Institute of Integrated Sensor Systems

Dept. of Electrical Engineering and Information Technology

Feasibility Study of a Novel Bio-inspired Location Sensor Concept for Indoor Location Based Services in Ambient Intelligence Applications

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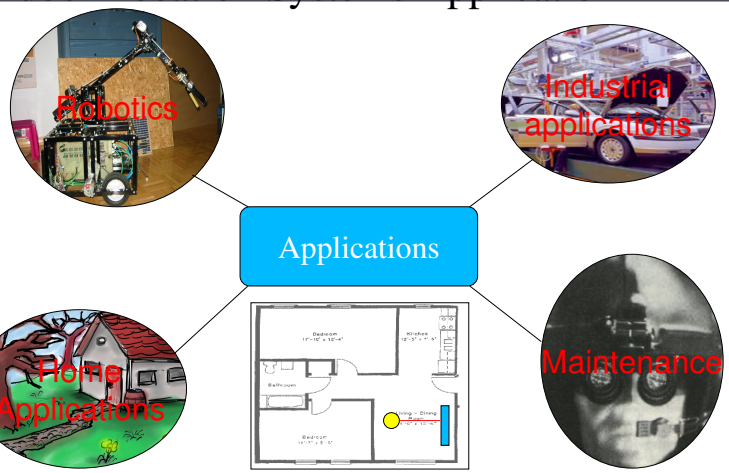
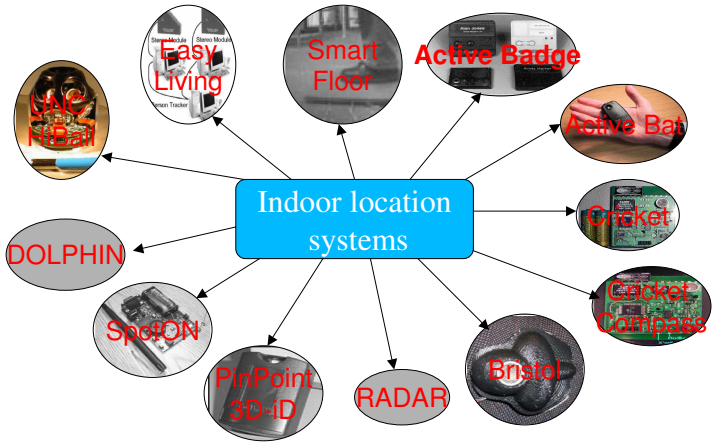
Indoor Location Systems Application



Introduction

Overview of Existing Indoor Location Systems



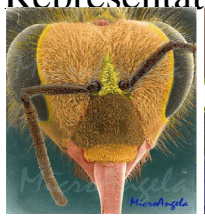
Introduction

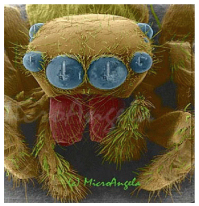
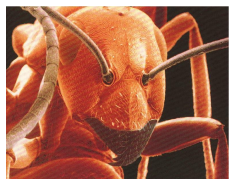
Baseline

- **Why yet another solution** ?
- **Problems & Challenges**:
  - Size
  - Power
  - Number of needed sensors
  - Cost
  - Spatial Resolution
  - Robustness
  - Unobtrusiveness
  - Electromagnetic compatibility
- **Approach:** Investigate and exploit biological evidence/solutions to same or similar challenges.

Inspiration from Biology: Polarization vision

Representative species



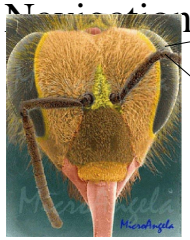
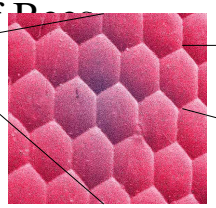
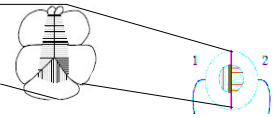



(Adapted from www.eyedesignbook.com)

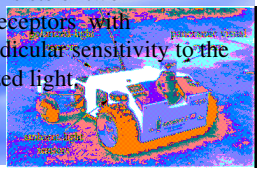
- The nautilus is able to see polarized light to determine their course of direction
- Crab and Octopus can sense the direction of sunlight
- Some ants and bees use the polarized light for navigation
- Butterfly use the polarization of light to increase the illustration of the images, ……

Inspiration from Biology: Polarization vision

Navigation of Bees

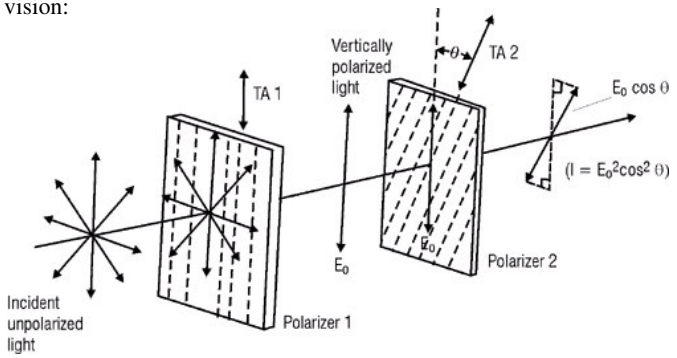
- Polarized light compass to detect the direction using the pattern of the blue sky.
- Path integration to calculate the position.
- Landmarks to finally pinpoint the nest.
- The basic polarization detection unit consists of two photoreceptors with perpendicular sensitivity to the polarized light.



Our Approach

Background of Linear Polarization

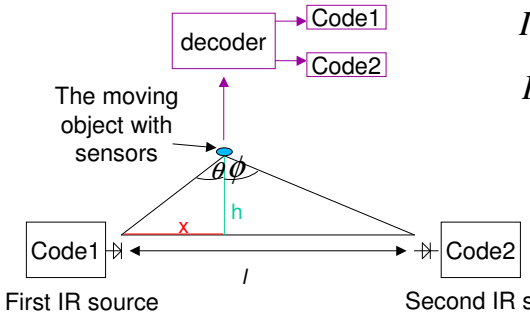
- Required background for technical exploitation of polarization in vision:



C. Law of Malus: $I = I_0 \times \cos^2(\theta)$

Our Approach

Mathematical Model of the Approach



$$I_1 = I_0 \times T_i \times \cos^2(\theta)$$

$$I_2 = I_0 \times T_i \times \sin^2(\theta)$$

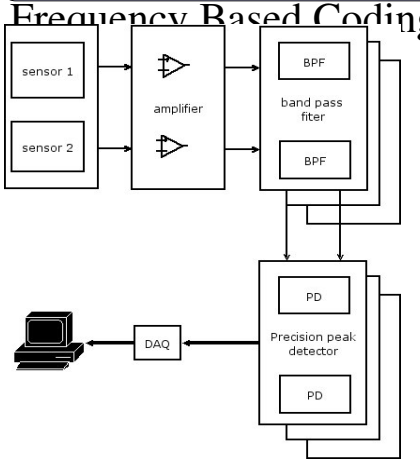
$$\theta = \tan^{-1}\left(\sqrt{\frac{I_2}{I_1}}\right)$$

$$x = \frac{l \times \cos(\phi) \times \sin(\theta)}{\sin(\theta + \phi)}$$

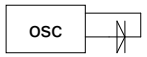
$$h = \frac{l \times \cos(\phi) \times \cos(\theta)}{\sin(\theta + \phi)}$$

Our Approach

Architecture of IR Sensing System Using Frequency Based Coding



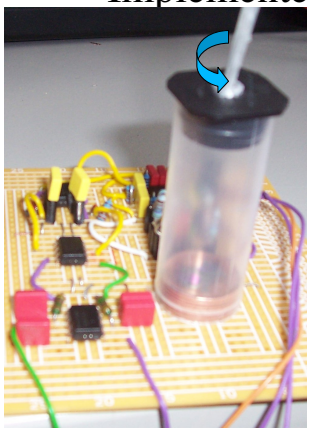
- Two perpendicular polarized IR sensors.
- Amplifiers
- 2 band pass filters to separate each source (2 x N filters for N sources)
- Precision peak detector (2 x N)
- Each transmitter consists of an oscillator and a photodiode

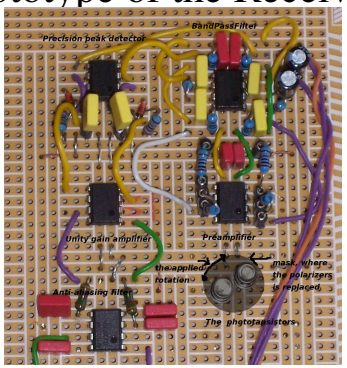


- Each transmitter uses different frequency to be separable.

Our Approach

Implemented Prototype of the Receiver

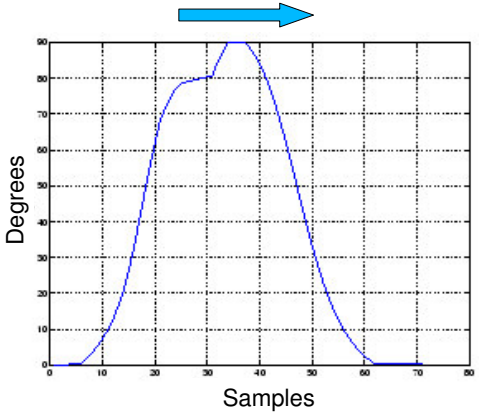




- The current system implementation of the approach is limited to angular displacement sensing (2D-compass !)
- Feasibility study is based on discrete components

Experiments and Results

Results of Angular Position Detector by Manual Rotation

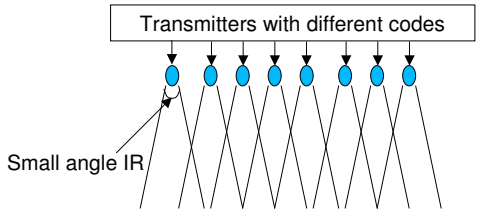


- High resolution at low sampling rate
- Little digital processing is required
- Some non-linearity is introduced because of the current imprecise mechanical system and the non-linearity of the current design of the peak detectors
- This non-linearity can be considered by the software for error compensation as it depends on the level of the signal

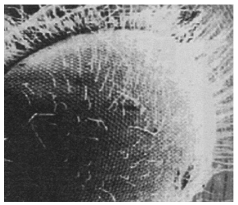
Experiments and Results

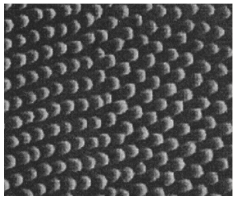
Open Issues

- The contrast ratio of the polarizers decreases with the angle of acceptance
- The reflection coefficient is related to the angle of acceptance
- As a result the error of the detected angle increases with the acceptance angle
- To reduce this error, we can increase the number of transmitters in which we always have small angles, and decrease the reception angle of the receiver

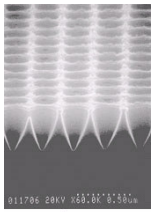


Experiments and Results
More Help from Nature: Moth's Eye





- Moth eyes absorb a high percentage of light so that very little light reflects from them
- This type of coating found on a moth is just now being used commercially, such as for production of anti-reflective coatings on solid plastic and other lenses.
- The size of the elements on the A/R coating are on the order of 200nm.



Convex

Moth Eye mimic structure fabricated on Si wafer

http://www.ntt-at.com/products_e/motheye/

Conclusions and Future Plans

- An alternative contribution to location-based-services based on polarized source/sensor arrangement was investigated and feasibility was confirmed
- We demonstrated 2D angle measurement with sufficient no. of coded polarized sources and decoded it at the receivers for signal separation
- Approach carries the promise to be a low cost and effective, but
  - The transmitters must be strong enough to be sensed in all the room
  - More transmitters will be needed for a big room
  - A moth's eye pattern carries the promise to improve acceptance angle
- Extension from 2D to 3D location detection is considered for future work
- Potential integration of the sensor concept by MOEMS technology
- Completing and miniaturizing of the concept requires substantial funding