Remote Sensing & Image-making

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Instrumentation



Computing

 $F(w) = \int f(t) e^{-jwt} dt$



- (1) What is Remote Sensing ?
- (2) Types of Remote Sensing (examples and images)
- (3) Basic idea of Image-making (Physics, Signal Processing, Computing)



What is remote sensing ?

"....the acquisition and measurement of spatially organized information on some property of an object, using one or more recording devices not in physical contact with the object being studied... "

=> Use a camera to take a picture of an object !

But what if the object is hidden ? ...or invisible to the human eye ? ...or too far away to see enough detail ?

Build instruments that use electromagnetic and sound waves to gather information about the object, and make an image / map / picture.

What is remote sensing ?



Types of Remote Sensing...



Satellite Imaging

Make maps of geological features on the surface of the Earth



Medical Imaging

Make pictures of structures inside the human body

A non-invasive diagnostic tool for the human body

Ground-Penetrating Radar

To identify buried objects and underground features.

Non-destructive testing of large man-made structures.



Astronomy and Astrophysics

Look at objects in outer space to study new Physics that cannot be observed on Earth.





Examples –Geographical Information Systems

Map of a river and its flood-plain - to monitor, study and predict floods.



Technique : Multi-Spectral Imaging

Infra-Red images of a hurricane - to predict its path and evacuate cities





Map of changes in elevation (height) - to study and monitor areas of volcanic activity.

Technique : Interferometric Synthetic Aperture Radar



Examples - Medical Imaging

CAT (Computer-Aided-Tomography) 3D image reconstruction from scans of a human thorax (+heart)



Movie shows a sequence of slices through the thorax

MRI (Magnetic Resonance Imaging) scans of the head, spine and a foetus











Examples -Ground-penetrating radar / sonar

3D map of underground water table - to dig wells (water, oil and gas exploration)



Image of Echo profiles from buried hazardous waste



3-D Image of iron rods inside a cement block - to monitor wear-and-tear of buildings



Image of an underwater plane-wreck - made using sound-waves





Examples : Astronomy and Astrophysics

Image of a Radio Galaxy in the Virgo cluster

- Can study High-energy-Physics, General Relativity, Magnetic Fields, Thermo-Dynamics, Shock Physics...



Images of the Crab Nebula - at different wavelengths



The Electromagnetic Spectrum



Objects can look different at different wavelengths (colours vs shades of grey)

- (1) Build detectors for different wavelengths (camera CCDs, antennae, ...)
- (2) Make images at all wavelengths with the same level of detail.



Detectors at Multiple Wavelengths (Astronomy)



Longer Wavelengths (50m - 0.5m)

Cannot build larger dishes !!





HUBBLE



How do you build a really large detector ?

Artificially synthesize a large 'dish''using many smaller ones...

Giant Meterwave Radio Telescope 80km N of Pune, India



30 dishes (45m each) spread across 27km

Very Large Array, New Mexico, USA



27 dishes (25m each) spread across 30km

... this is called 'Aperture Synthesis '

... this idea is used in many Remote Sensing applications.

How do you synthesize a large 'dish'' (aperture) ?



But ... this large 'dish'is not a real 'reflecting surface'....

So how do you make it behave like one ?

... by imitating how an ordinary lens works.

Measure interference fringes



http://vsg.quasihome.com/interfer.htm

Young's Double-Slit Experiment

Distance between slits controls the wavelength of interference fringes

One dish == One slit

=> Each pair of antennas measures a different 2D fringe.



Fourier Synthesis



Measure and add up enough different fringes

=> Good reconstruction of the image

Fourier Transforms !!!

Form an image by adding together different Fourier terms.



Signal Processing



Data Processing - 1

(1) Editing

=> Need to Identify and remove "bad data".

Stray signals : TV, Air-Traffic-Control, Radio stations, Cell phone services, satellite communication signals, etc....



(2) Instrument Calibration

Fourier Optics applies only under some ideal conditions

=> Need to model and undo instrumental effects

Data Processing - 2

(3) Image Reconstruction

- Need to artificially interpolate between measured Fourier terms to create the final image.

Steps (2) and (3) are done by "non-linear model fitting".



Uses concepts from Numerical Analysis, Optimization Techniques, Computational Physics, Fourier Transforms, Fourier Optics.

A step further : New Instruments (Telescopes) !



LOFAR, The Nederlands



MWA, Australia



- At even longer wavelengths, even single dishes cannot be built.
 - "Dishes" are synthesized electronically from "dipoles "...



SKA : Square Kilometer Array

To be constructed in 2020

Will be the largest telescope on the planet

This is an interdisciplinary field of work

Physics and Optics :

- The working of a lens, the signature of physical processes, deciding what to measure ...

Instrumentation :

- Design and construction of detectors, sensors, receivers ...

Analog and Digital Signal Processing :

- Signal acquisition and validation, Image processing, ...

Numerical Mathematics :

- Create algorithms to process the data and create a good / accurate image...

Computer Science :

- High-performance software implementation ...

Applications : Geographical Information Systems, Medical Imaging, Non-destructive Testing, Ground-penetrating Radar, Astrophysics, ...

This work happens at : Many Institutes and Universities, Govt. Research Labs, Companies like General Electric, Phillips, Siemens, ...

How to learn more at BITS.....



- Be adventurous with electives !!
 - Explore cross-disciplinary areas
- Get core-coursework in multiple disciplines (dual-degree).
 - Physics / Math + EEE / Instrumentation / Comp.Sc
- Do several projects to see what really interests you...
 - Signal and Image Processing, Remote Sensing
- Attend summer school programmes.
 - National Centre for Radio Astrophysics (www.ncra.tifr.res.in)
 - General Electric (www.ge.com/research/)
 - Indian Space Research Organization (www.isro.org)
 - National Remote Sensing Agency (www.nrsa.gov.in)
- Read !!
 - (www.wikipedia.org) + Google