What I Do

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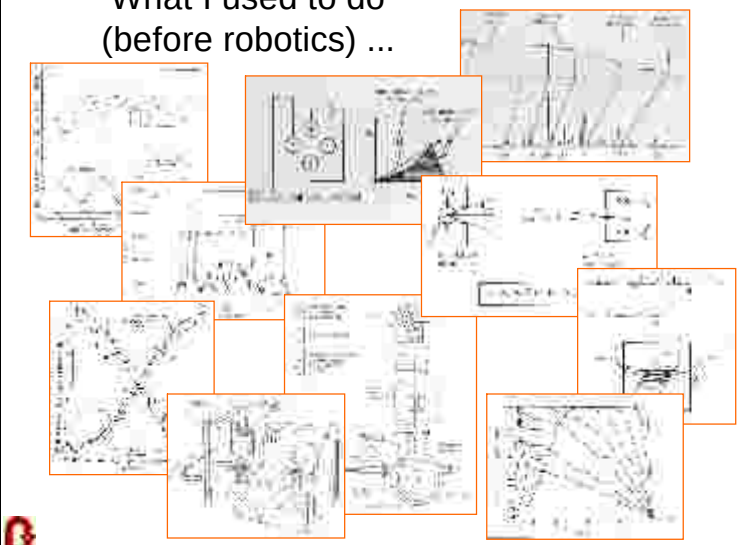
Sensor Devices and Gadgets	Aircraft Inspection Applications	Sensor Theory and Algorithms
Medical Applications	Stereo for People	Vehicle and Roadway Applications
"Sensing and Sensors" 16-722	Industrial Process Diagnosis	Difficult Measurement Environments

What I used to do (before robotics) ...



Measurement Science

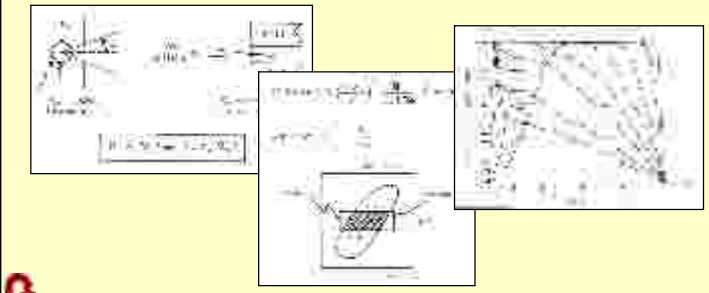
- Fundamental and technical sources of noise, sensor fusion to improve signal-to-noise ratio

Sensor Modeling and Simulation

- How can we make “virtual sensors” that will pass a “Sensor Turing Test”, i.e., impersonate real sensors?
- Such “virtual sensor software agents” are needed for …
  - “Wished for” sensor simulation in iteratively-developed systems
  - Testing large systems outside dynamic range of existing sensors
  - Real sensors too valuable to divert during system development
- Hypothesis: simulating the signal is relatively easy; the hard part is getting the noise right
  - Note analogy with computer graphics: the best fakes are betrayed by being too good
    - lacking “dirt” in the world model
    - lacking distortions in the imaging system
- Essential challenge is simulating chaotic features

Instrument Modeling

- Ray tracing and Monte Carlo approaches to generating “impulse response functions” of instruments for which we have no closed-form models

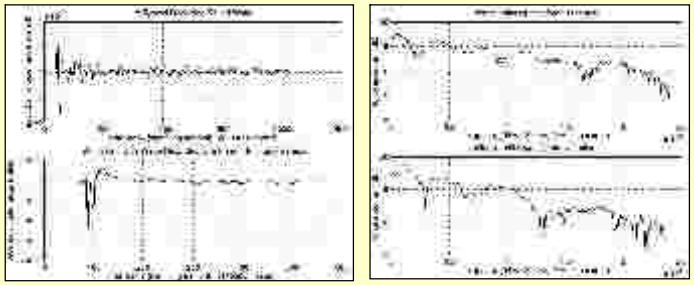


Instrument Modeling (2)

- Optimization with a “person in the loop”

Fusion of Competing Modalities

- “Coin Tap Test” for skin integrity
  - Manual methods use mostly sound
  - Automated instruments use hammer acceleration
- We show that fusion is the best “alternative”



Aircraft Inspection Systems

- Skin crack and corrosion detection shown here
- Internals, e.g., fuel tanks, on research agenda
- Combines sensing, mobility, human factors

ANDI at AANC-Sandia

CIMP at Northwest Airlines

Aircraft Inspection Systems (2)

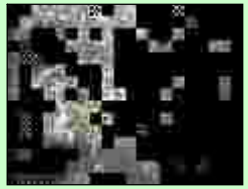
ANDI

CIMP

"Eyes-on-a-Stick"

Human Interface

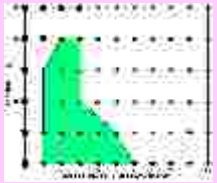
Crack Detection



Corrosion Detection

Stereo Vision for People

- Kinder Gentler Stereo vs. Virtual Reality Sickness



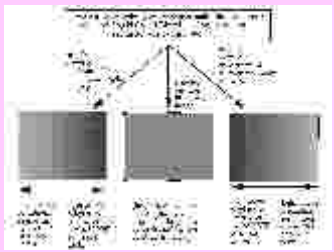
Stereo Vision for People (2)

above diagonal: normal interlace
below diagonal: stereo anaglyph

full screen animated (F5)

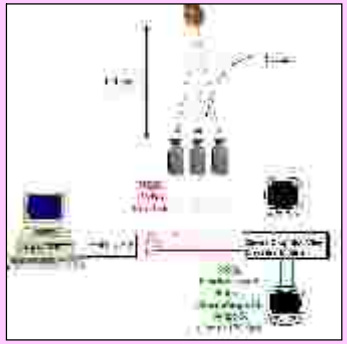
Stereo Capture and Display

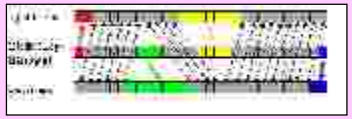
- Optics and optical algorithms: *microstereopsis*
- Human factors: perceptions of cross-talk as ghosting and as blur
- Release of engineering design constraints: toward a *zoneless autostereoscopic* display



Trinocular Stereo Camera

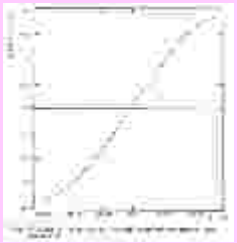
- HDTV cameras inconvenient for stereo (too big, too expensive, too much data to process)
- Trinocular design uses central HDTV camera with left and right outriggers for stereo capture (outriggers monochromatic, low resolution)
- Disparity generated from outrigger data stream allows synthesis of left and right HDTV stereo

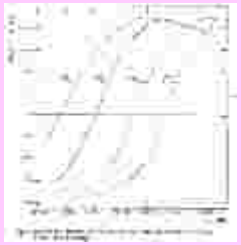




Range from Focus Error

- Human eye focuses anomalously rapidly, as if it can *measure focus error* vs. hunt for focus point
- Dithered (longitudinally oscillating) image sensor generates a focus error signal at 2x dither frequency
- Ratio of signals at 1x and 2x dither frequency is independent of the image gray level values
- Good application for complex on-chip processing



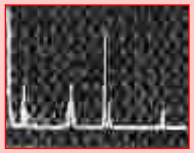


Lip-Reading Telephone Handset

- Communication between hearing and/or speech impaired users; improving audio in high noise environments (e.g., cell phones in subways)
- Local extraction of lip/tongue/teeth line drawing allows transmission of speech animation within audio channel bandwidth

Medical Robotics

- Pressure + ultrasonic sensing for custom fit medical assistance appliances, e.g. wheelchair cushions for paralyzed patients


Medical Odor Detection

- Practical requirement for odor sensing in understaffed nursing homes
- Prototype sampling wand uses sensor array, humidity compensation, and selective filtering
- Also applicable to rapid detection of infections



Laboratory Robotics

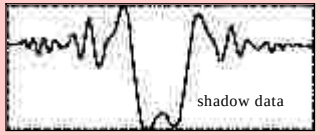
- Tailoring chemical or drug to function requires searching a large multidimensional space
- Robot work-cell permits uniform repetition of numerous evaluations and efficient search
- Automated repetitive thin layer chromatography (TLC) analyses with dynamic planning

Biotechnology Process Control

- Instrumentation and distributed rule-based control of complex industrial biochemical processes, e.g., fermentation

Industrial Processes Diagnosis

- Real-time measurement of fiberglass yardage
- Analysis of high-speed fiberglass chopping process



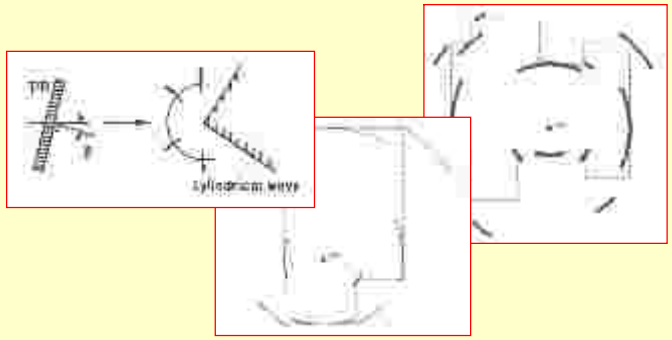
cutting data (high speed video microscope)

cutting theory

~ 200 μm strand of ~10 μm fibers

Modeling Ultrasonic Navigation

- CEWT = corners, edges, walls, transducers model of sensors & process
- Understanding of anomalous navigation data due to specular reflection and too simple signal processing



Scaling Relations in Robotics

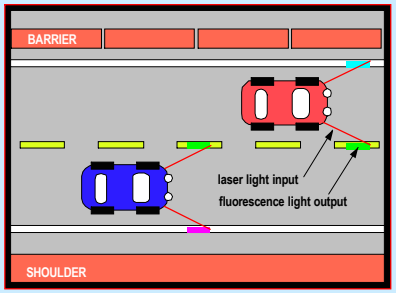
- How do robot capabilities and constraints scale as their dimensions change by multiple orders of magnitude?
- For example, energy carrying capacity of small devices
  - Onboard energy reservoir ~R^3
  - Internal and external friction ~R^2
  - So operating time ~R
  - Conclude that small robots will need to “forage” for fuel
- Science of scaling relations have a long and (usually) successful history in engineering and life sciences
- Has not been systematically applied to robotics
- Proper analysis and application will determine, literally, “the shape of future robots”

Power Transmission Lines

- Fault diagnosis
  - Expert system to aid set-up of microprocessor-based fault-protection relay
  - Expert system for fault-diagnosis by analysis of data captured by smart relay
- Communications
  - Investigate purported channeling of microwaves by powerline’s magnetic field

Vehicle-Roadway Systems

- Sensing, location, communication for transportation
- "Sensor Friendly Vehicles and Roadways"
  - Example: fluorescent lane-marking paint



Automotive Radar Systems

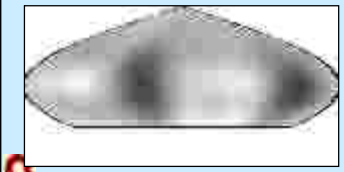
- Long range (automatic cruise control) and short range (urban obstacle detection) radars becoming available
- Investigate second order characteristics of signal (e.g., echo peak shape beyond just center and width) for clues about target geometry, material, dynamics, etc.

Magnetic Detection and Identification of Railway Cars

- Measure disturbance of magnetic field shape by understructure of car passing over sensor
- Need driven by employee vandalism of barcode, RF-tag, etc., tracking systems

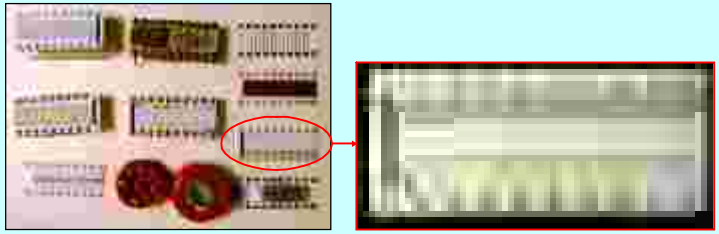
Automated Design of Automobile Headlamp Reflectors

- Image-based rendering of bulb patterns
- Mulitipole expansion-based data smoothing, interpolation, compression
- Iterative optimization of reflector design



Chemical Sensing Systems

- Sensor fusion using arrays of inexpensive, sensitive, but relatively non-selective sensors (nonlinear: neural net calibration)
- Gradient sensors: chemically sensitive surface, continuously-varying sensitivity in 2D (so can use image understanding tools)



High Speed Color Sensing

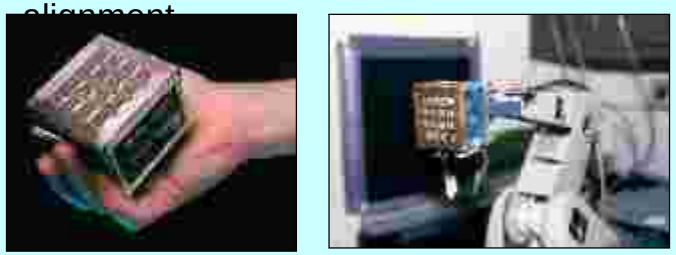
- RGB+IR LED-based
- Demonstrated rapid sorting of fruits and vegetables by type and ripeness

Finger-Tip Binary Imager

- LED + fiber-optic shadow detector array
- Demonstrated rapid identification of variety of small screws, nuts, etc

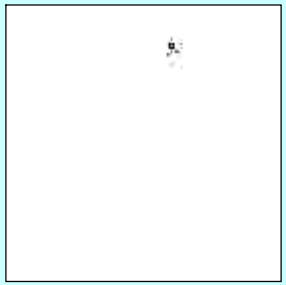
Palm-like Tactile Array

- PVDF piezo-electric sensor pad array
- Parallel signal digitization & processing
- Fusion into tactile pressure “video”
- Demonstrated robotic surface alignment



Explosives and Contraband Detection and Disposal

- "Difficult Measurements in Difficult Environments"



Education: Sensing & Sensors

- PhD-level course covering fundamental principles of sensing, measurement, communication, digitization, networking, in context of sensors for robots and robots for sensor deployment
  - Level suitable for well prepared Master's and very well prepared Senior undergrads
- Course videotaped; distance education version drafted on CDROM

Education: Sensing & Sensors (2)

The End but try a little data mining ☺