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Remote sensing: opportunities, challenges & results

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SAGENTIA

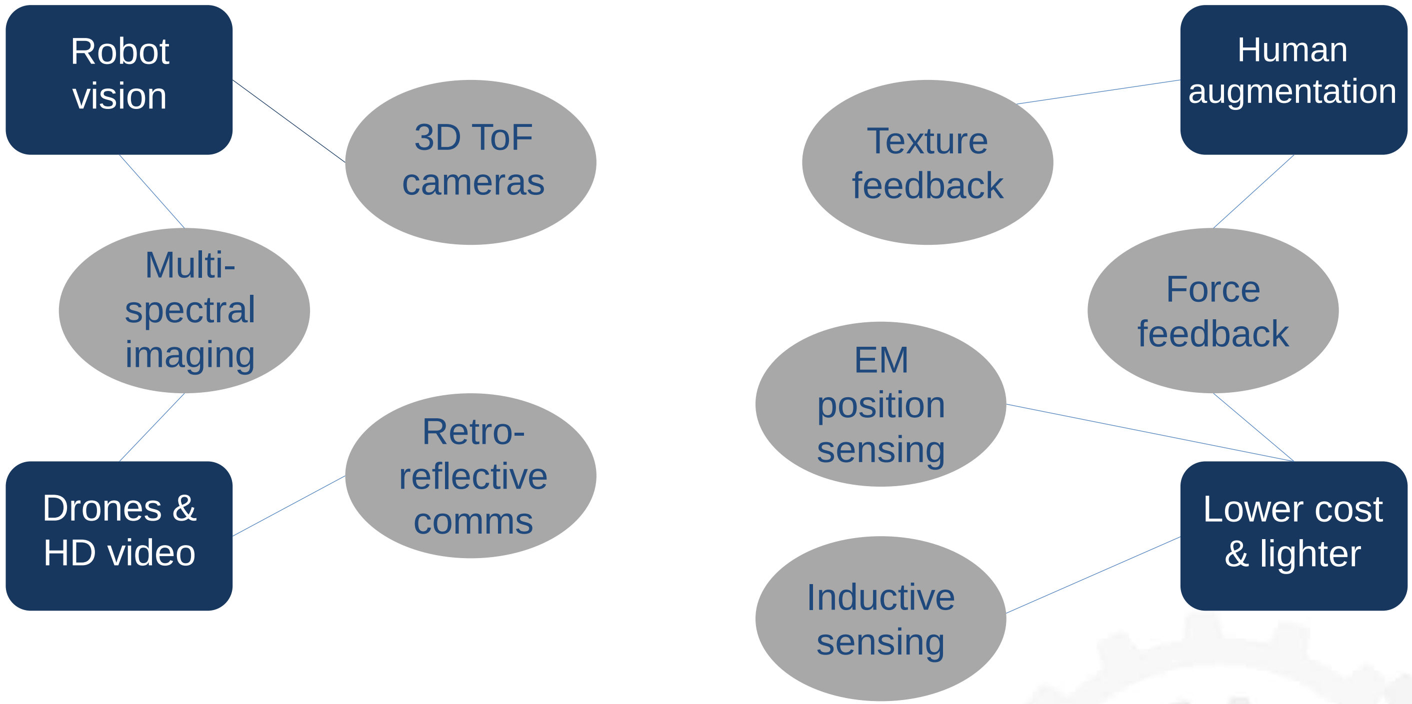
September 23-24, 2015

A next generation robotics upsurge is underway

Shift from traditional role doing assembly line tasks

To a new unstructured world involving multiple tasks and working alongside humans

Remote sensors for robotics can enable greater flexibility



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3D Image sensors

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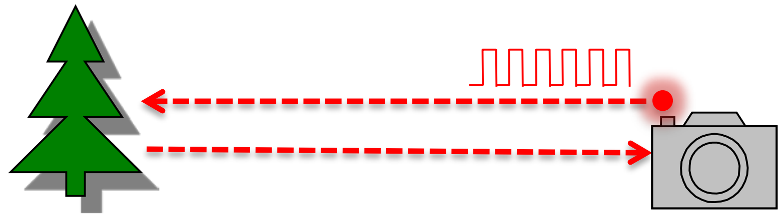
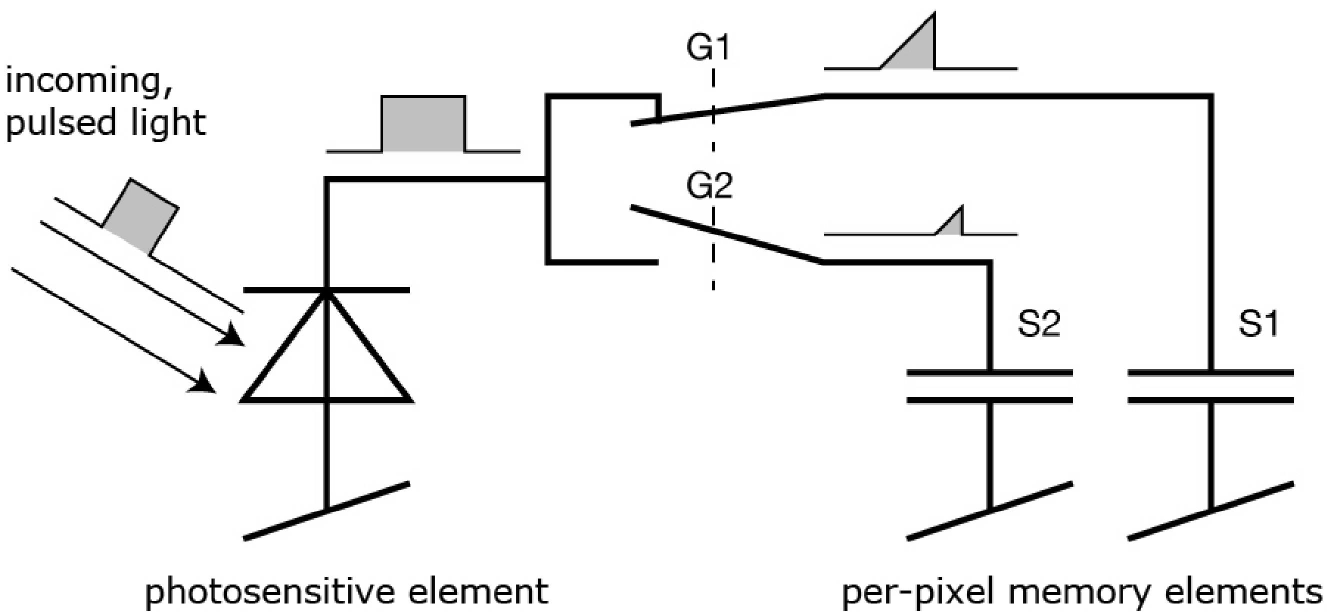
3D vision systems are now low-cost and simpler to implement

- There are several options for 3D imaging – eg structured lighting, scanning LIDAR, stereoscopic imaging, visual SLAM, time of flight (ToF) camera systems
- Each approach has its strengths
- To reduce algorithmic complexity, size and update delay, a ToF camera is rapidly becoming an attractive option

How does ToF work?





http://commons.wikimedia.org/wiki/File:TOF-Kamera-Prinzip.jpg

Strengths & weaknesses of ToF

Strengths

- High frame rate
- Compact
- Low software complexity
- Works in low and high ambient light

Weaknesses

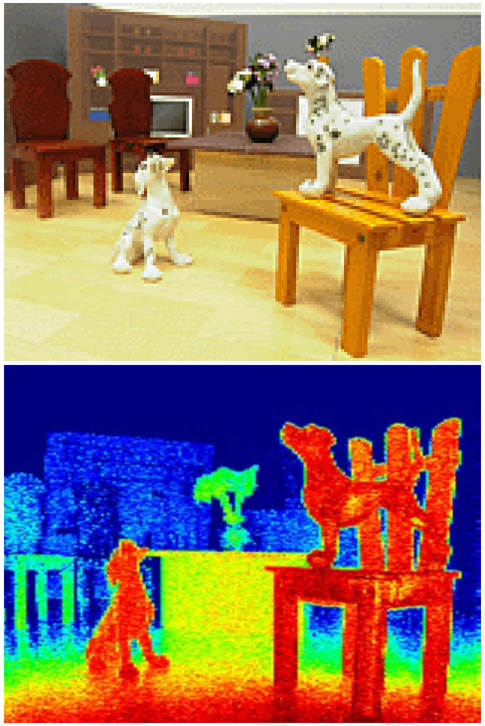
- Resolution lower than structured light
- Range limited by illumination power and phase wrapping

ToF cameras becoming widely available

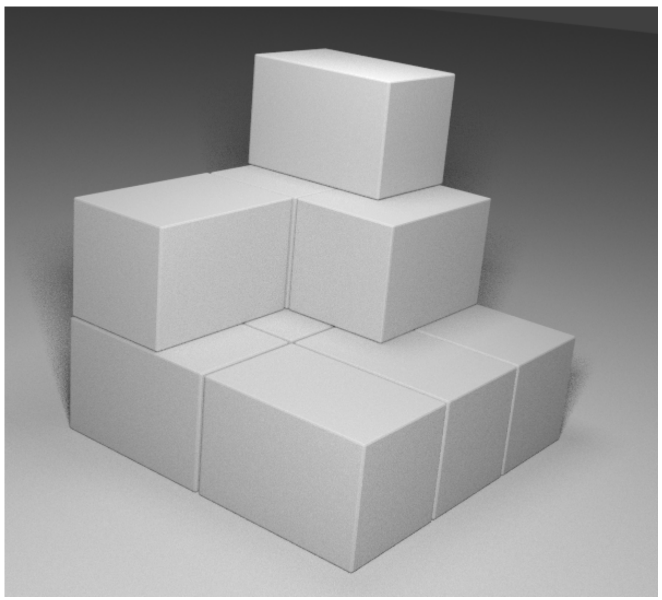
- ToF chipsets produced by several semiconductor companies
- ToF cameras using these chips now available from many vendors
- Finding their way into many applications as prices fall and functionality improves (mainly resolution)

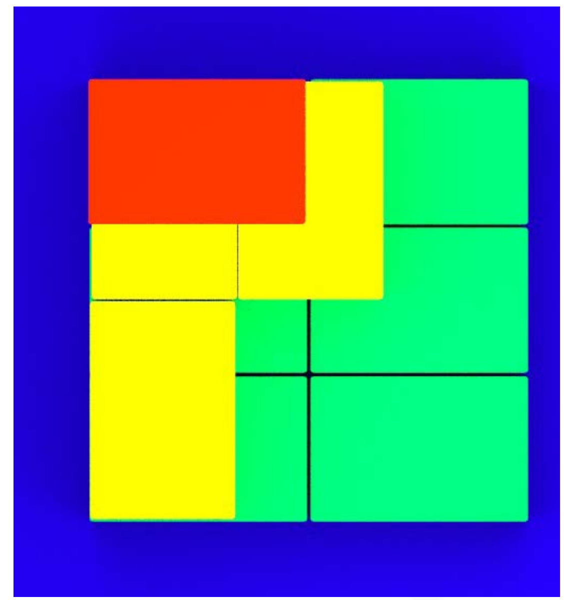
Depth data can greatly simplify image analysis

- Before we consider forming full 3D maps of the environment there are simpler applications
- Vision systems can use extra dimension to make more robust decisions than those provided by contrast alone



Depth data can greatly simplify image analysis





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Hyper & multispectral imaging

Instruments and applications

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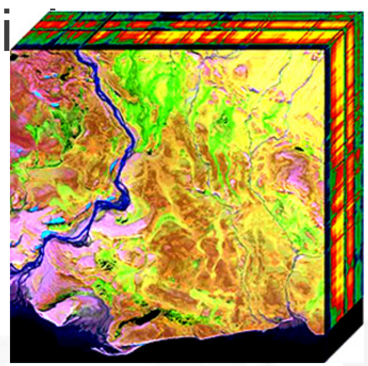
Seeing more than Red Green Blue

- Most cameras combine light from across the visible spectrum to form one image
- But we can see more if we
- Take an image from a narrow part of the spectrum of li
- Repeat for each part of the spectrum that is of interest



NASA hyperspectral cube

What is it used for ?

- Anything where changes in spectrum provide information about a process, condition or material presence
- Detecting changes in optical phenomena such as absorption, transmission, scattering, fluorescence, luminescence, interference
- Part inspection and identification
- Crop condition monitoring
- Pollution tracking
- Biomedical diagnostics

http://www.bayspec.com/spectroscopy/oci-uav-hyperspectral-camera/

What's in a traditional hyperspectral camera?

- Light source
- Tunable filter or dispersive element or interferometer
- Camera (>128fps best)
- Processor for control of light, tunable element, frame grab and analysis
- Algorithmic interpretation of spectral datacube

Typical systems

- Large satellite
- Airborne
- UAV borne
- Hand held

Aerial http://cubert-gmbh.de/uhd-185-firefly/

- Grating based camera
- VNIR and SWIR
- http://www.hyspex.no/products/

Integrated multi-spectral cameras have entered the market

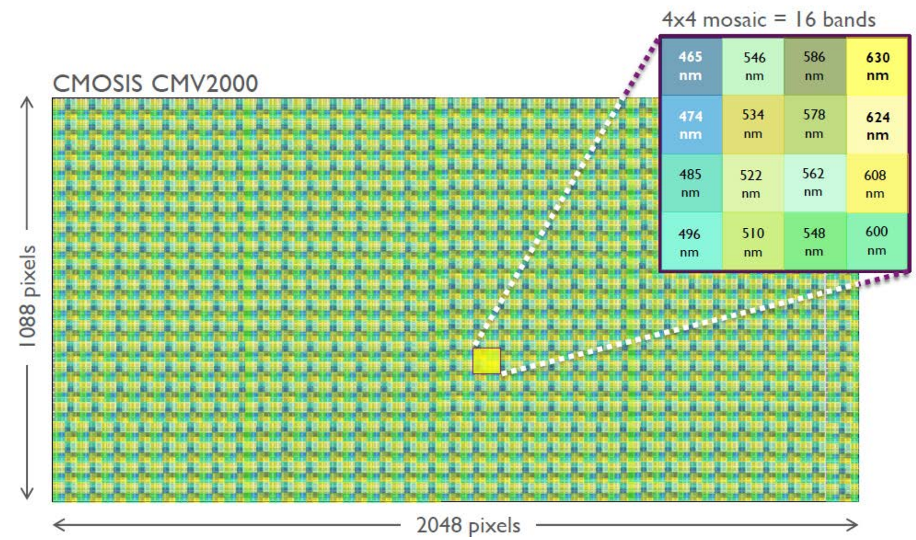
- IMEC has developed a range of solutions integrating the “light selecting” element with CMOS imagers
- Fabry-Perot filters placed over individual pixels
- Tradeoff between spatial resolution and number of bands
  e.g. 256x256 with 32 bands
- Technology in wide range of cameras

Imec’s mosaic and tiled imager chips

www.ximea.com

www.bayspec.com

Imec's tiled and mosaic approach



Imec's mosaic and tiled imager chips, http://www.imec-nl.nl

Tiled – requires imager duplicator behind lens

Mosaic – no duplicator required

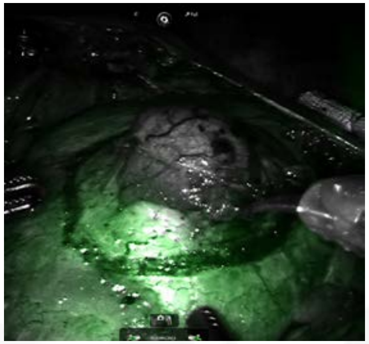
Application: smart surgery

Robotically assisted surgery is integrating tools to help surgeons

- Identify tissue structures – am I cutting the right thing?
- Identify areas of malignant tissue – is it all out?

For example:https://vimeo.com/132097972

- Visualizing blood oxygenation in tissues surrounding tumors "cancer field effect"
- Fluorescent Imaging – of stained and unstained tissues



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Retro-reflective communications

Light-weight, high-bandwidth, low-power

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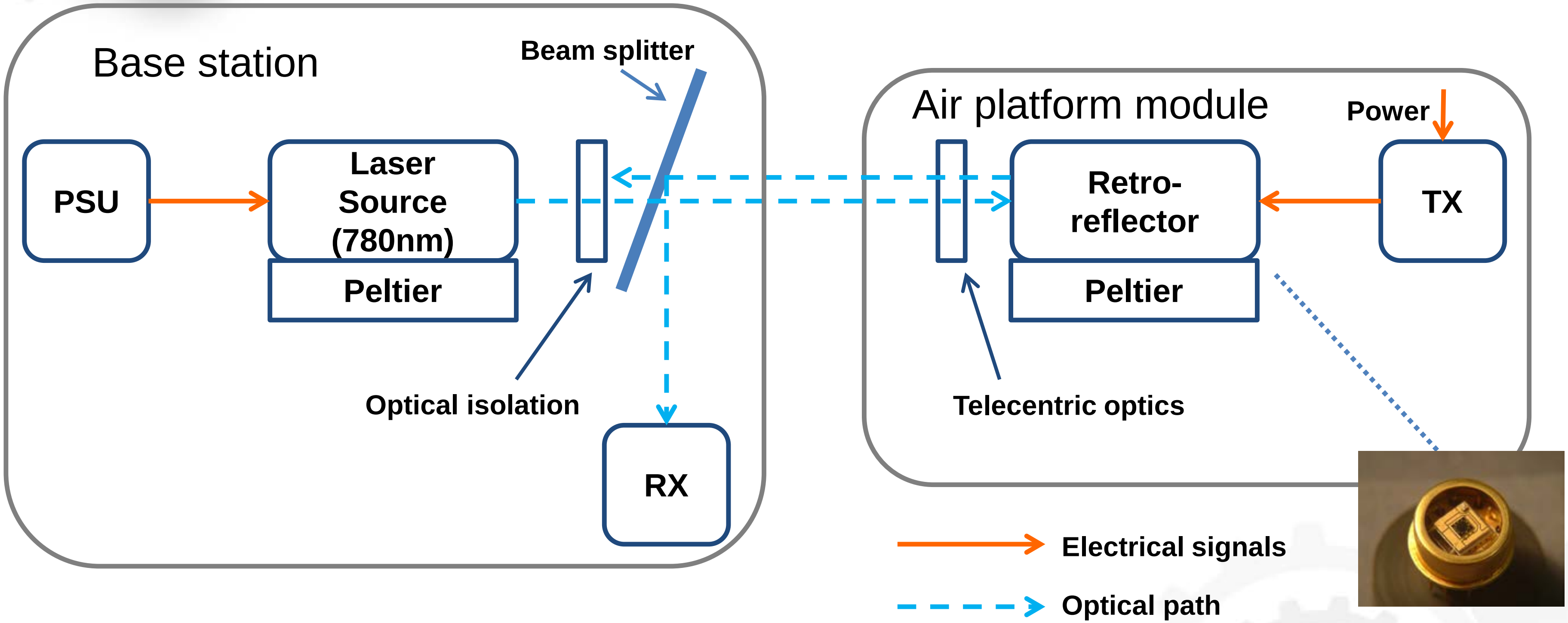
Passive optical comms

Line of sight optical communication:

- Uses a passive retro-reflective modulator
- High data-rates (0.1 to 1Gb/s)
- Low power requirement at passive reflective end
- Lower power/bandwidth than RF
- Reduces payload and power requirements
- Potential to harvest power from incident beam

How does it work?



What could it be used for?

- Aerial drones – where weight to power ratio is critical and high data rates are required
- Distributed sensors – networks of sensors that communicate with static or mobile base unit. RF comms is often the most power hungry function and a challenge for energy harvesting
- Mobile location where it is challenging to add weight or power e.g. end effectors

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Inductive sensing

Non-contact position sensing

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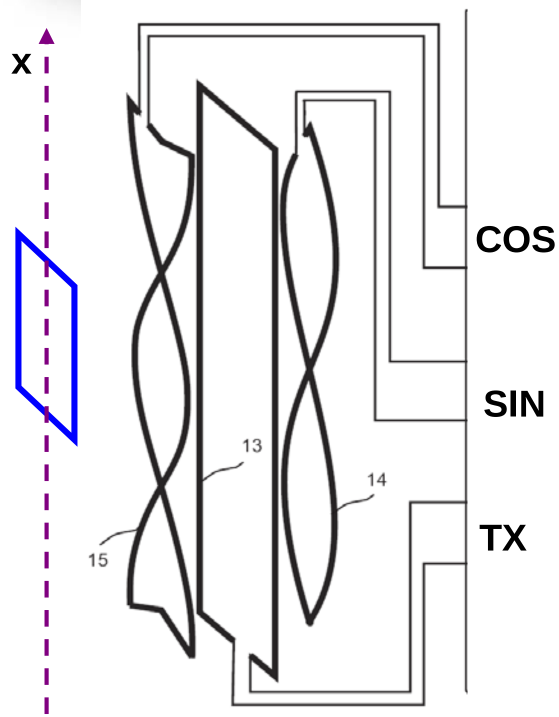
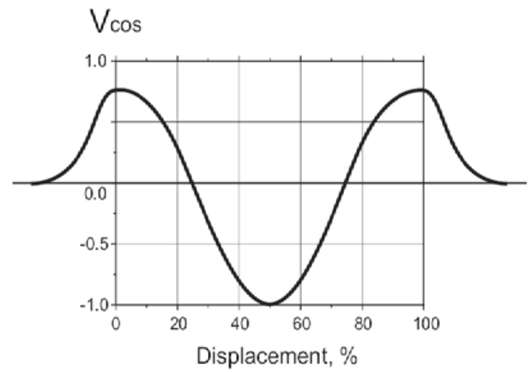
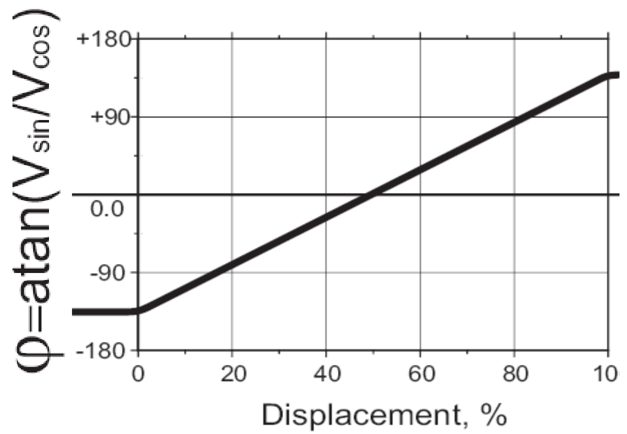
Short range inductive position sensing

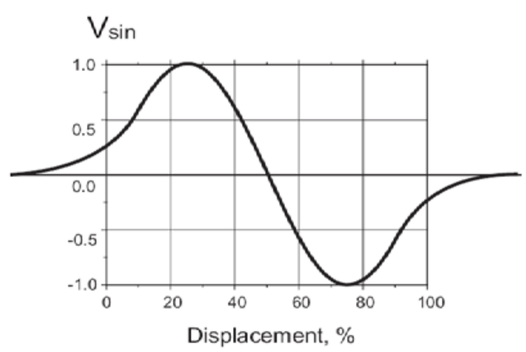
- Continuous non-contact position sensing in 1 or more dimensions
- Robust and reliable
- Historically large and expensive systems of LVDT etc used in rail and aerospace and costing >$200
- Modern systems offer much lower cost and design flexibility – reached maturity in automotive market and costing ~$2
- Based around coils on printed circuit boards

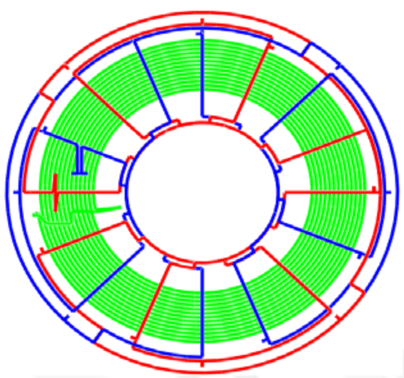
Position encoded in shape of coils











Application areas

- Low cost joint position sensing
- Curvilinear path sensing

  e.g. position along a conveyor
- Simultaneous identification and location

  e.g. exchangeable tools

Cutlass robot by Remotec

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EM position sensing

Long range EM position sensing

- Non-contact position sensing in freespace (6Dof)
- Unconstrained motion – flexible robotics
- Avoids calculating position via angle of many rigid linkages
- Avoids need to compensate for compliance (droop) in system
- Low-cost systems from gaming industry – short range lower accuracy
- Higher performance from medical industry

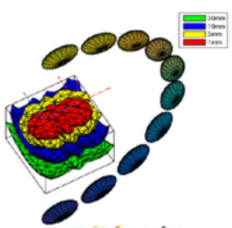
Example technologies

AC electromagnetic

Measure strength and direction of AC field

Pros: high accuracy

Cons: short range (<1m)



RF Pseudolite

GPS like solutions
Time of arrival and signal strength

Pros: range (km)

Cons: multipath and calibration

Large scale inductive

Phase measurement

Pros: Large areas (10m)

Cons: Antennas are size of area covered

Application areas

- Location of end effector – in flexible robotics. The classic example are catheters used in robotically assisted surgery
- Human augmentation in cutting, welding, painting
- Location of mobile robots

Tactile feedback

Robust low-cost tactile sensing for haptics

- Human augmentation requires us to find the right interface to our machines – using our senses
- Example is restoring the sense of touch in surgery
- Faithful reproduction of touch is expensive and hard to achieve in robust devices
- Alternative is to use human’s ability to learn the dynamics – we are good at this
- This solution uses encoders already present in the control system

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Texture sensing for haptics

- What if we could digitally transmit, share and analyse the sensation of touch and texture to the finger tips?
- Simple, accelerometer and voice coil solutions provide accurate, low cost solutions
- Applicability in teleoperation, robotic surgery, consumer care

Summary

- There are many sensor technologies available to robotics
- As we move into less structured environments these become crucial
- Many components of these sensor technologies are entering maturity
- There remains the need to integrate them into each specific application, understanding the performance and cost tradeoffs

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Thank you
Any questions?

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