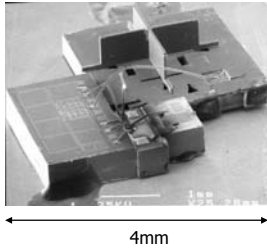


The Lighthouse Location System for Tiny Sensor Nodes

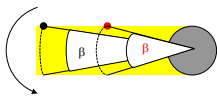
Kay Römer – Distributed Systems Group, ETHZ

Smart Dust

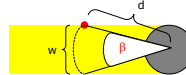


- **Tiny autonomous devices**
 - Sensors, processor, wireless communication, power supply
 - Within few mm³
- **Dense, large networks of Smart Dust**
 - Deployed in physical environment
 - Unobtrusive monitoring of real-world phenomena
- **Smart Dust prototype (UC Berkeley)**
 - Passive laser-based communication with a base station
 - Single-hop network, star topology
- **Node localization required**
 - Where did something happen?
 - Geographical node addressing
 - Foundation for data fusion
- **Localization challenges**
 - Too small and too few energy for traditional enabling technologies (e.g., radio, ultra sound)
 - Large scale of networks

Ranging with Lighthouses

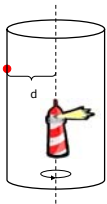


- **Lighthouse with parallel beam**
 - Observer sees lighthouse flash as beam rotates by
 - β depends on observers distance from lighthouse rotation axis
 - Only optical receiver required!

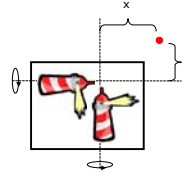


- **Distance calculation**
 - Time t_{turn} for complete rotation
 - Time t_{beam} for beam to pass by (sweep time)
 - $\beta = 2\pi \cdot t_{\text{beam}} / t_{\text{turn}}$
 - $d = w / (2\sin(\beta/2))$

Localization with Lighthouses

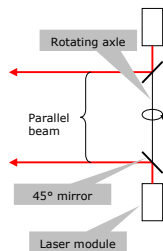


- **Cylindrical lighthouse**
 - We obtain distance to the lighthouse rotation axis!
 - All observer locations with a given d form the hull of a cylinder

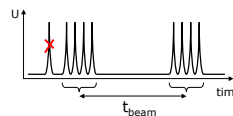


- **2D localization system**
 - Rotation axes define coordinate system
 - Distances from axes are 2D coordinates
 - Combine lighthouses into single device
 - 3D accordingly

Implementation

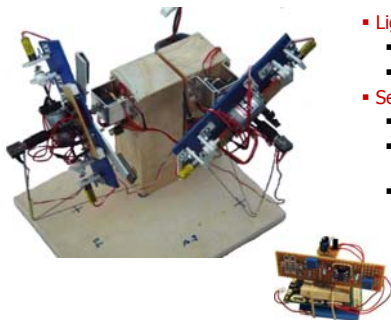


- **Lighthouse**
 - Two laser beams form outline of wide parallel beam
 - Rotating 45° mirror
- **Additional issues**
 - Beam not parallel
 - More complex non-linear lighthouse model
 - Iterative solution
 - Lighthouse calibration



- **Receiver (sensor node)**
 - Photo detector sees sequence of laser pulses as rotating laser passes by
 - Time between two sequences equals t_{beam}

Prototype



- **Lighthouse device**
 - Rotating platform at 1rpm
 - Mirrors rotate at 15000rpm
- **Sensor node**
 - Based on BTnode
 - Prototype receiver: photo diode, amplifier, trigger
 - Interrupt-driven
- **Features**
 - Accuracy: ~2% of distance from lighthouse (few cm in room-scale experiment)
 - Autonomous location estimation
 - Energy-efficient (passive optical receiver)
 - Single localization device
 - Scalable (broadcast-based, no inter-node communication)

