Calamari’s Design Decisions

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Project Summary

- Collecting large amounts of data
  - 10,000’s data points
  - Connectivity, RSSI, acoustic, ultrasound
- Calibration and auto-calibration techniques
- Matlab simulation of algorithms using real data
- Implementation in NesC on pc, mica, and dot3
- Designing new hardware

http://www.cs.berkeley.edu/~kamin/calamari
Outline

- Design Requirements
- Radio Ranging
- Acoustic Ranging
- Algorithms
- TinyOS code and demo
- Evaluation
A Motivating Application

Event–triggered Activity in Z–Racer

1. Z–Racer drives
2. Magnetometer readings are broadcast
3. Position estimate is routed to camera
Design Principles

- Node-level Resolution
- Scalable Deployment
- Event-driven
- Simple and Approximate Operation
Existing Systems

- GPS
- Cricket
- AHLoS
- Millibots
Radio Ranging – Connectivity

Data courtesy Alec Woo, Ganesan, et al
Radio Ranging – Connectivity

Grid Row

Grid Column

Probability of Packet Transmission: Transmitter #254

Data courtesy Alec Woo, Ganesan, et al
Radio Ranging – Signal Strength

Outdoors: Density Plot of Distance Estimates: RSSI: 24.0407% error, 118.5437 cm error
Indoors: Density Plot of Distance Estimates: RSSI: 43.6981% error, 159.5373cm error
Radio Ranging – Signal Strength

Average Signal Strength over Distance

Signal Strength (V) vs Distance (ft)

-5 0 5 10 15 20 25 30 35 40 45

Signal Strength (V)

1.3 1.35 1.4 1.45 1.5 1.55 1.6 1.65 1.7 1.75
Radio Ranging – Signal Strength

Average Signal Strength over Distance

Signal Strength (V)

Distance (ft)

Small Error

Large Error
Radio Ranging – **Signal Strength**

- **Error equation:**

\[
\text{error (cm)} \approx \frac{\text{noise (dB)}}{\text{Attenuation rate (dB/cm)}}.
\]
Radio Ranging – Signal Strength

![Graph](image-url)

- **Noise(V) / Rate of Attenuation (V/ft)**
- **Distance (ft)**
- **Error**
Acoustic Ranging
Acoustic Ranging – 4.3KHz Analog

- Simultaneously send acoustic and RF
- Time stamp RF; turn on acoustic circuit
- Time stamp tone-detector interrupt
- Subtract timestamps
- Multiply by speed of sound
- Filter
Acoustic Ranging – 4.3KHz Analog
Acoustic Ranging – 4.3KHz Analog

Filtered Time of Flight Estimates

- Raw Distance Estimates
- Filtered Distance Estimates

Distances:
- Normal Noise
- False positives
- Outliers
Acoustic Ranging – 4.3KHz Digital

- Digital sampling and filtering
- Better range and accuracy
- Slow, costly process
- Scheduling needed
Acoustic Ranging – Ultrasound
Acoustic Ranging – Ultrasound

The graph shows the relationship between Time of Flight (TOF) and True Distance (m).

The equation for the data is:

\[ y = 3.2 \times 10^3 x - 1.4 \times 10^3 \]
Acoustic Ranging – Ultrasound
Localization
Localization Accuracy

Empirical Probability of Error (kernel smoothing)

Resolution of Forces

-0.1 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8

Probability

0 0.02 0.04

Error (relative to maximum range)
Localization Accuracy

Empirical Probability of Error (kernel smoothing)

Resolution of Forces
Localization Accuracy

Empirical Probability of Error (kernel smoothing)

Resolution of Forces
NesC Implementation

- Mica platform being integrated with VU
- Dot3 being integrated with ultrasound
- Simulated ranging estimates for PC
Evaluation

- Node-level Resolution
- Scalable Deployment
- Event-driven
- Simple and Approximate Operation