Energy-Aware Distributed Sampling for Environmental Modeling with MICAz

Afroze Ibrahim Baqapuri
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Distributed Intelligent Systems Project

Experiments

1) Calibration
2) Actual Setup
3) Post Processing

Results

Best performance of reached = 0.81

Compared with 0.33 performance of uniform sampling, this is a very good improvement!

Questions?

Interdisciplinary Learning Outcomes

Learned that it is a good idea to share and discuss with people belonging to other disciplines as it often leads to out-of-box thinking and creative ideas.

How to learn from people of other disciplines and how to use differentiation of expertise among group members to enhance team efficiency.

Got insight into "Scientific Reduction": how to explain standards of one field to someone from another discipline without using technical jargon.
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Introduction

Wireless Sensor Network

MICAz

Light Sensors

TinyOS
Wireless Sensor Networks

Spatially distributed sensor nodes forming a network

Typical applications lie in environmental, military and commercial sectors

Basic problem of enhancing their life time. In other words make them energy efficient
Operating system to drive MICAz

Support for NesC event driven language

Easy modeling of system using built-in components
MICAz

A wireless communication module used as a WSN node

MSS300CA sensor

A light sensor which can be plugged onto the MICAz to form a network of sensors
Improving per-unit energy consumption of operations (sensing, communication)

Improving the performance of Batteries

Using Intelligent Distributed Sampling to minimize number of operations
Improving the performance of Batteries
Improving per-unit energy consumption of operations (sensing, communication)
Using Intelligent Distributed Sampling to minimize number of operations

- No additional physical costs / constraints.
- Hardware remains exactly same.
- More general approach (can be implemented on generic WSN).
No additional physical costs / constraints.

Hardware remains exactly same.

More general approach (can be implemented on generic WSN).
Our Contribution

Developed an adaptive sampling strategy to minimize energy requirements.
Our Contribution

Developed an adaptive sampling strategy to minimize energy requirements
Finite State Machine for our microscopic model
Adaptive Sampling Strategy

- Time Division Scheduling
- Space Division Scheduling
Time Division Scheduling

- Local sampling strategy (specific to a node).

- Linear Regression model to predict next value.

- If sampled value fits the predicted model: sampling interval doubles (upto a maximum of 8 seconds).

- Else if it does not fit: sampling interval re-initializes from lowest value (1 second).
Mathematics of model

\[ \text{fits} = \begin{cases} 
\text{NO} & \theta > 0.1t \\
\text{YES} & \delta < \theta \\
\text{NO} & \text{otherwise}
\end{cases} \]

Parameters involved

\[ \delta = |y - \text{model}(t)| \]

\[ \theta = 0.5 \sqrt{ \frac{\sum (\epsilon[i])^2}{N - 1} + \left( \frac{\sum \epsilon[i]}{N} \right)^2 } + 0.01y \]

\[ \epsilon = \{|y_m[i] - \text{model}(t_m[i])|\}: \text{error of the model} \]
Space Division Scheduling

- Global sampling strategy.
- Communication between nodes of a WSN.
- Each node (MICAz) has 2 hard-coded neighbors.
- Underlying assumption: high degree of spatial coherence.
Details:

- When a node does not fit the model it alerts its neighbors.
- When nodes receive an alert they immediately do a sampling (regardless of sampling interval).
- If it also doesn't fit the model it propagates the alert, otherwise it continues normally.
Experiments

1) Calibration

2) Actual Setup

3) Post Processing
1) Calibration
Different sensors have different sensitivities towards light so give varying measurements for similar conditions.

Linear calibration with regards to an arbitrarily selected reference sensor to give uniform behavior for all.
2) Actual Setup
8 MICAz for uniform sampling and 8 programmed with our custom adaptive sampling strategy.

Side-by-side experiment for comparing our strategy with uniform sampling in terms of performance.

Repeatability of experiment ensured by using LED with a signal generator to give same variation of light intensity for same signal
3) Post Processing
Performance of the sampling strategy is measured using a standard metric which takes into account:
- Accuracy of measurements
- Energy expended in sampling
- Energy expended in communicating

Our goal is to improve performance as compared to that achieved by uniform sampling (Ceteris Paribus)

Interpolation (time-space) required for accurate comparison since measurements timings of both experiments may not match
Performance metric

\[ M_c(\alpha, \beta, \gamma, \delta) = \alpha \cdot \left( 1 - \frac{\int (\phi(x, y, t) - \phi_0(x, y, t))^2 \, dx \, dy \, dt}{\int (\phi_0(x, y, t))^2 \, dx \, dy \, dt} \right) + \beta \cdot \left( 1 - \frac{\sum_{i=1}^{N} S_i}{N \cdot T \cdot F_s / L_s} \right) + \gamma \cdot \left( 1 - \frac{\sum_{i=1}^{N} P_i}{N \cdot T \cdot F_m} \right) + \delta \cdot \left( 1 - \frac{\sum_{i=1}^{N} V_i}{N \cdot T \cdot v_{max}} \right) \]

\[ \alpha + \beta + \gamma + \delta = 1 \]

- \( \phi_0 \): fully sampled dataset
- \( \phi \): sub-sampled dataset
- \( S_i \): no. of measurements taken by node \( n \)
- \( T \): length experiment (time)
- \( F_s \): sampling frequency
- \( L_s \): samples per measurement
- \( P_i \): the number of messages sent by node \( n \)
- \( F_m \): maximum message transmission rate
- \( V_i \): length of agent \( n \)'s trajectory
- \( v_{max} \): maximum agent velocity
Results

Best performance of reached = 0.81

Compared with 0.33 performance of uniform sampling, this is a very good improvement!
Measurement Map

X-space [cm]

[300,350]
(350,400]
(400,450]
(450,500]
(500,550]
(550,600]
(600,650]
(650,700]
(700,750]
(750,800]
(800,850]
(850,900]
(900,950]
(950,1000]

time [10^s]
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## Task Distribution

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<thead>
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<th>Task</th>
<th>Afrozeh</th>
<th>Gillian</th>
<th>Paul</th>
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<td>Strategy elaboration</td>
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<td>Python scripts for data processing</td>
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REFERENCES


Questions?