Title
Deep Vision: Experiments in Exploiting Vision in Wireless Sensor Networks

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Publication Date
2005

Center for Embedded Networked Sensing

Deep Vision : Image Based Sensing for Wireless Sensor Networks

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This work is in collaboration with Agilent Technology

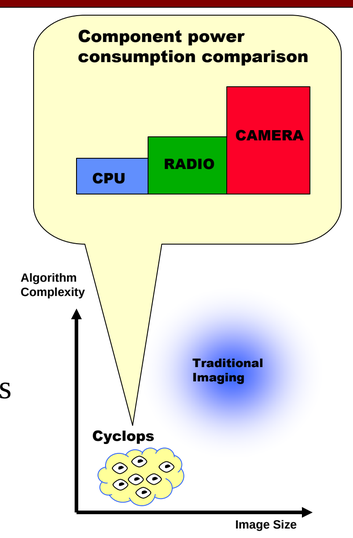
Agilent Technologies

Deep vision extends visual observation to the finest granularity of the network!

Problem: Vision Network

Why Vision

- **Disambiguate the environment**
  - Context, texture, shape or change in shape, presence or absence, displacement, interaction, color
- **Network of low power image sensors**
  - Enables new classes of applications
    - Security , smart environment, biology, precision agriculture, gesture recognition, enhanced toys
  - Lossy inferences that are reinforced by multiple observations in the network
    - Multiple view, avoid occlusion, close-up observation
    - Scalability can lead to power efficient algorithms



Enabling Technology

- CMOS vision sensors are low power and low cost
  - Comparable with computation and networking
- CMOS imagers mate with complex processor
  - Commercial market: Cell phones, PDAs , Cameras
  - Occasional use, frequent recharge, availability of computation
- Many vision inferences can be performed on reduced-sized images
  - The high quality is not needed for many applications
  - Reduced image size reduces power consumption
- Image capture and interpretation on a single chip sensor

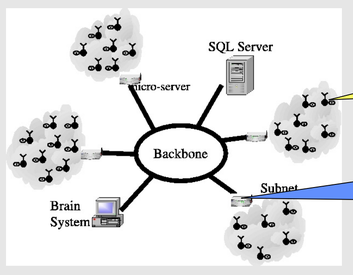
Approach

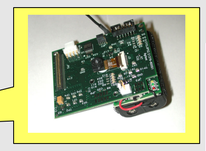
Design Principles

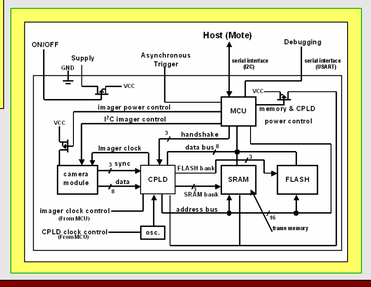
- Sensor Nodes can perform small computation on the images
- Attribute based sensing
  - Visual computation as sensors
  - Visual sensors are addressed through attributes
- Composition of attributes extracts information from the network

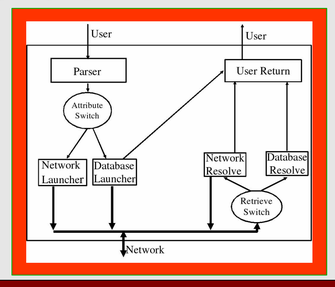
System Components

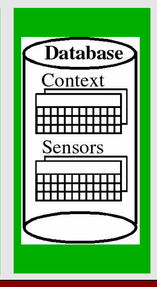
- **Subnets**
- **Network node with vision sensor**
- **Database**
- **Central computer**











Central Computer

- Human interaction
- Binding visual observation to the environmental context
- Relate environmental attributes to the visual attribute

Database

- Data archival
- Intermediate level book-keeping
- Recording environmental context

Network

- High speed backbone
- Local subnets with different frequency
  - Extend geographical coverage

Cyclops: Sensing Platform

- Stand alone MCU
  - Isolate delay stringent networking from imaging
- CPLD
  - Low power frame grabber, dedicated logic
- Imager
  - CMOS, medium quality and Low power
- External SRAM

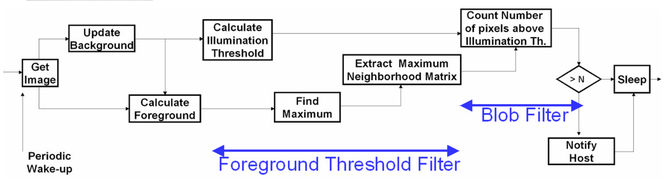
Cyclops: Design principle

- Hardware
  - Low power consumption,
  - Simple interface as sensor
  - On-demand access to resources
  - Flexible Sensor
- Software
  - Transparency in using resources
  - Supporting long computations

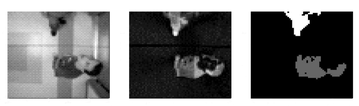
Experimental Result

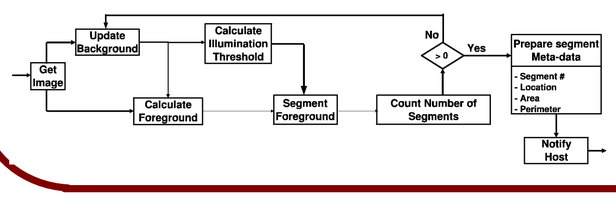
Object Detection

- **Background model**
  - Moving average of instantaneous images

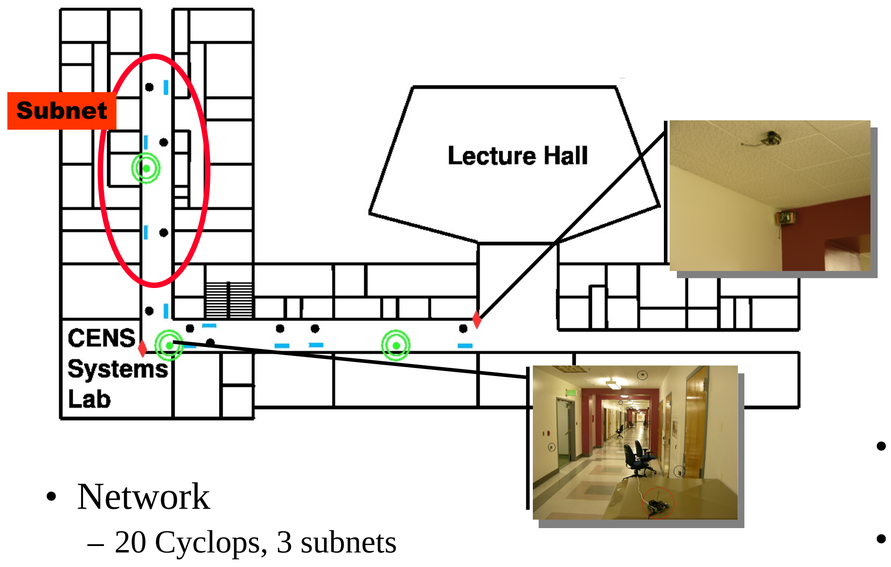


Object Segmentation

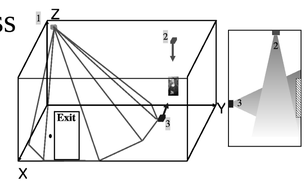




Bolter Hall Deployment

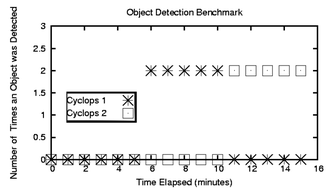


- Network
  - 20 Cyclops, 3 subnets
  - 9 art-view, 9 top-view, 2 access
- Infrastructure
  - View: Side, Top, and Corner
- Environmental Context
  - Galleries, art type, piece name
  - Public vs. Private

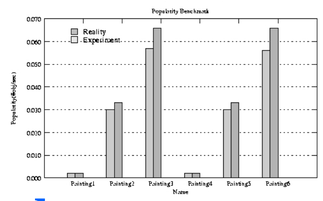


Benchmark

- Security
  - Detecting presence of objects



- Popularity
  - Number of objects per unit time



Future Work

- Permanent Test-bed
  - Large scale, controlled experiments
- Simulator
- Deployment
  - Smart environment (museum), biological studies (bird nest boxes)
- Incorporation of other sensing modalities
- Tiered imaging

UCLA – UCR – Caltech – USC – CSU – JPL – UC Merced