New sensors, new missions, new challenges in VHRRS

Jordi Inglada

CENTRE NATIONAL D'ÉTUDES SPATIALES

Who am I

- Jordi INGLADA, from Centre National d'Etudes Spatiales, Toulouse, France
- Ph.D. in Signal Processing and Telecommunications
- Responsible for the Methodological part of the ORFEO Program
  - ORFEO Toolbox, OTB, `http://otb.cnes.fr`
- Associated Editor for IEEE TGARS

Introduction

- New HR/VHR sensors and systems are becoming available
- Beyond the spatial resolution there are also the spectral and the temporal dimensions
- Many operational sensors allow multi-sensor synergy
- Other sources of geographical information: maps, GIS, GoogleEarth, ...
- How to design new applications?

Scope of the talk

- This is an introduction talk, so I will just say general things
  - No equations
  - No RS images
- Please ask questions, so we can diverge from the slides
- I have some demos ready to illustrate things
- I have the first question:
  - What is your definition of VHRRS?

Outline

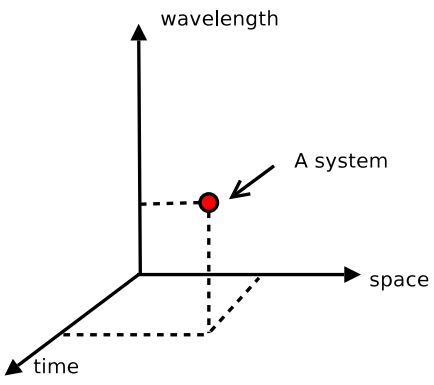
Definition of resolution

- The fineness of details that can be distinguished;
- Usually used in RS for spatial resolution, eg.
  - The spatial size of the smallest detail that can be distinguished in an image;
- This is not the same as the ground sampling distance, GSD

Outline

The dimensions of resolution

- We want to distinguish details in other dimensions:
  - time;
  - wavelength;
- Therefore, there are other dimensions of resolution



Spatial resolution

- Directly linked to the system's passband
  - size of the optics in optical sensors;
  - power, frequency excursion in SAR systems;
- But also to sampling
  - size of the detector, AD converter in optical systems;
  - PRF and AD converter in SAR;
- Why the effective resolution is always worse:
  - non nadir acquisitions in optical systems;
  - bad Doppler, focusing problems in SAR.

Improving the spatial resolution of a system

- super-resolution (SPOT5);
- image restauration (most of recent optical systems);
- oversampling by platform steering (spotlight SAR modes or similar approaches for optical sensors);
- fusion as pan-sharpening.

Temporal resolution

- Directly linked to the system's revisit time
  - 23 days for SPOT 5
  - 1 day for the SPOT system
- What is interesting is not the nominal resolution
  - but the effective temporal resolution of the resulting multi-temporal series;
- Why the effective resolution is always worse:
  - images that you have to discard: clouds, haze, UFOs;
  - images that are not taken: system unavailability, tasking conflicts;

Improving the temporal resolution of a system

- not much to do;
- mix similar systems with shifted temporal cycles
  - ERS and Envisat;
- Less constraining but more tricky: mix data coming from different sources
  - I think they call it *fusion*

Spectral resolution

- Directly linked to the number of detectors/filters on the system
  - one band is one detector behind a spectral filter;
- Typically inversely proportional to spatial resolution
  - sensitivity of the sensor
- Analogy between SAR polarimetry and multi-spectral acquisitions
  - Also multi-frequency SAR acquisitions;
- Why the effective resolution may be worse:
  - some very noisy bands;
  - some systems acquire only a subset of the available bands (capacity limitations).

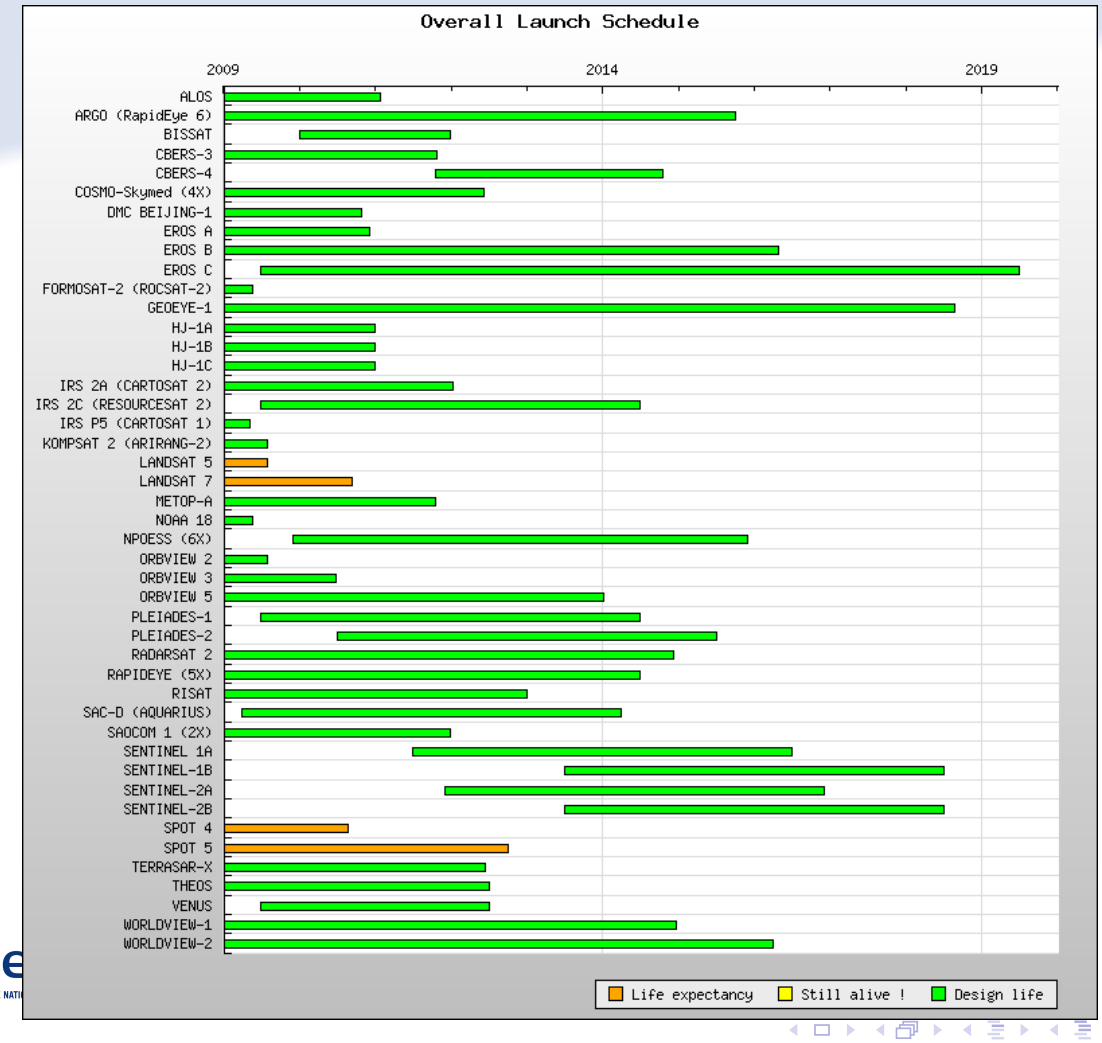
Improving the spectral resolution of a system

- not much to do;
- fusion as pan-sharpening, or generalized multi-band fusion.

Upcoming systems

- More and more countries are launching their own Earth observation systems
- Several private companies are building and operating satellites
- Many EO satellites will be launched in the coming years
- Many are similar: easy to fuse and combine
- Many are complementary: challenging to fuse and interesting to combine!
- Let us see some examples of systems
  - `http://www.space-risks.com/`

VHR Systems Missions Challenges Some examples Spatial Spectral Temporal



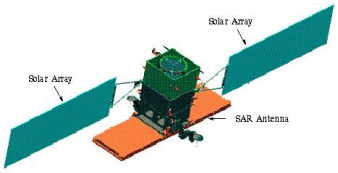
Outline

VHR Systems Missions Challenges Some examples Spatial Spectral Temporal

Pleiades

- Spatial
  - Spatial resolution: 0.7 m
  - Swath: 20 km + mono-pass mosaics
- Temporal (1 sat)
  - Orbit cycle: 26 days
  - Revisit time: 3 days (1 m.), 1.5 days (1.5 m.)
- Spectral:
  - Pan + XS (B, G, R, NIR)

COSMO SkyMed



- Spatial (Spotlight mode)
  - Spatial resolution: 1 m.
  - Swath: 5 km.
- Temporal
  - less than 16 days with 1 satellite
  - 3 to 6 h. with 4 satellites
- Spectral
  - Single frequency (X band)
  - Dual pol (ping-pong) mode

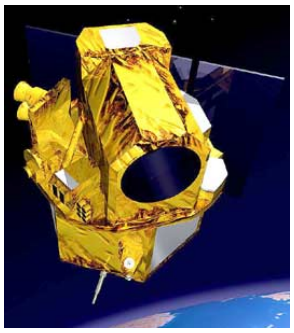
VHR Systems Missions Challenges Some examples Spatial Spectral Temporal

GeoEye 1

- Spatial
  - Spatial resolution: 0.41 m
  - Swath: 15.2 km.
- Temporal
  - Revisit time: more than 2 days
- Spectral
  - Pan + XS (B, G, R, NIR)

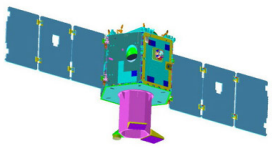
cnes CENTRE NATIONAL D'ÉTUDES SPATIALES
Grenoble, 2008/09/08

Formosat 2



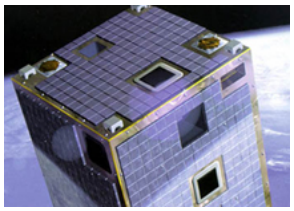
- Spatial
  - Spatial resolution: 2 m
  - Swath: 24 km.
- Temporal
  - Revisit time: 1 day
- Spectral
  - Pan + XS (B, G, R, NIR)

Venμs



- Spatial
  - Spatial resolution: 5 m
  - Swath: 27 km.
- Temporal
  - Revisit time: 2 days (on selected sites)
- Spectral
  - 12 bands (VIS-NIR)

Proba



- Spatial
  - Spatial resolution: 25 m or 50 m
  - Swath: 14 km.
- Temporal
  - Revisit time: 7 days
- Spectral
  - 400 - 1050 nm.
  - 19 or 62 bands

Outline

Spatial resolution

- Increasing resolution in recent years:
  - Ikonos, Quickbird, Pleiades, Geoeye, etc.
  - Radarsat 2, Terra SAR X, COSMO Skymed, etc.
- Metric resolution still needed:
  - The best choice for many applications: precision farming, urban growing, some natural disasters, etc.
  - SPOT 5, Kompsat, Formosat, etc.
- New decametric resolution systems will be launched:
  - Enough for some applications where the other 2 dimensions are more constrained.
  - ESA's Sentinel program

Outline

Spectral resolution

- Most current optical systems are P+XS
  - 4 or 5 XS bands (B, G, R, NIR, SWIR)
  - often pan-sharpening is possible or even proposed as the standard product
- Not many space-borne hyper-spectral systems
- Raising interest for super-spectral systems
  - usually, a particular application only needs several spectral bands
  - good balance between spatial and spectral resolutions
  - Sentinel-2, Venμs
- For SAR
  - No multi-frequency systems
  - Full polarimetry is expensive (in terms of power, thus resolution)
  - Partial polarimetric systems (Envisat ASAR, COSMO Skymed)
  - Raising interest for smart compact polarimetry concepts

Outline

Temporal resolution

- Classical polar sun-synchronous orbits give revisit cycles of more than 20 days
- Revisit times are typically lowered by:
  - Changing viewing angles (affects radiometry)
  - Using more satellites (expensive)
  - Choosing specific orbit inclinations (some locations are seldom seen)
  - Increasing swath (degrades the spatial resolution)
- No free lunch!

What is a mission?

- The mission is the purpose of the space-borne system we are going to build. Example:
  - *To fulfill its scientific objectives, VENμS has to acquire frequent, high resolution, multi-spectral images of sites of interest all around the world.*
- By extension, we also call mission the system itself (satellites + ground segment)

Outline

How is a mission developed?

- Usual steps
  1. A user community (scientists, military, etc.) formulates a need
  2. The users' needs are translated into product specifications
  3. Product specifications are translated into system specifications
  4. The technology for the system (spatial and ground segments) is developed and validated
  5. The system is developed, implemented and validated on ground
  6. Launch and in flight commissioning phase
  7. Exploitation

Outline

Where can image processing be useful in the mission?

- Classical uses of IP
  1. On board compression
  2. On ground decompression and restauration
  3. Radiometric calibration
  4. Geometric corrections
  5. Generic classifications, standard products

Where can image processing be useful in the mission?

- Less classical uses
  1. Given a product specification
     - Which is the state of the art in IP/fusion?
     - Which is the minimum amount/quality of data required as input for these algorithms?
  2. Which are the on ground algorithmic approaches which could put less constraints on the spatial segment?
     - Ex.: automatic image registration, super-resolution, etc.
  3. How to simplify information extraction approaches so they can be implemented on board for decision taking

Outline

Classical way

- 2 different approaches
  1. General purpose observation missions, typically close to land mapping applications
     - SPOT, ERS, Landsat, Sentinels, etc.
  2. Very specific, niche-oriented missions
     - SRTM, SPOT-VGT, SPOT-HRS, Demeter, Polder, etc.
- Nevertheless, users have found new uses for some of them
  - SAR interferometry, Permanent Scatterers, with ERS-1
  - Water color with SPOT-VGT
  - DEM extraction with SPOT 5 P+XS data
  - More in this later on

Which are the new missions?

- Some new missions are devoted to data continuity
  - ESA's Sentinel program (SPOT 1-4 and Landsat, ERS and ENVISAT)
  - Astrium's Astroterra (SPOT 5)
- Many upcoming missions are more *service oriented*
  - Disaster management
  - Maritime security
  - Crop monitoring
- Service oriented approaches bring a new set of constraints to the mission