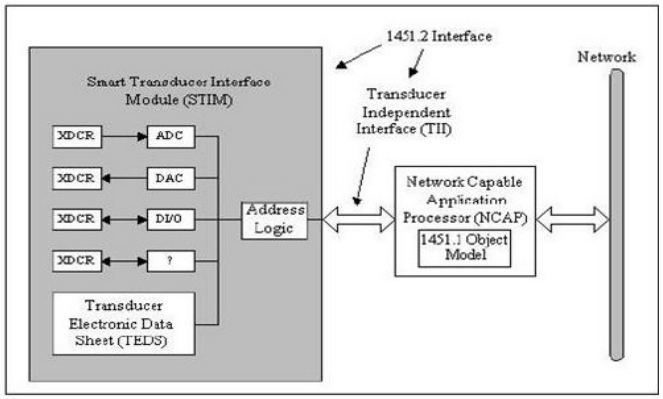
MOTIVATING EXAMPLES

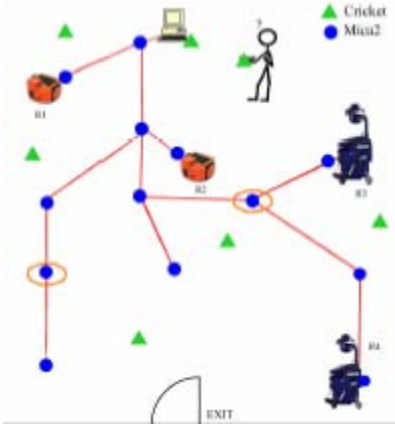


Distributed Data Acquisition & Real Time Interpretation



IEEE 1451 standard for smart sensor networks

Heating and Air Conditioning Plant



Warehouse Scenario with distributed network of sensors and mobile robots

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RELATED RESEARCH

I. *Controller Area Networks (CAN)*[1]

- Developed in 1980's for interconnection of control components in automotive vehicles, industrial plants, etc.
- Though it reduced the wiring complexity and made it possible to interconnect several devices using a single pair of wires allowing data exchange between them at the same time; it has its own limitations such as network faults, scalability issues and above all limited range due to physical wires.

II. *Wireless Sensor Networks (WSN)*[2]

- Originally developed by military for large scale surveillance
- Later with the availability of low-cost sensors the application expanded to many other areas such as infrastructure security, industrial sensing, habitat monitoring, traffic control etc.

1. *Barbosa M., Farsi M., Ratcliff K., "An overview of controller area network", Computing & Control Engineering Journal, Volume: 10, Issue: 3, Page(s): 113-120, Aug 1999*
2. *Lewis F., "Wireless sensor networks: Smart environments- technologies, protocols, and applications", ed. D. J. Cook and S. K. Das, John Wiley, New York, 2004.*
3. *Chong C., Kumar S.P., "Sensor Networks: Evolution, Opportunities and Challenges", Proceedings of the IEEE, VOL. 91, No. 8 Aug 2003*

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RELATED RESEARCH (contd.)

III. Supervisory Control & Automation of Sensor Networks[2]

- Due to the extended application and demand for issues such as mass deployment of sensors, deployment in potentially hazardous environment such as war field or chemical plants etc. and also precise & large/complex calculation requirements; the need for automating the wireless sensor network arises.
- Some of the well known systems are SCADA, DCS etc.

IV. WSN Databases and Visualization

- The versatile and widely used application Tiny-DB[1] is a database style interface designed by Cross-Bow to run on the their sensor nodes. Though it has a few event based operation handling capability, but the stress is more on the network and not on the data. Issues such as large data handling, advanced/complex data processing, issue based event handling, data security etc are not efficiently addressed.

1. *Mayer K., Taylor K., "TinyDB by remote", World Conf. On Integrated Design and Process Tech., Austin, Texas, 3-6 Dec 2003*
2. *Cook D., Harris B., Lewis F., "Machine planning for manufacturing: dynamic resource allocation and on-line supervisory control", Journal of Intelligent Manufacturing, p. 413-430, vol. 9, 1998*

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DISCRETE EVENT CONTROLLER

$$\bar{x} = F_v \bar{v} + F_r \bar{r} + F_u \bar{u} + F_{ud} \bar{u}_d$$
$$v_s = S_v x$$
$$r_s = S_r x$$
$$y = S_y x$$

x → task or state logical vector

Fv → task sequencing matrix

Fr → resource requirement matrix

Fu → input matrix

Fud → conflict resolution matrix

Ud → conflict resolution vector

Sv → task start matrix

Sr → resource release matrix

Sy → output matrix

- The discrete event controller (DEC)[1,2] is a rule based matrix controller
- The matrix formulation allows fast, direct design and reconfiguration
- In the event of any critical situation demanding attention the DEC prepared a sequence of tasks according to the available resources and jobs to deal with the situation.

1. *Lewis F., Mireles J., "Intelligent material handling: development and implementation of a matrix-based discrete event controller" IEEE Transactions on Industrial Electronics, vol. 48, Issue: 6, Dec. 2001*
2. *Lewis F., Tacconi D., "A new matrix model for discrete event systems: application to simulation", IEEE Transactions on Industrial Informatics, Volume: 1, Issue: 1, Page(s) 39-46, Feb 2005*

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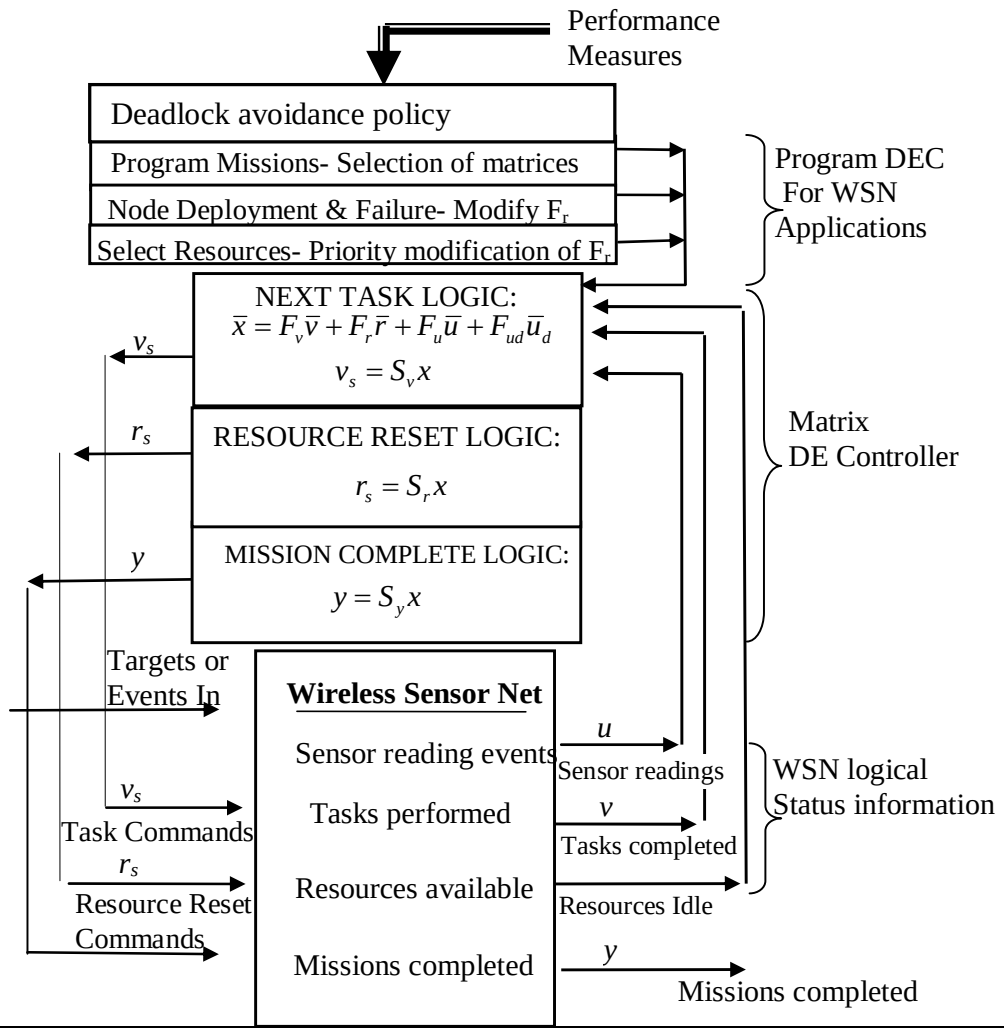
DEC ARCHITECTURE



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CONTRIBUTIONS OF THE WORK

The aim of this research work is to take the basic concepts of available supervisory control systems, add data-logging & data processing/analysis modules to it and incorporate with wireless sensor networks in various deployment schemes.

Some of the features developed by the software module are as follows:

- Provide way to collect data from the network more efficiently
- Process the raw data through various conditioning methods and advanced analysis schemes to extract required information
- Design of new analysis modules such as sound & vibration module,
- Controlling the network through various information based event handling modules of novel discrete event controller
- Securing data from unauthorized access
- Broadcasting the data such as to PDAs, Webs, Reports etc

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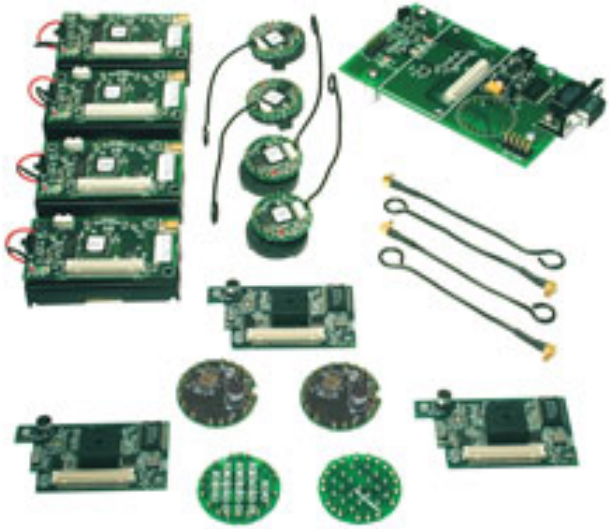
TARGET APPLICATION

The proposed wireless sensor network has been designed and being tested at the Distributed Intelligence and Autonomy Lab (DIAL) of UTA's Automation & Robotics Research Institute in various WSN scenarios such as:

- Strain, vibration, and temperature wireless sensors for Condition Based Maintenance
- Vibration, light, magnetism, temperature and color sensors in stationary unattended ground sensors (UGS)
- Mobile wireless sensor network nodes mounted on robots both commercially available and indigenously developed in ARRI
- Aerial robots such as blimps, and under water robots

SENSORS



Manufactured By: CROSS BOW

Type: Third Generation wireless platforms for smart sensors [MICA2 & MICA2DOT]

On Board Sensors: Light, Temperature, Sound, Vibration, Magnetic Field Intensity

Transmission Method: Wireless Radio Link

Range: 10-200ft

Operating Software: Tiny-OS

Cricket Motes

On Board Sensors: Basic MICA2, Ultrasonic transceiver

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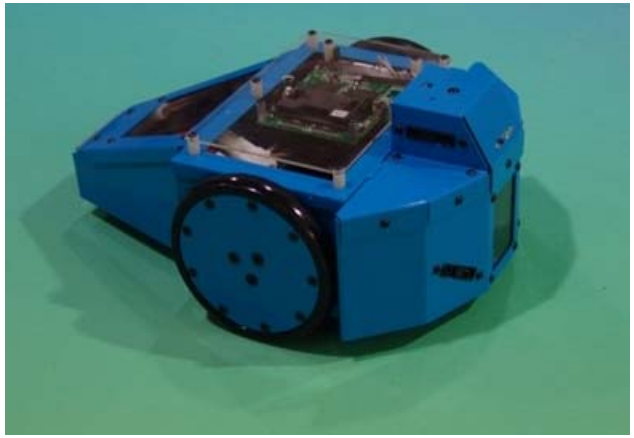
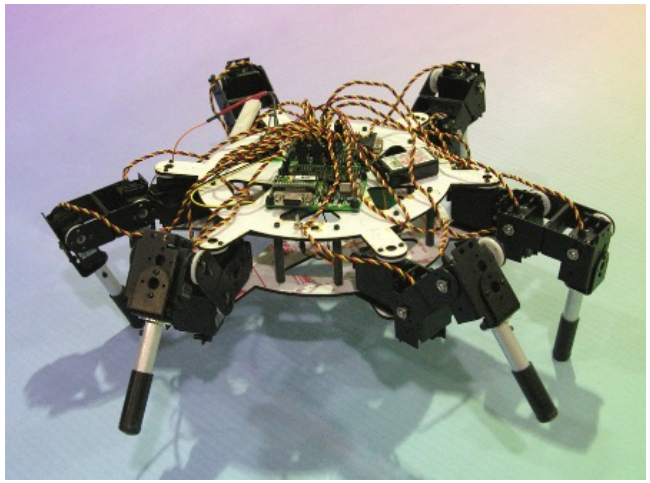
ROBOTS



GARCIA

BLIMP



HEXAPOD

CYBER MOTION SR2/ESP

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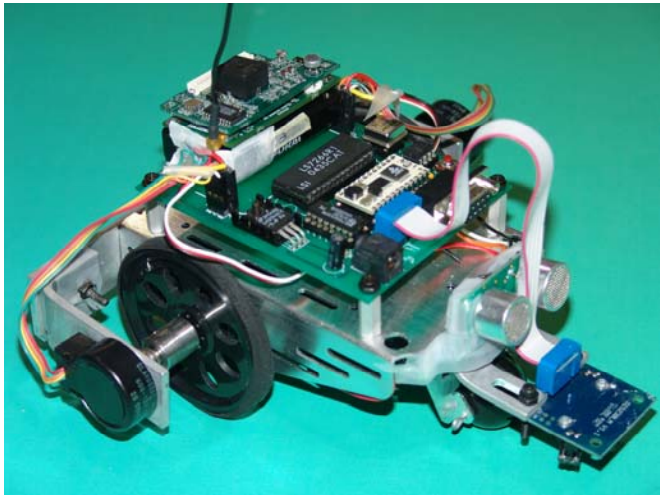
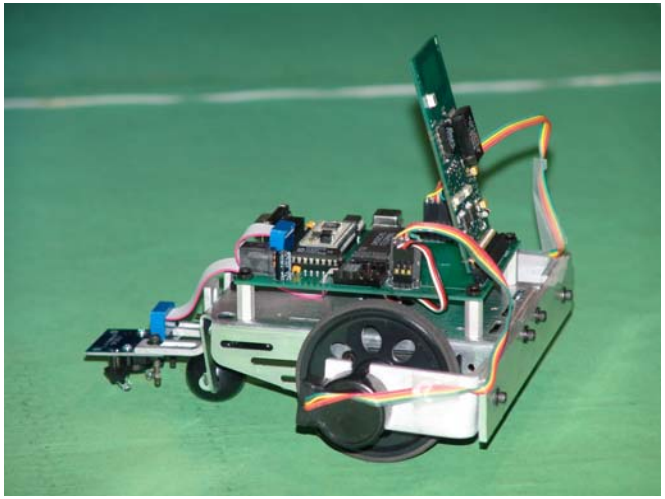
ROBOTS





ARRIBOT

Indigenously Developed By ARRI

A low-cost mobile Robot ($650~$750)

<u>On Board Sensors</u>

- Ultra-sonic range detectors
- High-Resolution Color Sensors
- MICA Sensor package

<u>Transmission Method</u>

- Wireless Link Parallax Transceiver
- Wireless Link through MICA

<u>Alternate Power Source</u>

- Solar Panel

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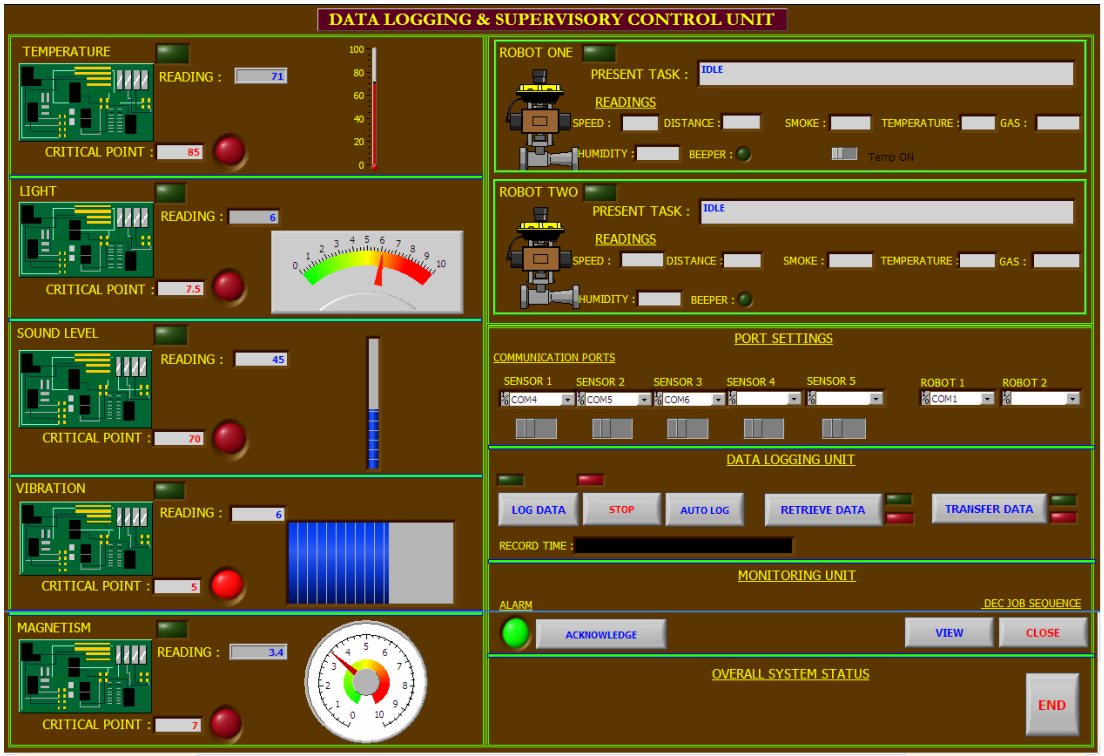
IMPLEMENTATION PLATFORM



- LabVIEW® - A graphical development environment for creating flexible and scalable test, measurement, and control applications.
- Citadel® Database – A streaming database, it logs only when the user defined value differential has been exceeded

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IMPLEMENTATION

Some challenges in WSN

- Diversity in Sensor Data
- Storage of Data
- Retrieval of Data
- Alarm & Event Handling
- Data Exportation
- Data Security

Role of the proposed Data-Logging & Supervisory Control (DSC) Unit

- Continuously monitor the flow of raw data
- Extract only important or significant data from raw data
- Store the extracted data and export it when necessary
- In the process identify critical data
- Protect the data from unauthorized access

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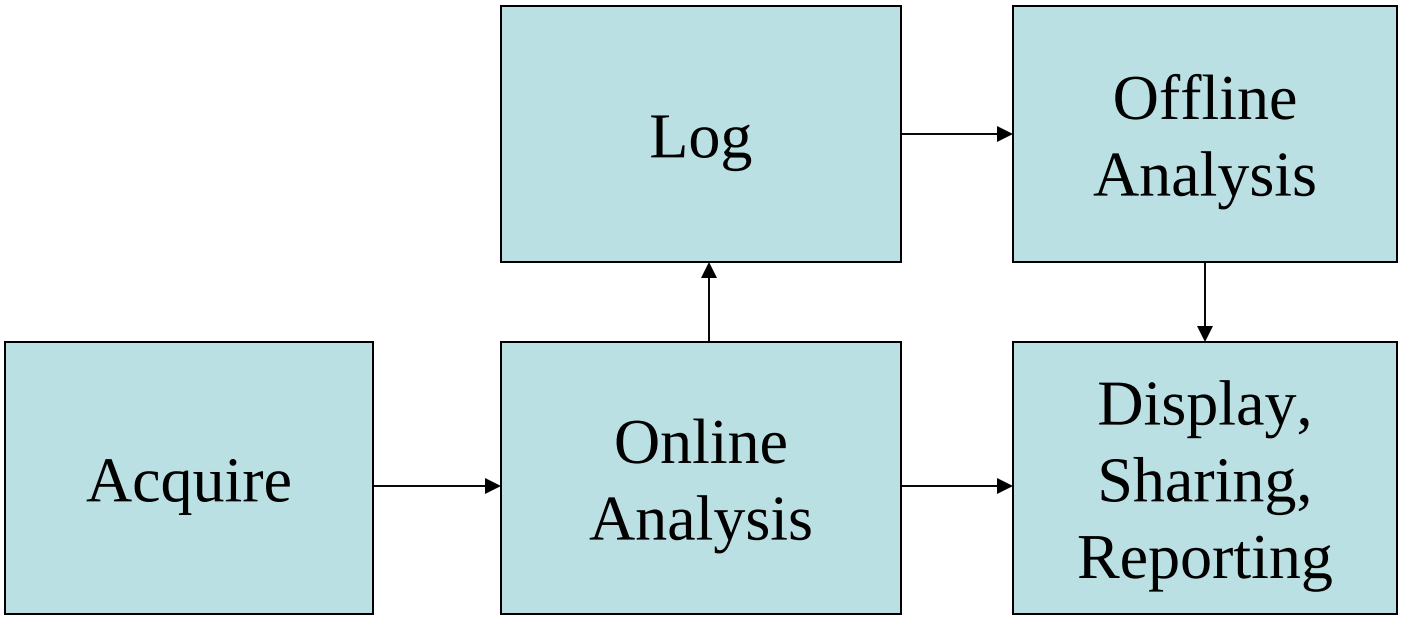
FUNCTIONAL BLOCK DIAGRAM



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1. ACQUISITION

In a PC based system, data acquisition is a coordinated process of the measurement hardware & data processing concepts some of which are:

- sensors
- signal connectivity
- signal conditioning
  - Amplification and Attenuation
  - Sampling
  - Multiplexing
  - Filtering
  - Linearization
- analog to digital converters

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2. ONLINE ANALYSIS

- Channel Scaling

  Conversion of raw binary values captured by acquisition unit into properly scaled measurements with appropriate measurement units

- Alarming & Event Management

  Monitoring of channel and providing notification if limits are exceeded. Alarming can also include an automated response to certain events

- Feedback Control System

  Comparison of the actual value with the desired value and minimization the error the system

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3. LOGGING & STORAGE

There are three general formats commonly used for storage of data –

I. ASCII Text Files

- Easy to open and import into any package
- Easy to transfer between operating systems
- Inefficient Usage of disk space
- Need of additional process units for read and write to file
- Can be used for only slow data acquisition models
- Cannot be used when the data size is large

II. Binary Files

- Less processor overhead
- Less processor space
- Appropriate for faster data acquisition models
- Requires to be translated before sharing

III. Databases

- Capable of handling large amount of data
- More structured and efficient way of storing data
- Increased complexity

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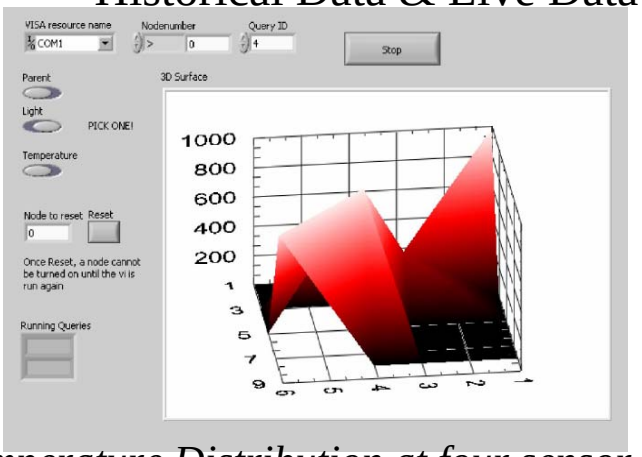
4. OFFLINE ANALYSIS

- Performing mathematical functions on data after it has been acquired in order to extract important information.
- Includes computing basic statistics of measured parameters
- Also includes more advanced functions such as the frequency content of signals and order analysis
- Can be integrated with the rest of the data logging application,
- Also it can occur separately through stand-alone analysis software packages.

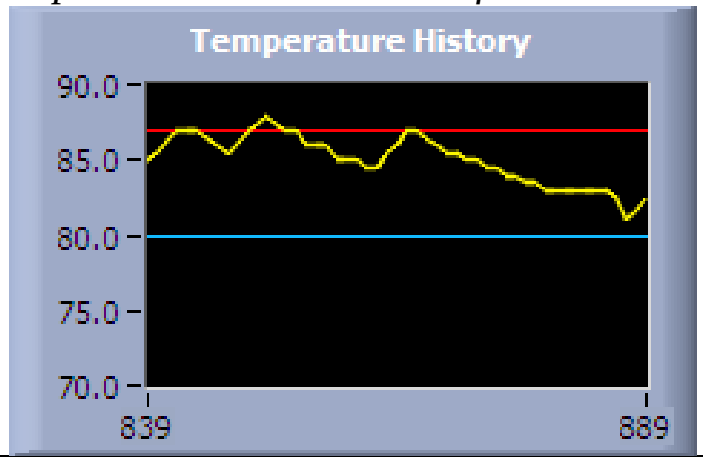
5. DISPLAY, SHARING & REPORTING

The display can be of two types,

- Historical Data & Live Data



Temperature Distribution at four sensor nodes



test - Notepad

File Edit Format View Help

```
Number of rows: 29
Interpolation interval: 0 seconds

Row      Time      \\andromeda\D__WORK_Natior
1        2:22:07.500 PM   79.5898
2        2:22:08.125 PM   82.4898
3        2:22:08.234 PM   83.8898
4        2:22:08.937 PM   85.8898
5        2:22:09.343 PM   87.3898
6        2:22:09.640 PM   85.9898
7        2:22:10.031 PM   84.4898
8        2:22:10.828 PM   83.0898
9        2:22:11.234 PM   84.3898
10       2:22:11.531 PM   86.3898
11       2:22:12.531 PM   87.8898
12       2:22:12.937 PM   85.9898
13       2:22:13.531 PM   84.4898
14       2:22:13.828 PM   85.8898
15       2:22:14.734 PM   84.4898
16       2:22:15.328 PM   83.0898
17       2:22:16.140 PM   81.0898
18       2:22:16.328 PM   82.4898
19       2:22:17.437 PM   79.6898
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21       2:22:18.234 PM   83.8898
22       2:22:18.937 PM   85.8898
23       2:22:19.328 PM   87.3898
24       2:22:19.640 PM   85.9898
25       2:22:20.031 PM   84.4898
26       2:22:20.843 PM   83.0898
27       2:22:21.234 PM   84.3898
28       2:22:21.562 PM   86.3898
29       2:22:22.531 PM   87.8898
```

Historical Data Trends

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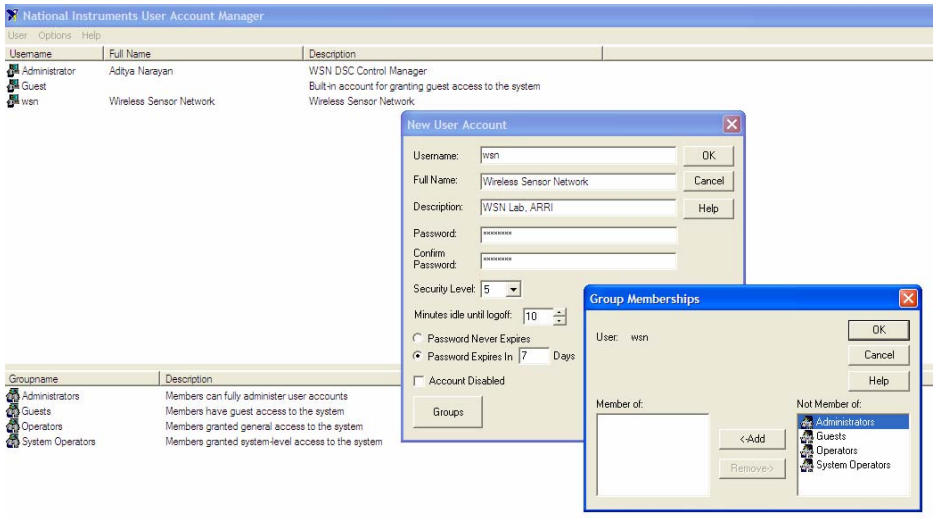
SECURING DATA BY USER ACCOUNTS



Security in the application has been implemented by setting up of user and group accounts. WSN DSC module has a User Account Manager which creates and edits the properties of groups, user accounts. It assigns users to one or more groups and manages security accounts for applications.

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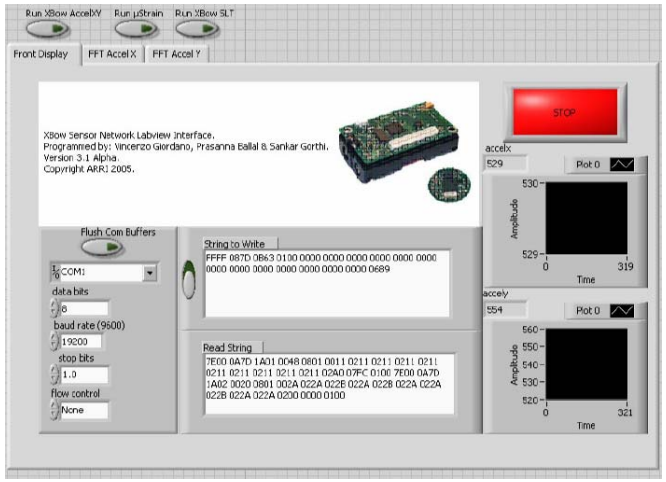
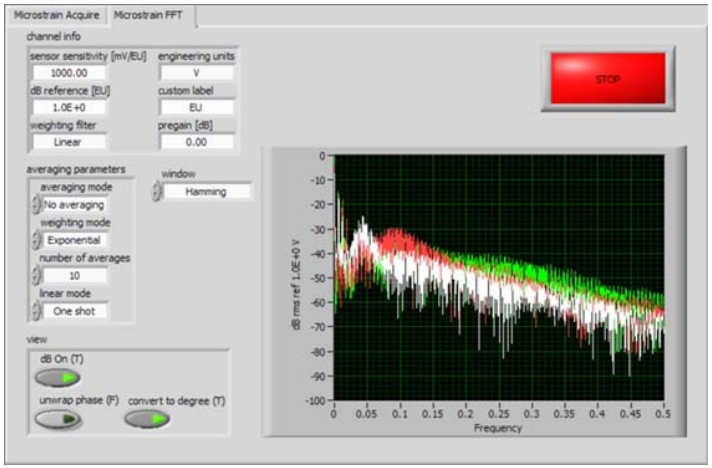
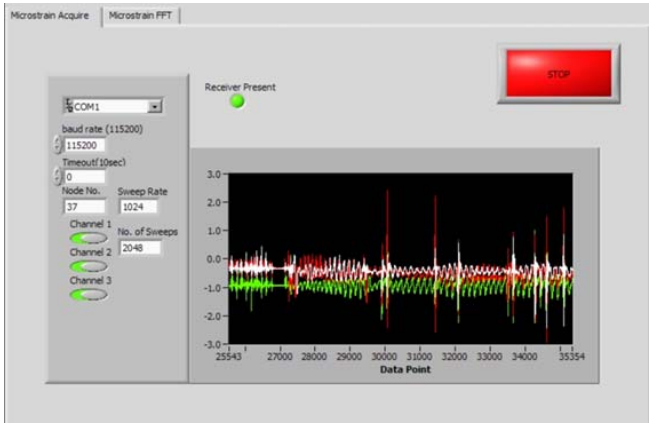
SOME SAMPLE RESULTS



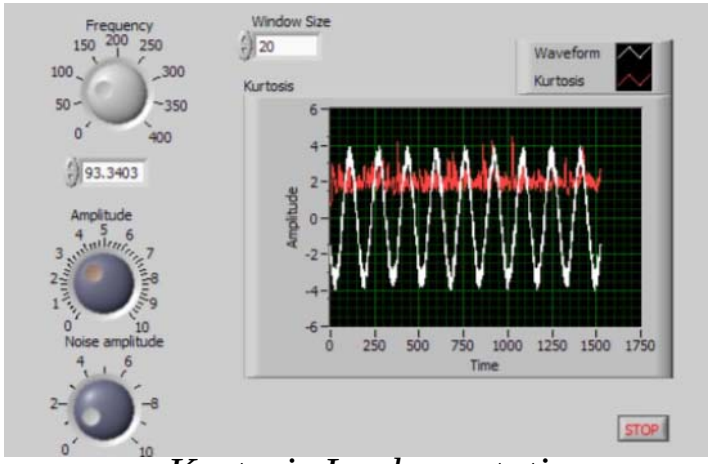
Raw Data from X-Bow Sensors



Vibration data from sensors



FFT of vibration data



Kurtosis Implementation

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CONCLUSION AND FUTURE WORKS

- By using the LabVIEW® programming interface we enable robust and cross platform monitoring, programming, and maintenance of the WSN.
- DSC adds more strength and flexibility to the Wireless Sensor Networks by allowing the network to interface to a mission-aware Discrete Event Controller (DEC) application.
- Future work includes studying the scalability, robustness and reconfiguration ability of the DSC/DEC framework to address different WSN scenarios.
- Also research is undergoing on distributing more computation at sensor nodes.

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