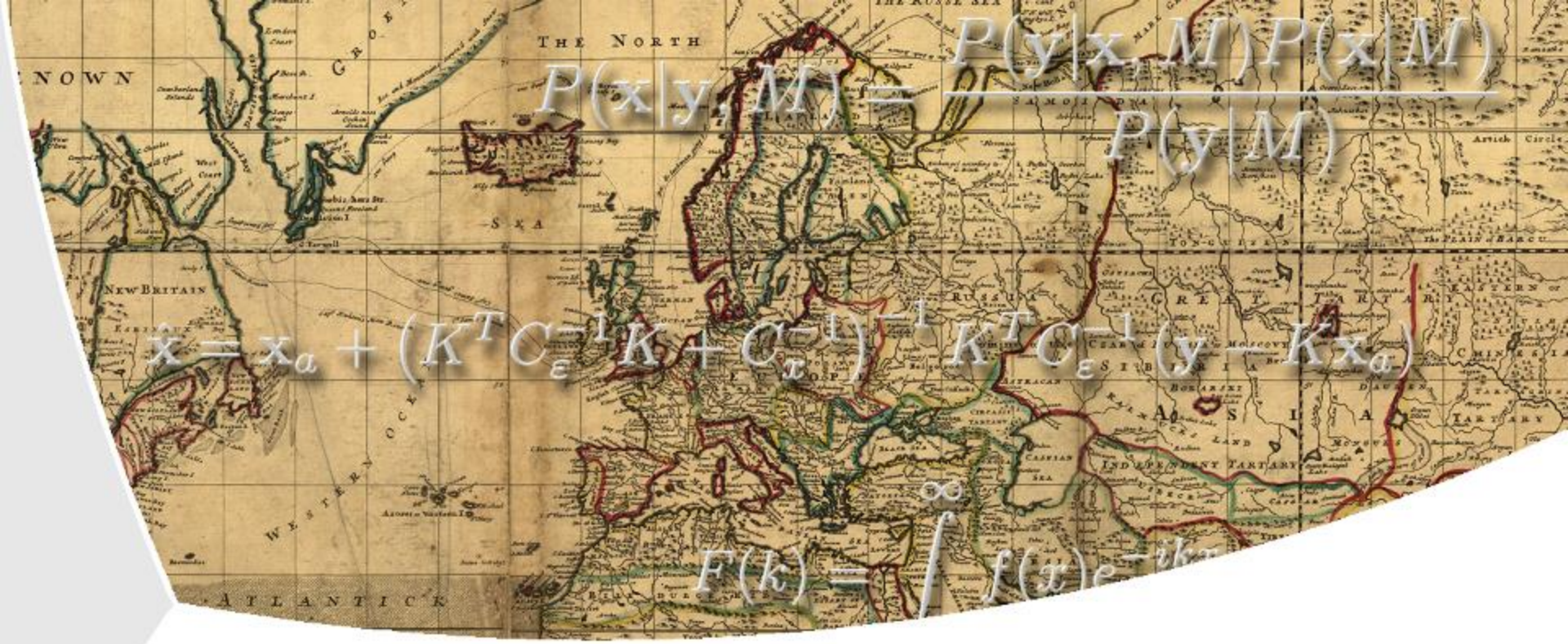
A Mathematical Theory of Communication

By C. E. SHANNON

INTRODUCTION

THE recent development of various methods of modulation such as PCM and PPM which exchange bandwidth for signal-to-noise ratio has intensified the interest in a general theory of communication. A basis for such a theory is contained in the important papers of Nyquist[1] and Hartley[2] on this subject. In the present paper we will extend the theory to include a number of new factors, in particular the effect of noise in the channel, and the savings possible due to the statistical structure of the original message and due to the nature of the final destination of the information.

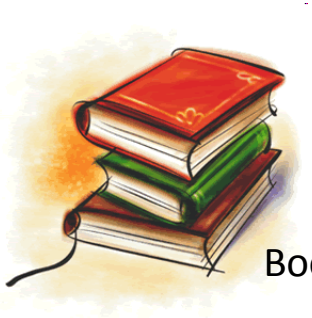
The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have *meaning*; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one *selected from a set* of possible messages. The system must be designed to operate for each possible selection, not just the one which will actually be chosen since this is unknown at the time of design.



Media semantic content extraction: the perspectives

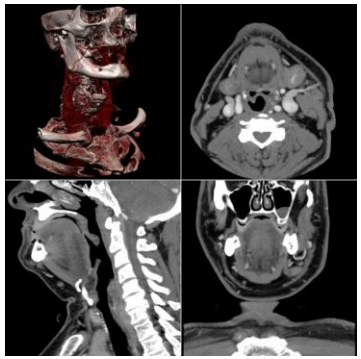
Prof. Mihai Datcu

The Data



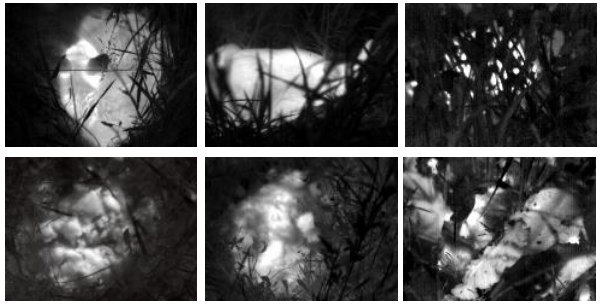
Books

Photos and hand-drawn images (Corel)

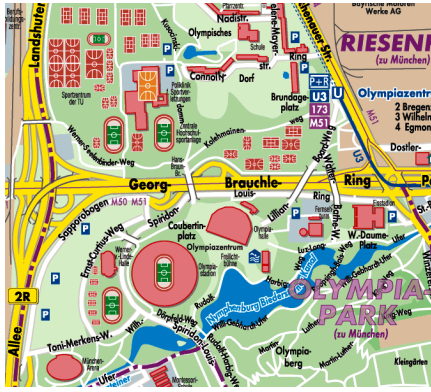


Tomography

Video frames (Run, Lola, Run)

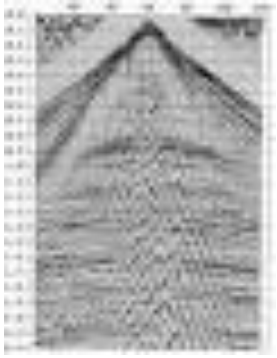


Infrared images of fawns (DLR)



Maps

Genome



Seismic records

Satellite images

Past years: Meta-data based file access

Competence Centre on Information Extraction and Image Understanding for Earth Observation

The data archive

The meta - data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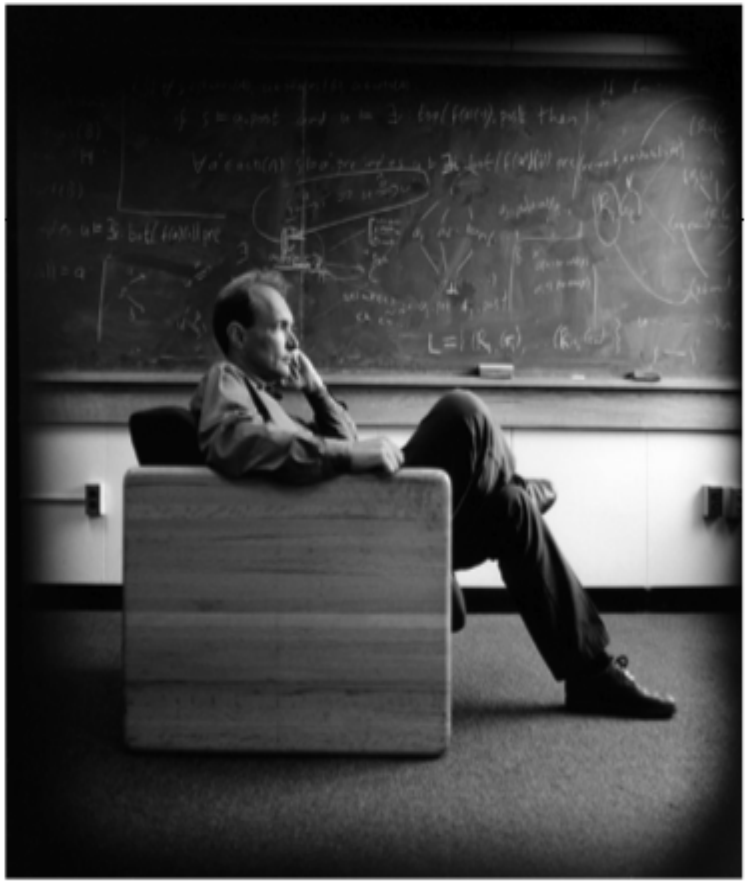
The data

Istoric

1989 - ***Tim Berners-Lee*** (poza) propune si realizeaza prima comunicare **HTTP (Hypertext Transfer Protocol)** server-client. El folosea deja existentul **Internet**. Se naste **WWW (World Wide Web)**

WWW – sistem global de documente hypertext interconectate logic;
Internet – sistem global de retele de computere interconectate fizic;
TCT/IP – set de protocoale de comunicare intre sistemele de calcul din Internet;



1990 : 2001 – **WWW** este referit, retroactiv, drept **Web 1.0**
Caracteristici pricipale: Pagini statice; folosirea de: framesеturi, extensii HTML, butoane GIF, guestbook-uri on line, etc.

2002 : prezent – **WWW** este referit drept **Web 2.0**
Caracteristici pricipale: Pagini (mai) dinamice; aplicatii care permit schimbul interactiv de informatii, interoperabilitate, etc.

~2006 : prezent – apare, lansat de acelasi ***Tim Berners-Lee***, si evolueaza conceptul de **Web 3.0** (urmatoarea „epoca" a WWW)
Caracteristici pricipale: Pagini dinamice; Semantica; Personalizare;

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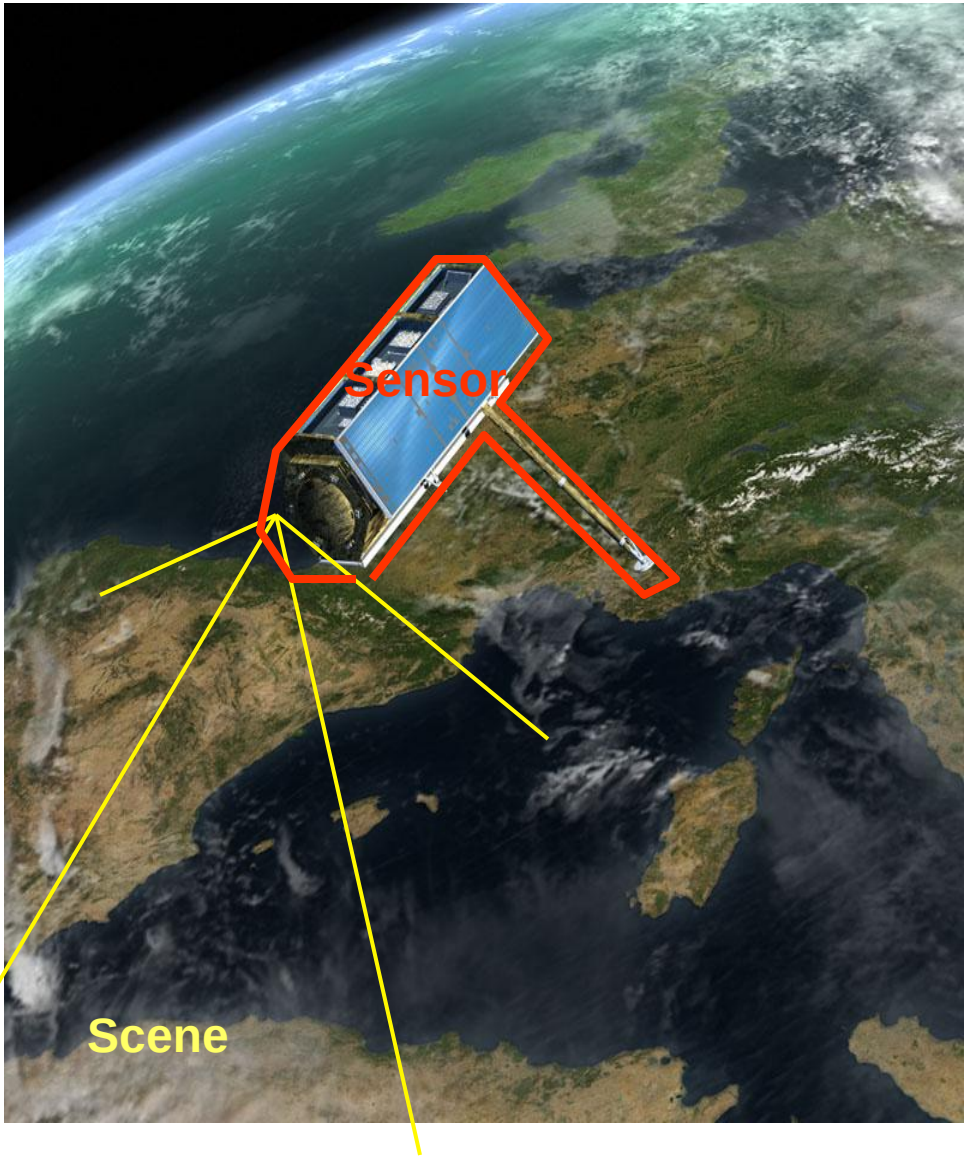
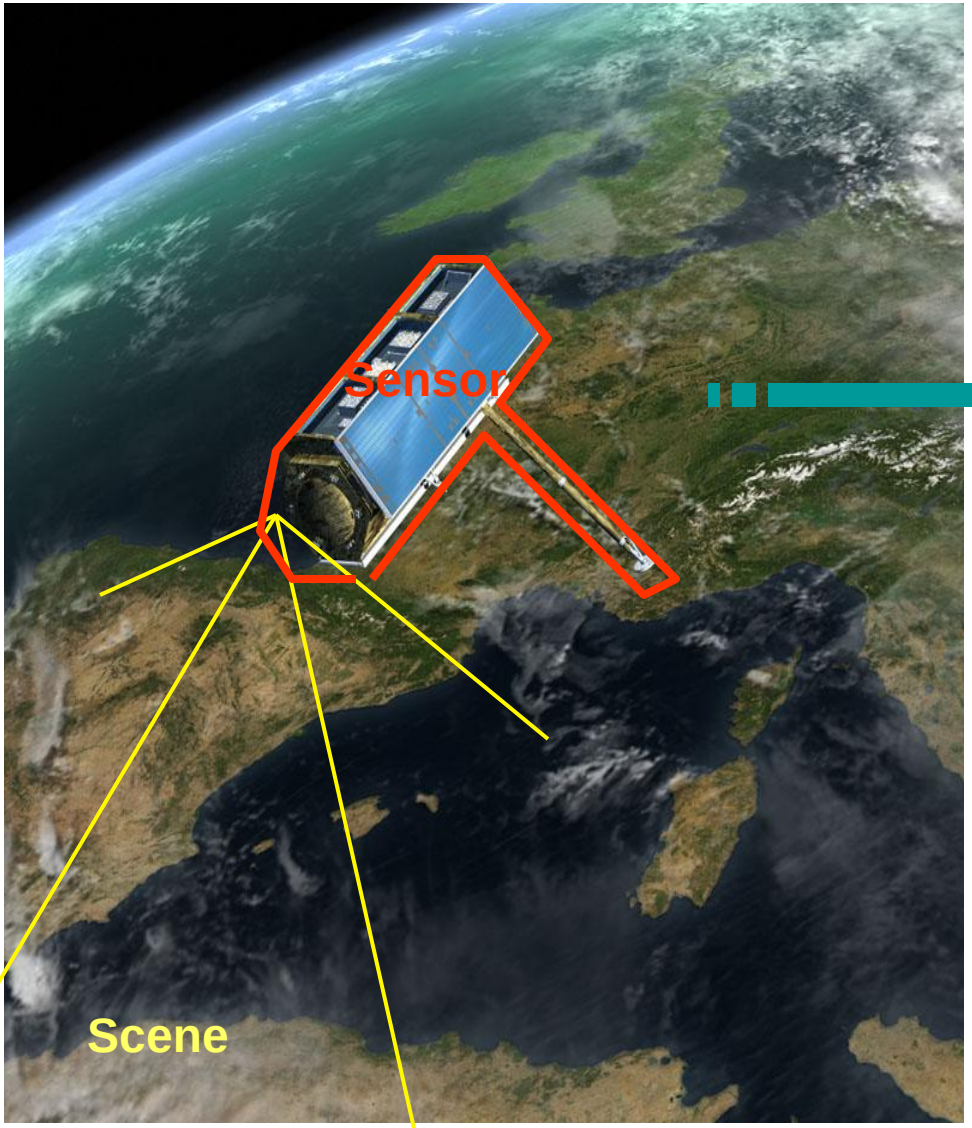
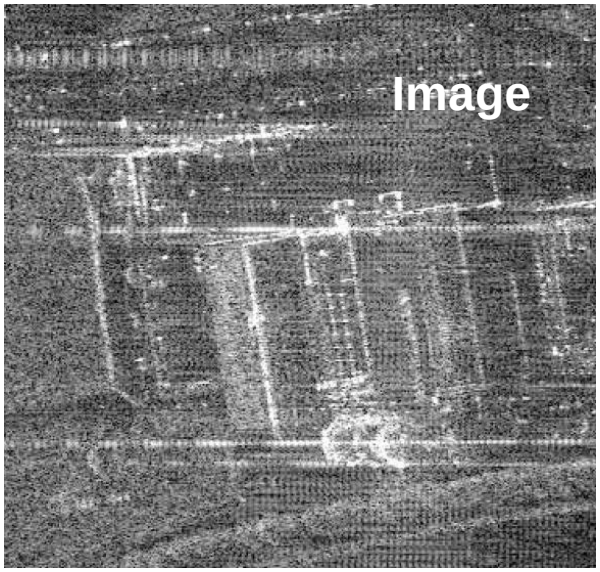
Data, Content and Knowledge

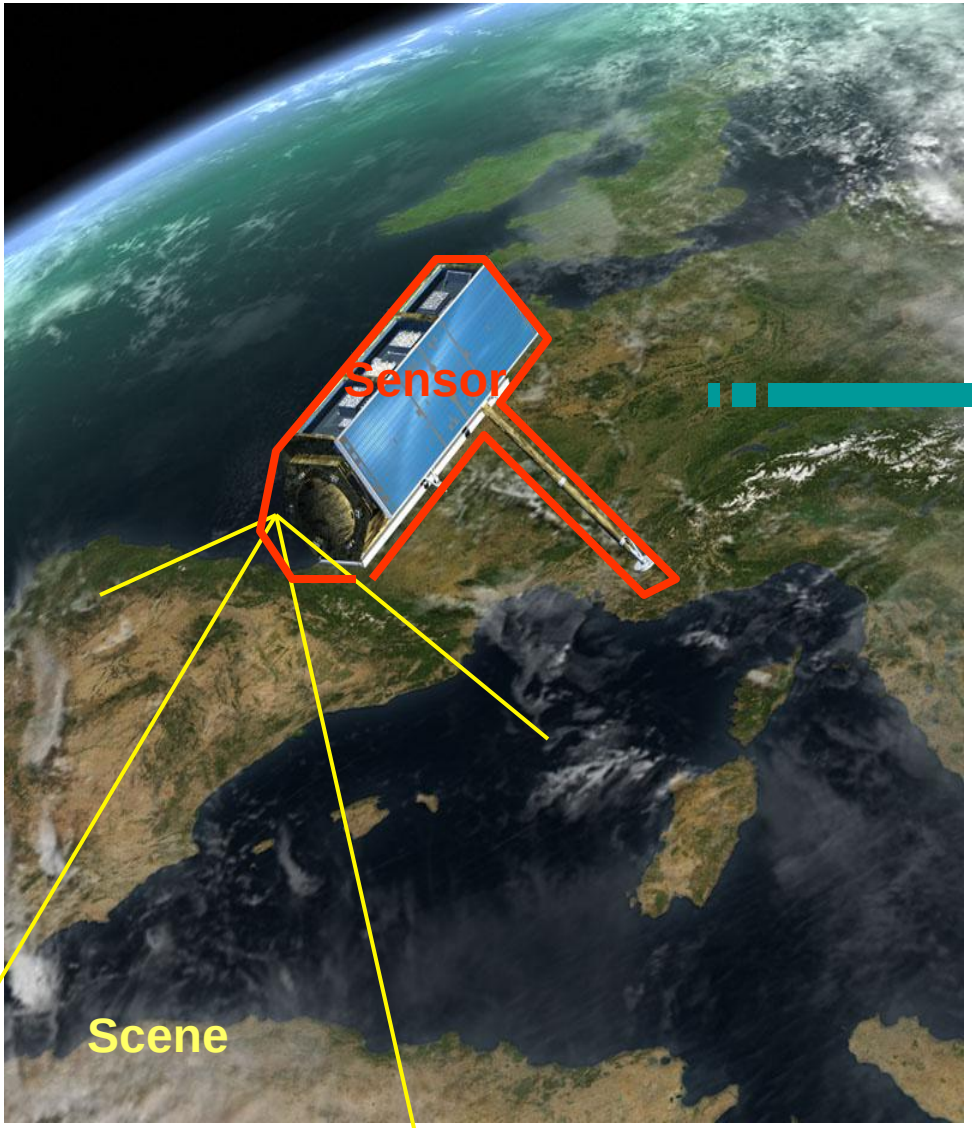


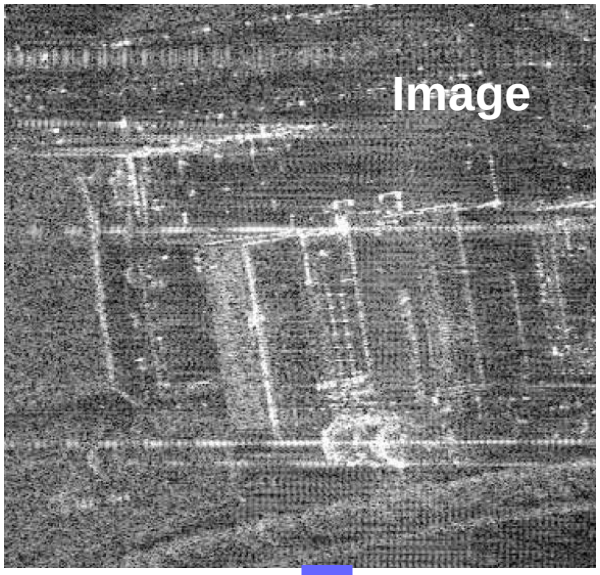
Data, Content and Knowledge





How EO is working ?

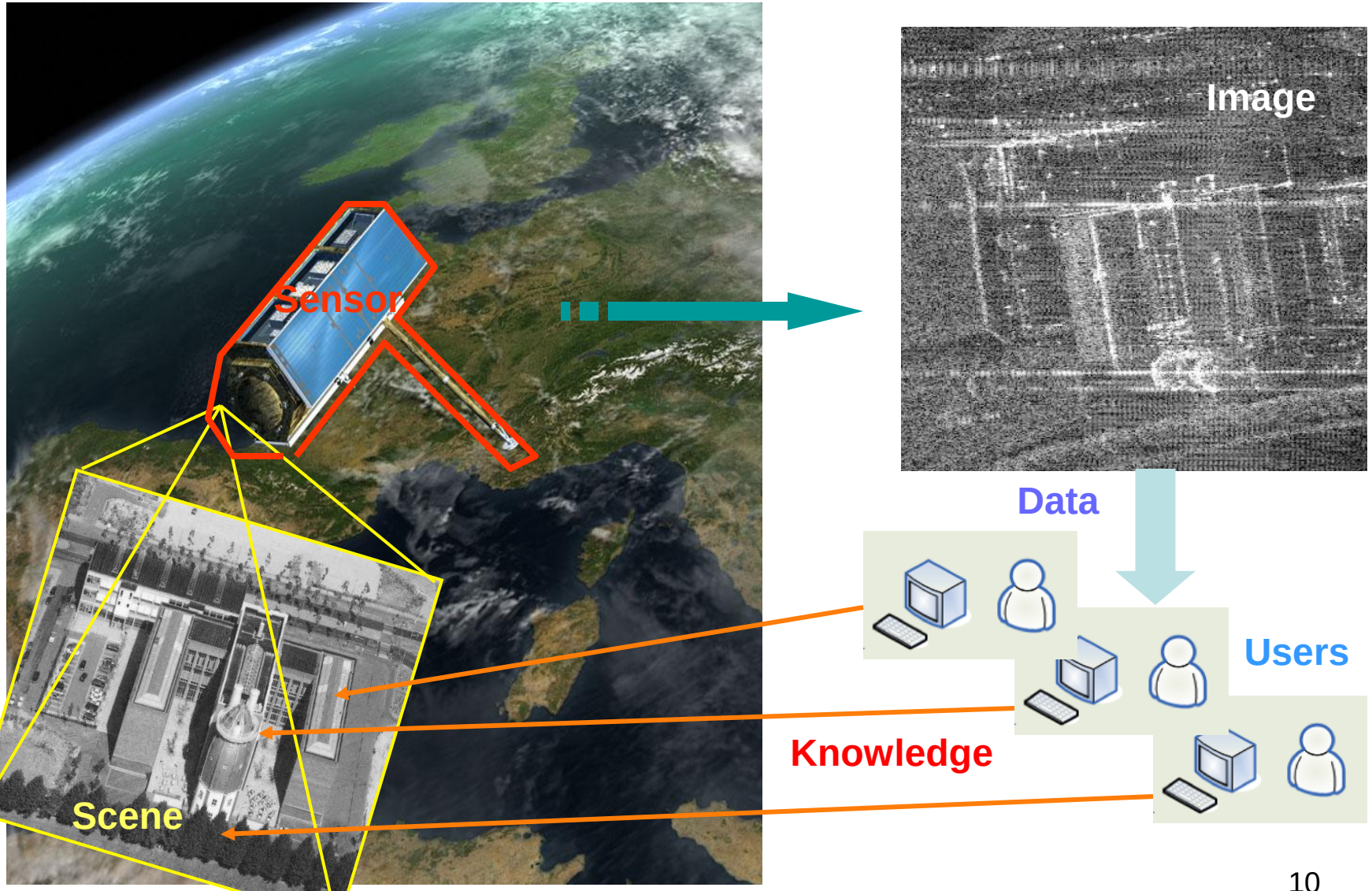




Data

Users

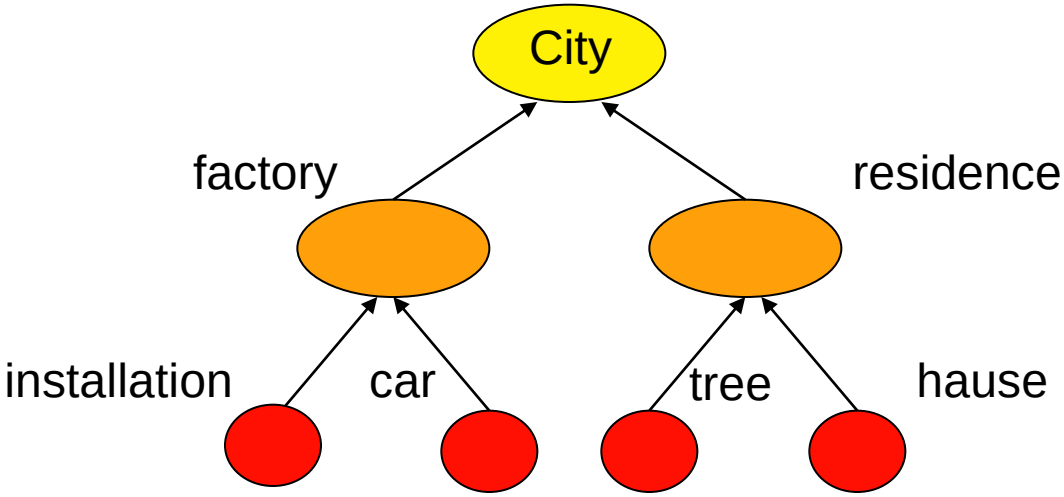
Data, Content and Knowledge



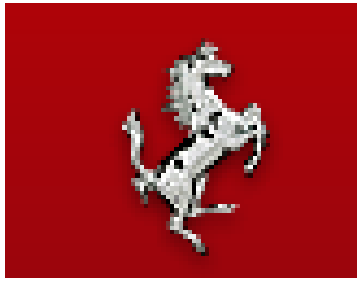
Understanding and semantics

- Roots of understanding
  - Content => semantic => ontology
  - Grand challenge – interoperability of semantics
  - Communication between machines vs communication between individuals
  - Syntactic metadata vs Semantic metadata vs semiotic metadata (Umberto Ecco)
  - Semiotics

Semantic compositionality: the meaning of a hole is a function of the meanings of its parts and their mode of syntactic combination



Symbolic *synonymy*



Symbolic *synonymy*

Symbolic *synonymy*

Data Mining

- 1974 at the Office of Naval Research

- a boiler explosion on a distroyer
- the boiler was the problem for other accidents

- data/information existed, but was ignored
- no tools to find patterns

- R&D program to discover such problems

Data Mining

What is data mining?

Data created by people

- A process of sorting through a large amount of data and picking out relevant information.
- Data => information => knowledge => actionable intelligence (understanding)

Data Mining

What is information mining?

Data created by sensor

- Data understanding from **Observation**: A contextual approach
  - Creation of contextual understanding from data.
  - Sensor Data => models working on data create information (content) => contextual knowledge about geopolitical and socioeconomic factors => actionable intelligence at the local level (understanding)

- How does data mining build knowledge?
  Memory, communication, pattern recognition

- Challenge is to understand data and to have all data accessible
  Issues – formats, etc.

Features

Information must be obtained from the data

Databases and search engines were not designed to provide contents

Visualization is very important

HMI are crucial

Words – signals – semantics

Visual – perception – cognition

Memory – latency – knowledge - relevance

Archives and Libraries

- **Archive:** a long-term storage area, place or collection containing records, documents, or other materials of historical interest (that's passive and static!)
- **Library:** a depository built to contain books and other materials ***for reading and study*** (that's active and dynamic!)

What makes the difference?

- **Library has:**
  - **A catalogue (better then archives):** indexing books based on multiple criteria, e.g. author, title, keywords, domains (ontology!)...
  - **A librarian:** one who has the care of a library and its contents, selecting the books, documents and non-book materials which comprise its collection, and providing information and loan services to meet the needs of its users

Searching Libraries

- **Use the catalogue:** select indexes and search the books. Next, read them.
- **Walk trough the library**: browse till you get interested...
- ***A friend told me***...: go to the material using prior information

- ***Ask the librarian:*** the *ideal* librarian, he
  - **reads all the incoming books**
  - **interprets contents**
  - **associate with other information**
  - **creates categories**
  - **understand the inquiry**
  - **dialogues**
  - **comments, and**
  - **suggest ...**

Knowledge based Image Information Mining TSX Ground Segment Systems

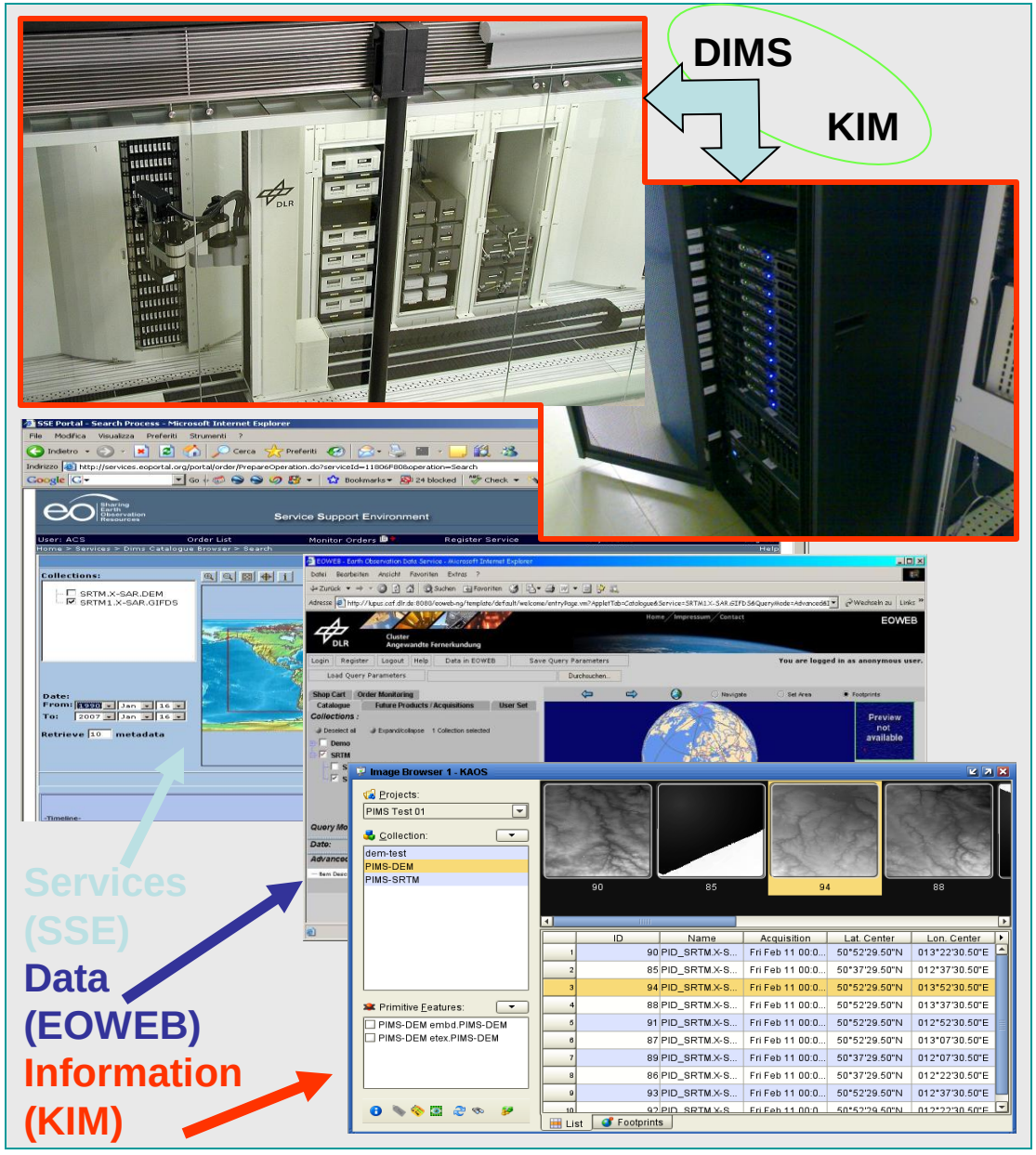
Competence Centre on Information Extraction and Image Understanding for Earth Observation

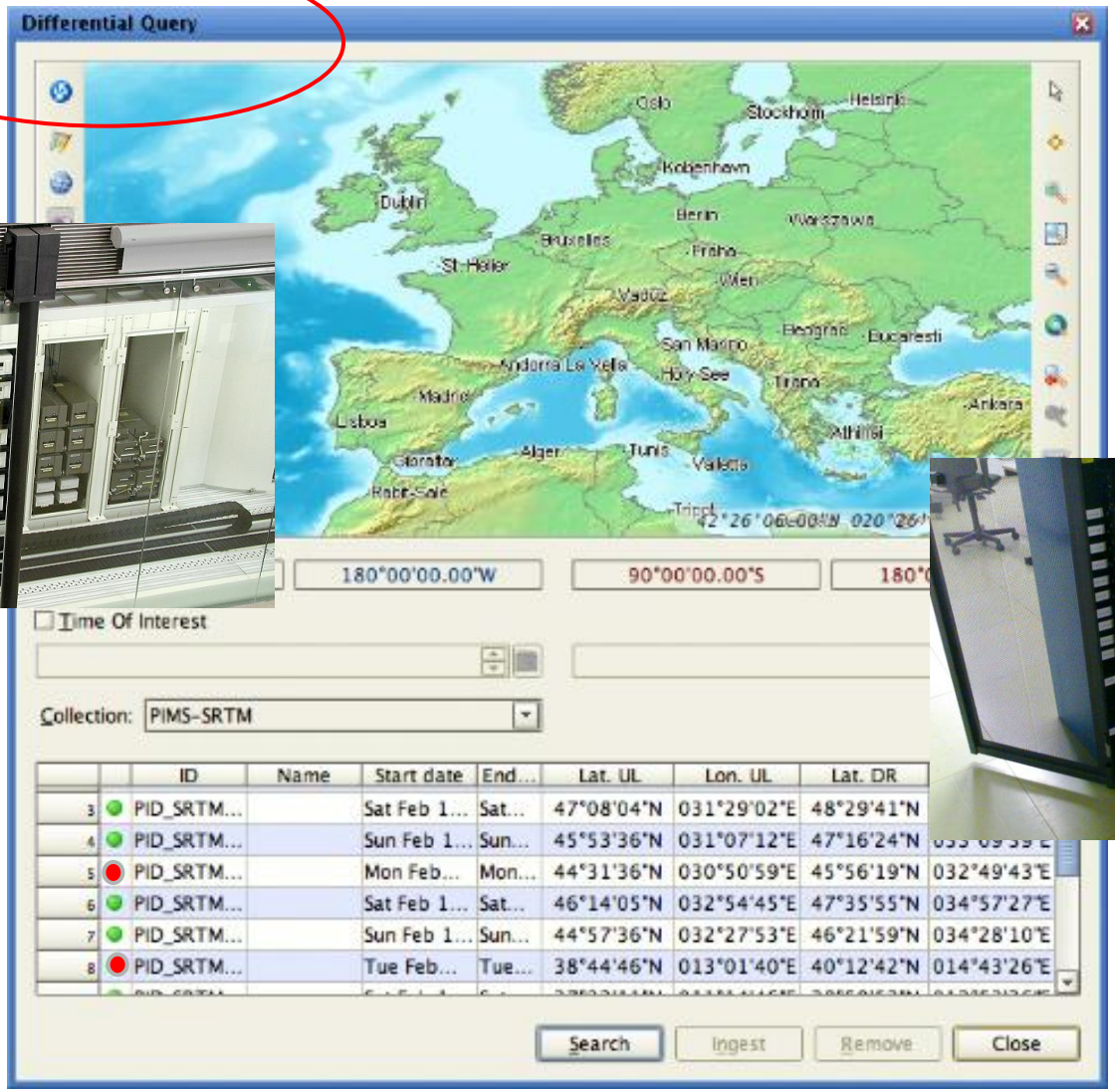
Integrated in operational environments Image Information Mining (IIM) technologies for enhanced information content extraction from EO image archives. Operate the new functionalities in the TerraSAR-X Payload GS.

Method: Interface of DIMS and KIM systems. Extend the DIMS product catalogue with the semantic and image feature catalogues of KIM. Provide IIM functions.

Applications:
- concurrent queries of DIMS and KIM catalogue
- interactive selection of EO products information content
- IIM functions (explore, semantic annotation, detection-discovery, etc.)
- new generations of GS systems

Envisaged missions:
- TerraSAR-X, TanDEM-X
- SRTM
- MERIS
- GMES




Differential Query
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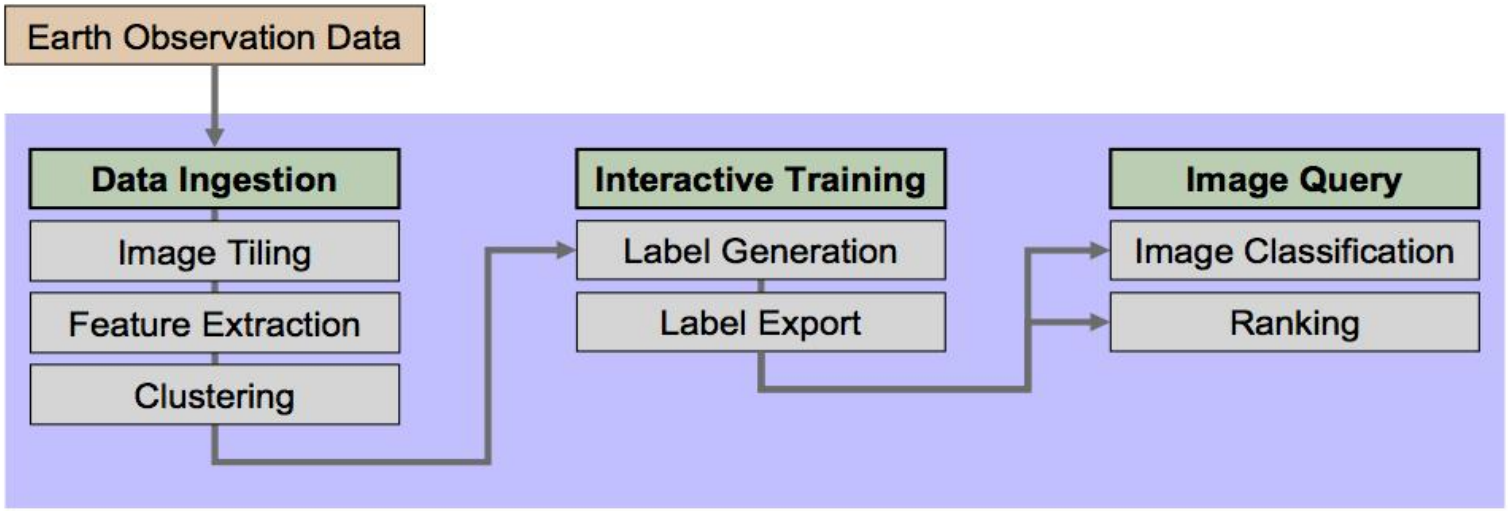
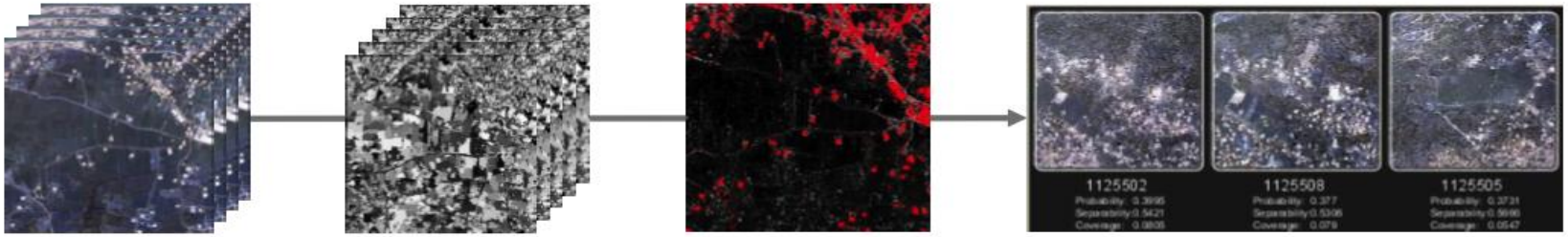
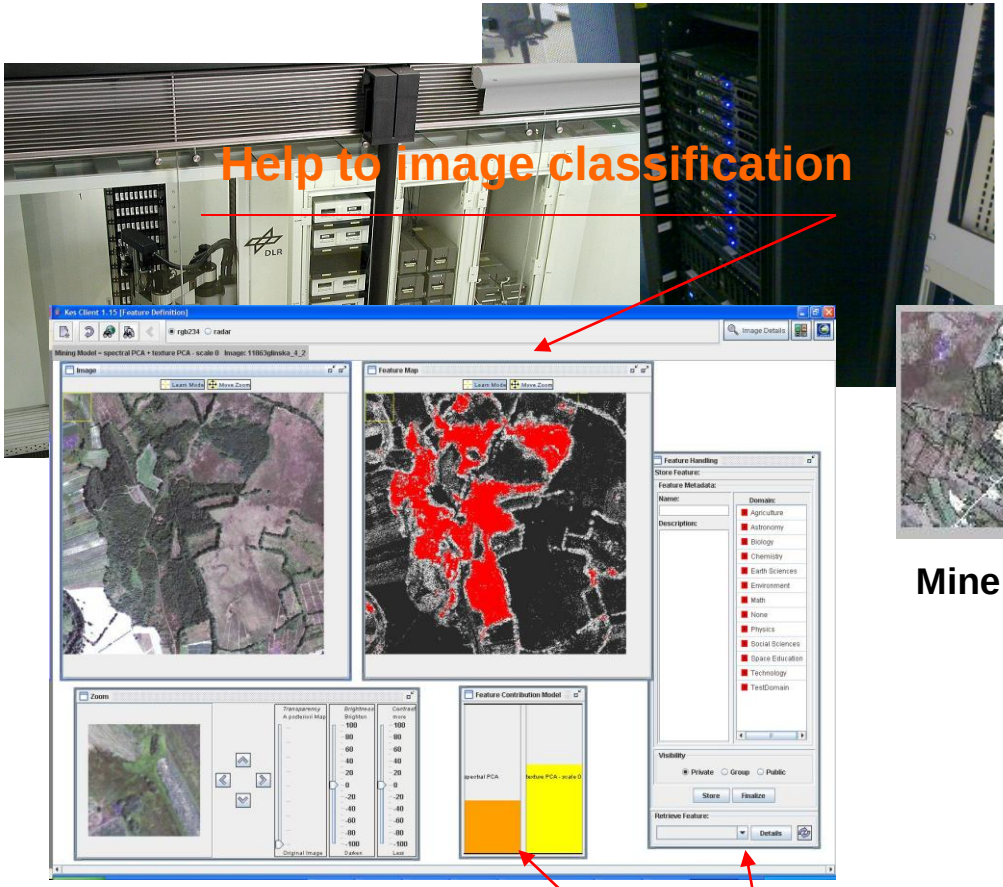
Helsinki
København
Dublin
Berlin
Warszawa
Bruxelles
Praha
St. Heller
Wien
Vaduz
Beograd
București
San Marino
Andorra La Vella
Holy See
Madrid
Tirana
Ankara
Lisboa
Athinai
Gibraltar
Alger
Tunis
Valletta
Rabat-Sale
Tripoli
180°00'00.00"W
90°00'00.00"S
Time Of Interest
Collection: PIMS-SRTM
ID
Name
Start date
End...
Lat. UL
Lon. UL
Lat. DR
3 PID_SRTM... Sat Feb 1... Sat... 47°08'04"N 031°29'02"E 48°29'41"N
4 PID_SRTM... Sun Feb 1... Sun... 45°53'36"N 031°07'12"E 47°16'24"N
5 PID_SRTM... Mon Feb... Mon... 44°31'36"N 030°50'59"E 45°56'19"N 032°49'43"E
6 PID_SRTM... Sat Feb 1... Sat... 46°14'05"N 032°54'45"E 47°35'55"N 034°57'27"E
7 PID_SRTM... Sun Feb 1... Sun... 44°57'36"N 032°27'53"E 46°21'59"N 034°28'10"E
8 PID_SRTM... Tue Feb... Tue... 38°44'46"N 013°01'40"E 40°12'42"N 014°43'26"E
Search
Ingest
Remove
Close

KIM CONCEPT: SIMPLE





Today: Interactive, user adapted, EO data content access



Suggest data

Mine Fields

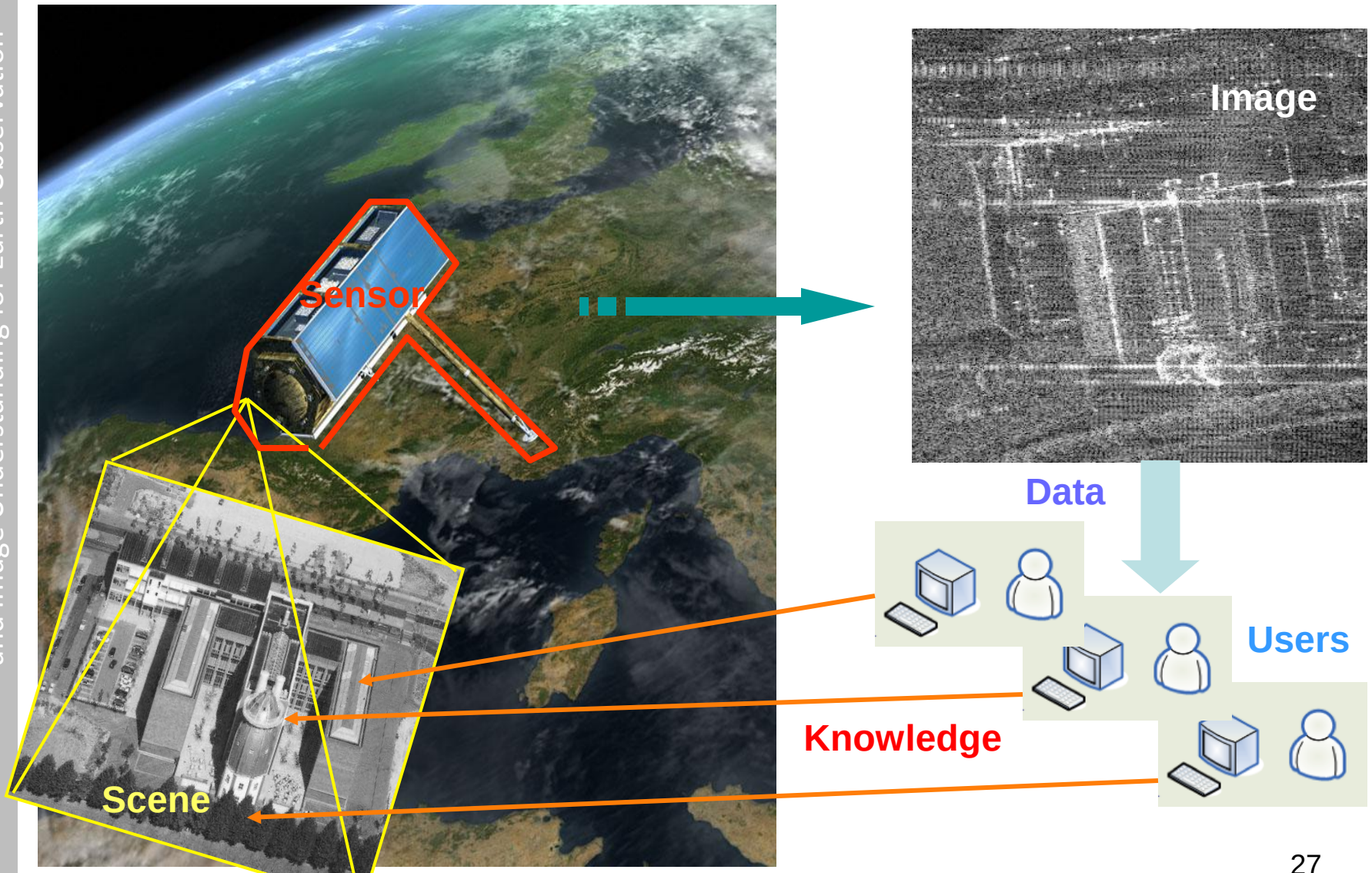
Access to:
information
knowledge

Knowledge share

Advances in Image and Heterogeneous Data Mining

The Image Librarian

Data, Content and Knowledge



Rationale

- An observation, strictly, is only a sensation. … But as soon as we go beyond sensations we are making inferences. (Jeffreys)

What is *image ?*

Data Structure

@image{*filename* [*width* [*height* [*alttext* [*extension*]]]]}

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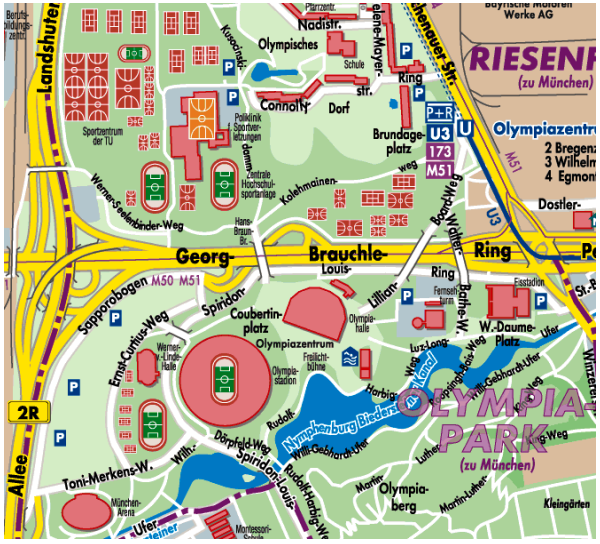
@image{*filename* [*width* [*height* [*alttext* [*extension*]]]]}



Signs & Symbols

What is *image* ?

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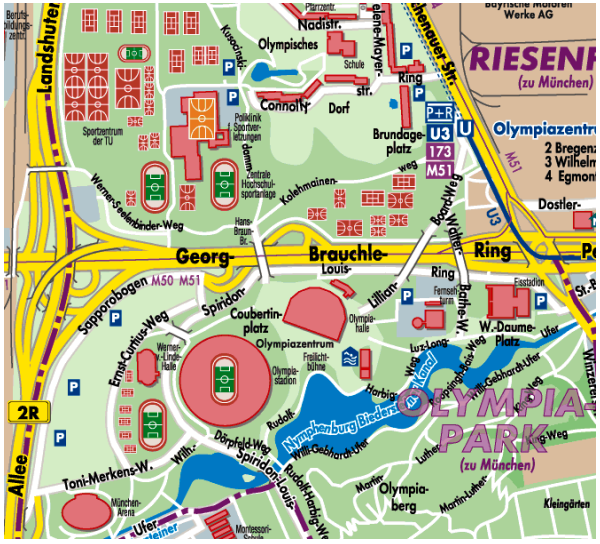

Signs & Symbols

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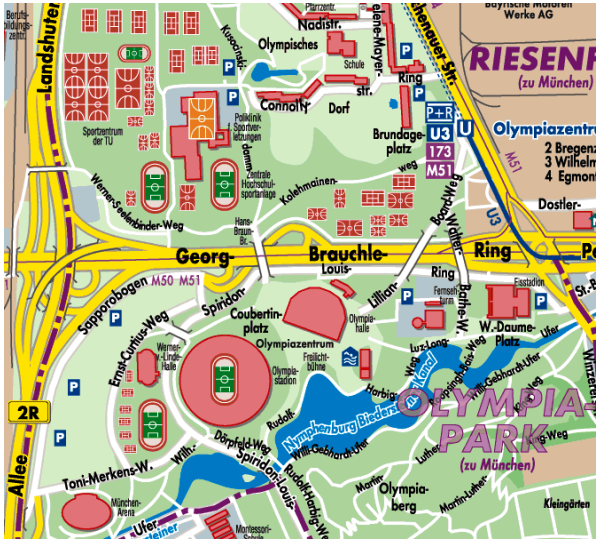

Signs & Symbols

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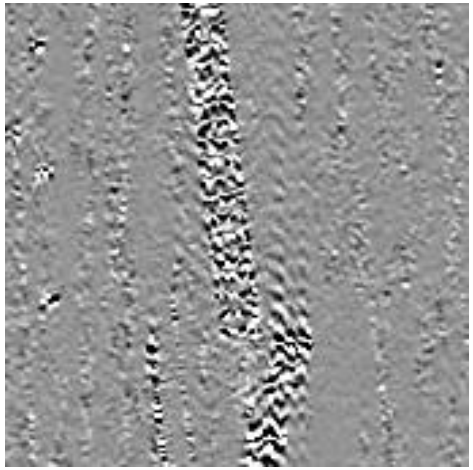


Signal

Rationale

- An observation, strictly, is only a sensation. … But as soon as we go beyond sensations we are making inferences. (Jeffreys)
- Signals, signs, symbols: images are messages

Scene meaning inferred from images

Scene meaning inferred from images

Jail

Scene meaning inferred from images

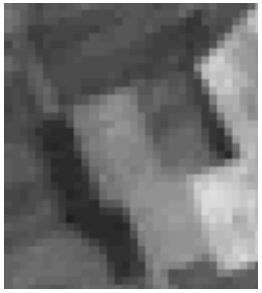
Villas

Rationale

- An observation, strictly, is only a sensation. … But as soon as we go beyond sensations we are making inferences. (Jeffreys)
- Signals, signs, symbols: images are messages
- Meaning depends on components

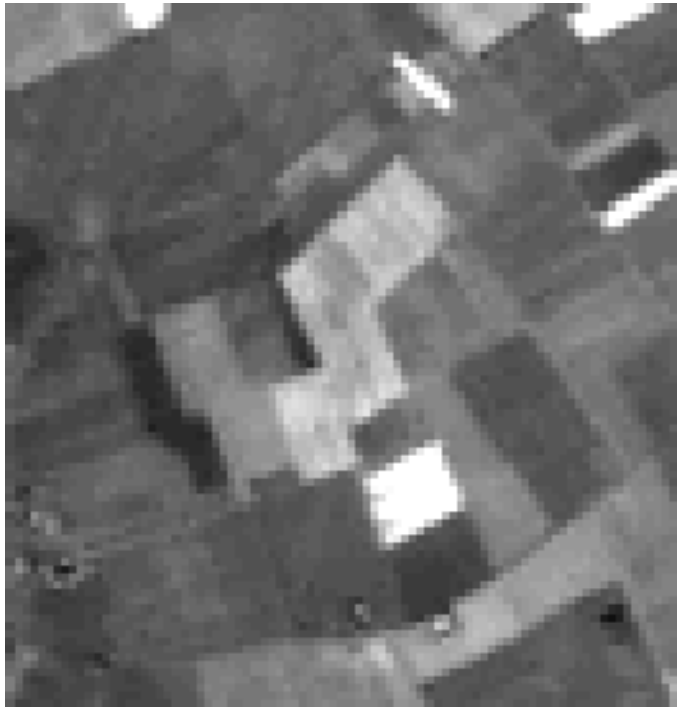
Scene meaning inferred from images

Buildings



Scene meaning inferred from images

Agriculture Fields



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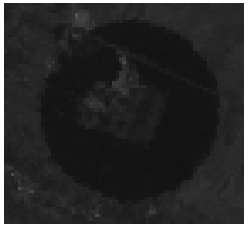
- Meaning depends on spatial context

Scene meaning inferred from images

Circular Forest

Landsat 30 m resolution



Scene meaning inferred from images

Nuclear Facility

0.6 resolution

Rationale

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- Meaning depends on spatial context
- Meaning depends on resolution

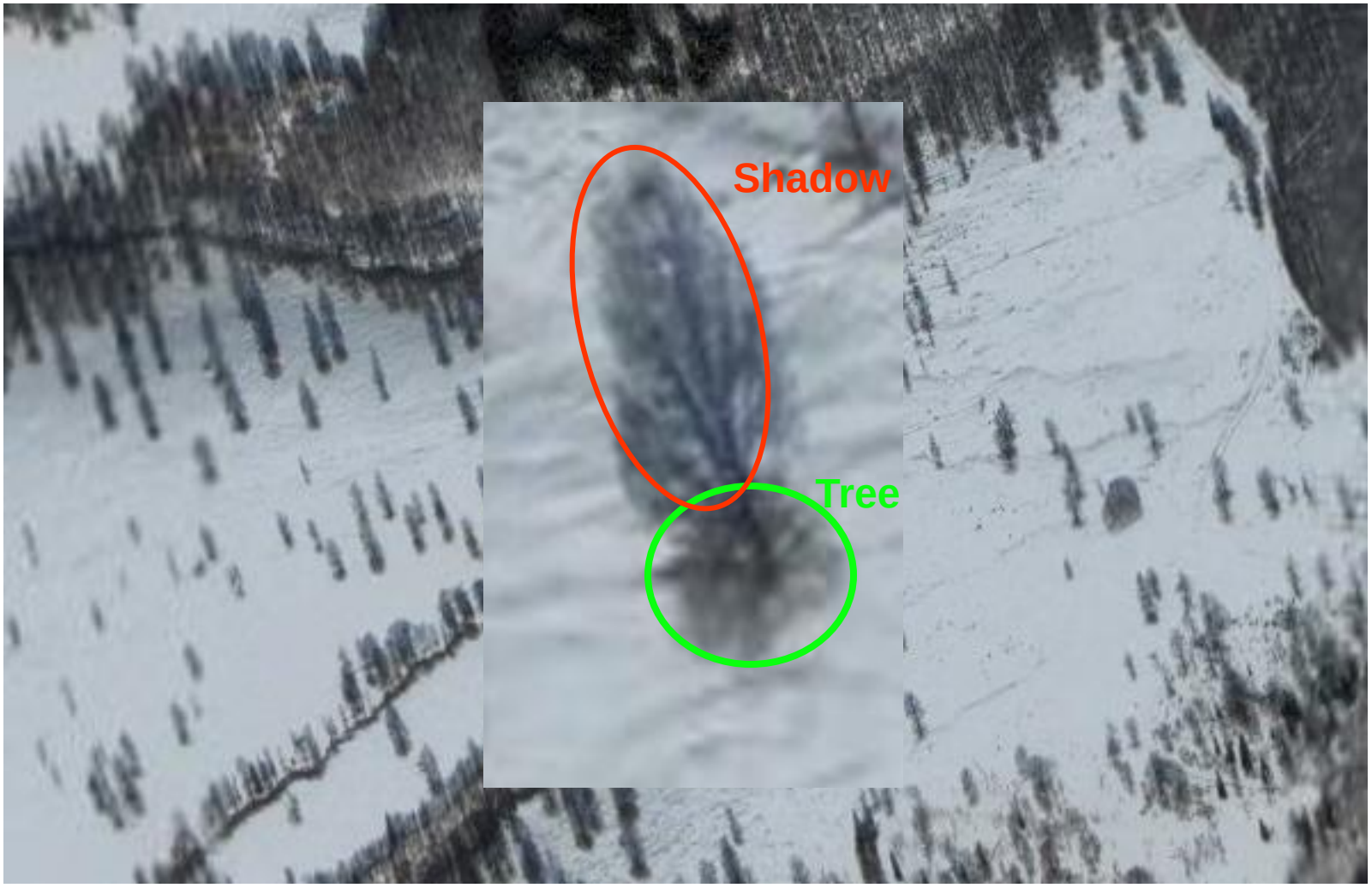
Scene meaning inferred from images

Winter Landscape: Pine

Scene meaning inferred from images

Image geometry context

Winter Landscape: Oak



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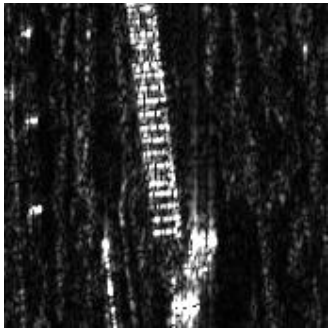
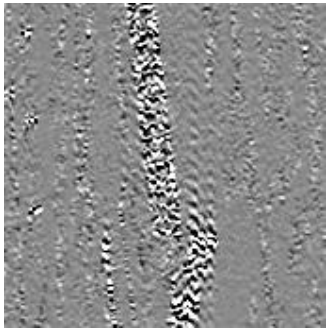
- Meaning depends on spatial context
- Meaning depends on resolution
- Meaning depends on imaging geometry

Scene meaning inferred from images

Building: aggregation of signal components

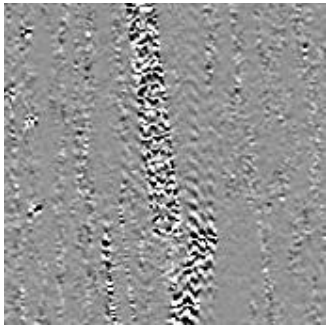


Amplitude



Real channel

Phase

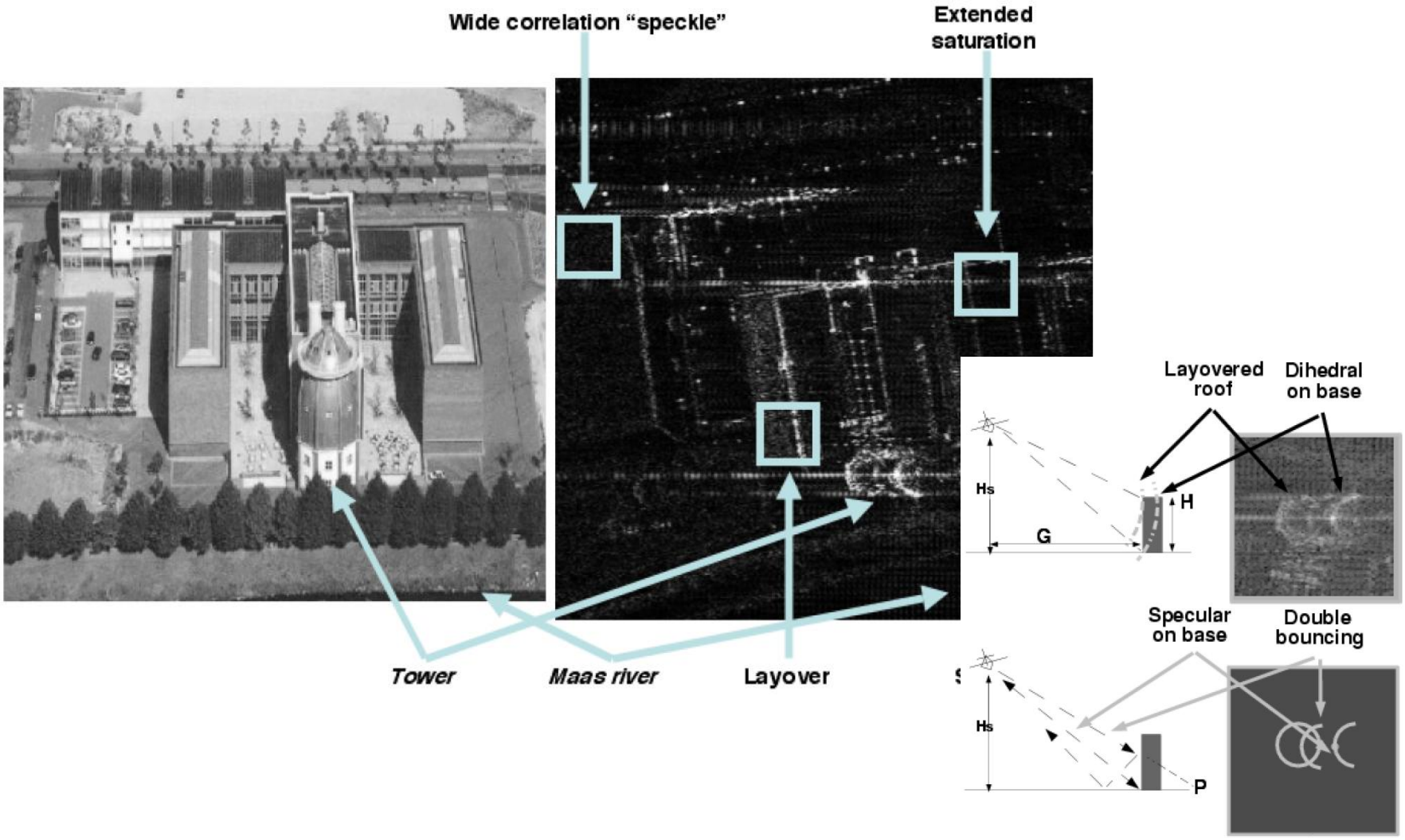


Imaginary channel

E-SAR X band, Dresden

Scene meaning inferred from images

Building: aggregation of image components



Rationale

- An observation, strictly, is only a sensation. … But as soon as we go beyond sensations we are making inferences. (Jeffreys)
- Signals, signs, symbols: images are messages
- Meaning depends on components
- Meaning depends on spatial context
- Meaning depends on resolution
- Meaning depends on imaging geometry
- Meaning depends on perceptual context
- Meaning depends on temporal context
- Meaning depends on signal components

Semantic compositionality: **the meaning of a hole is a function of the meanings of its parts and their mode of syntactic combination**

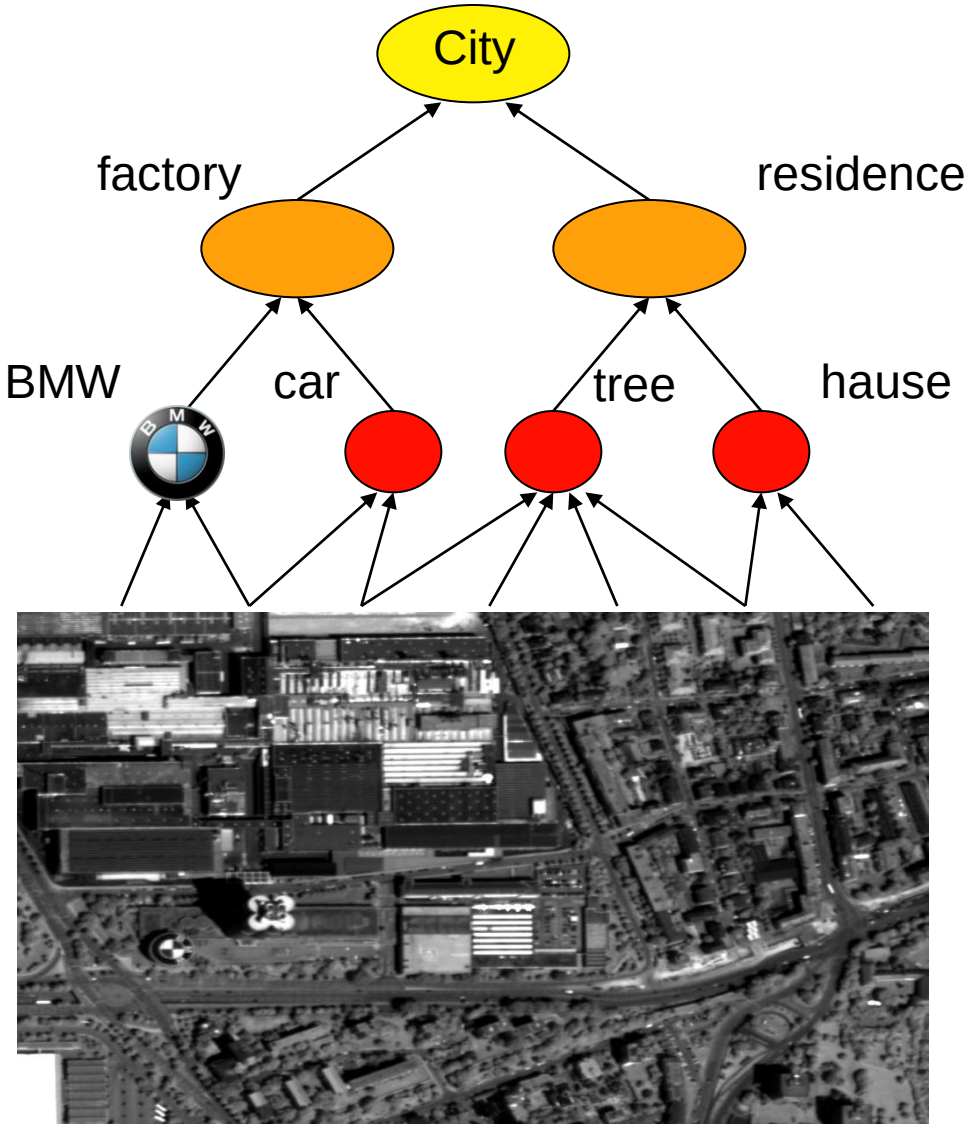
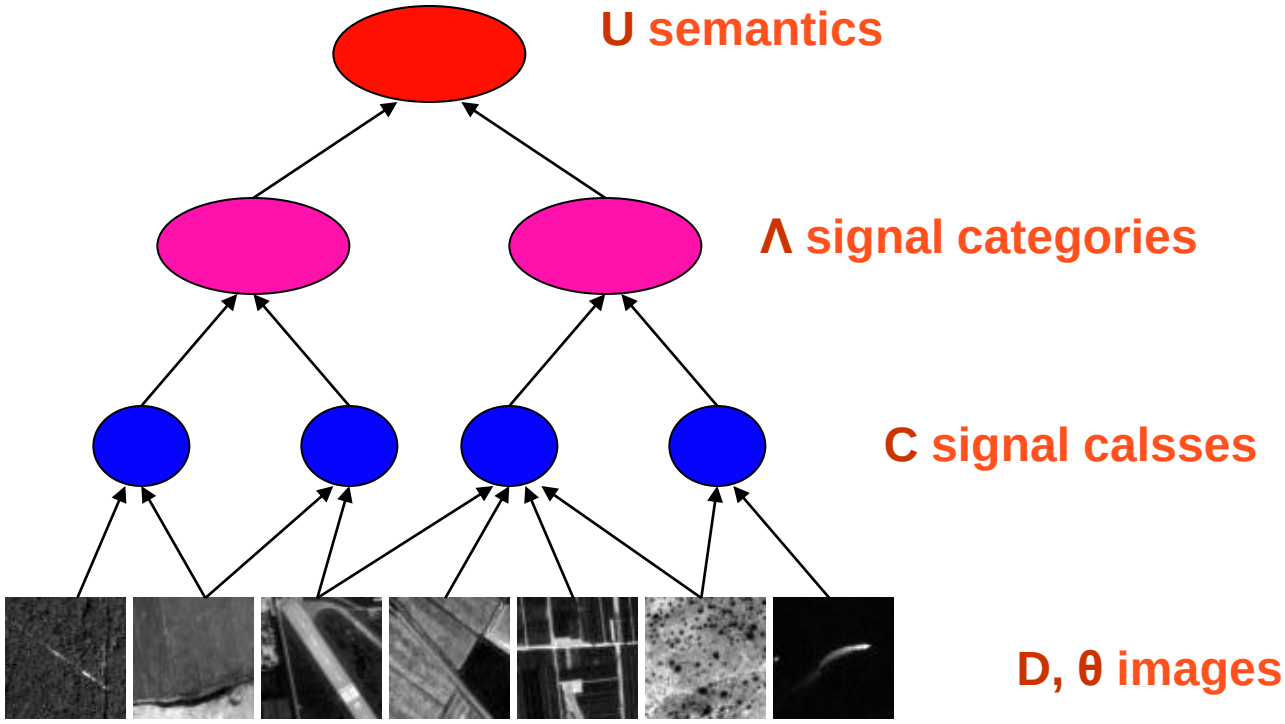


Image Semantics Generative Model

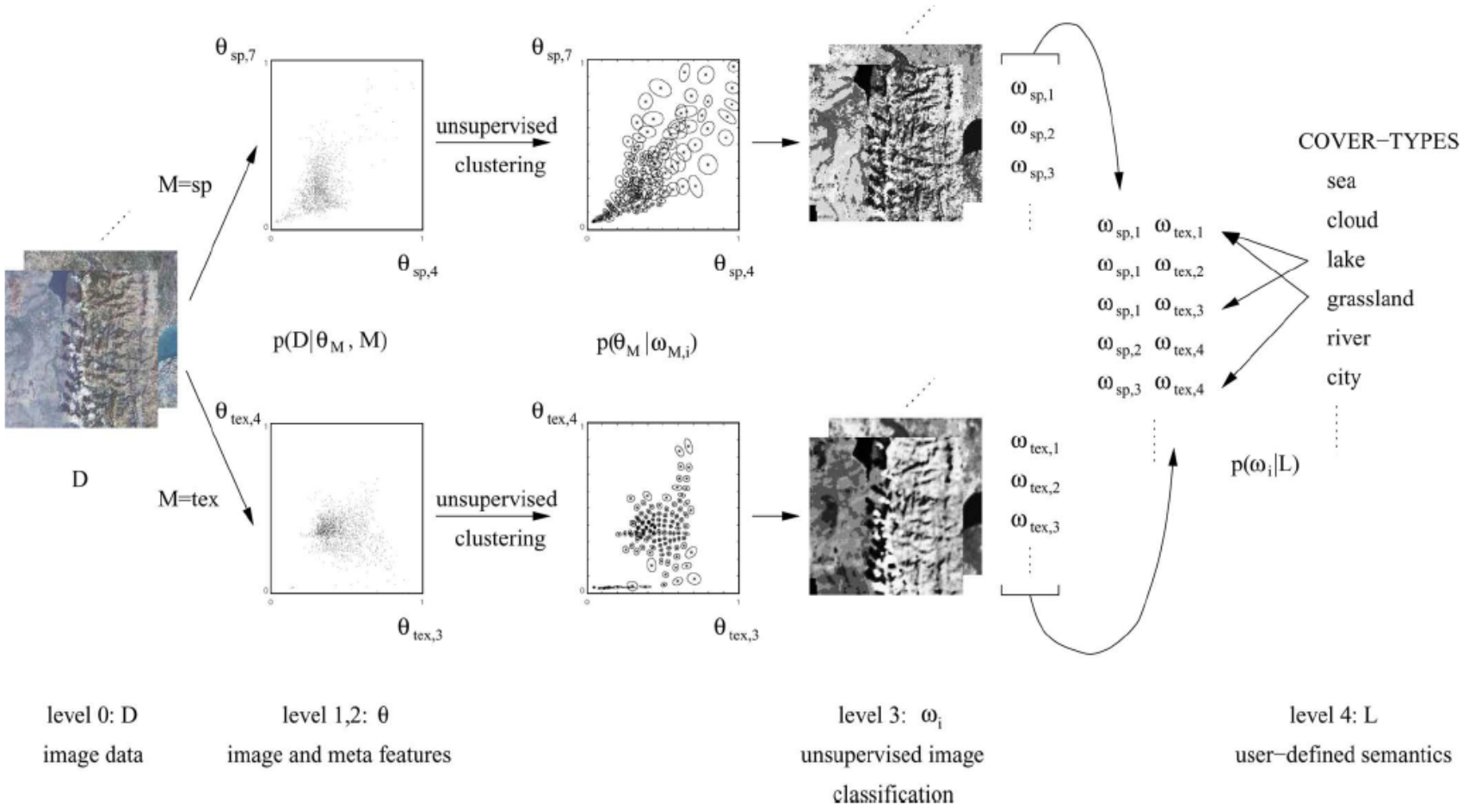


The syntax

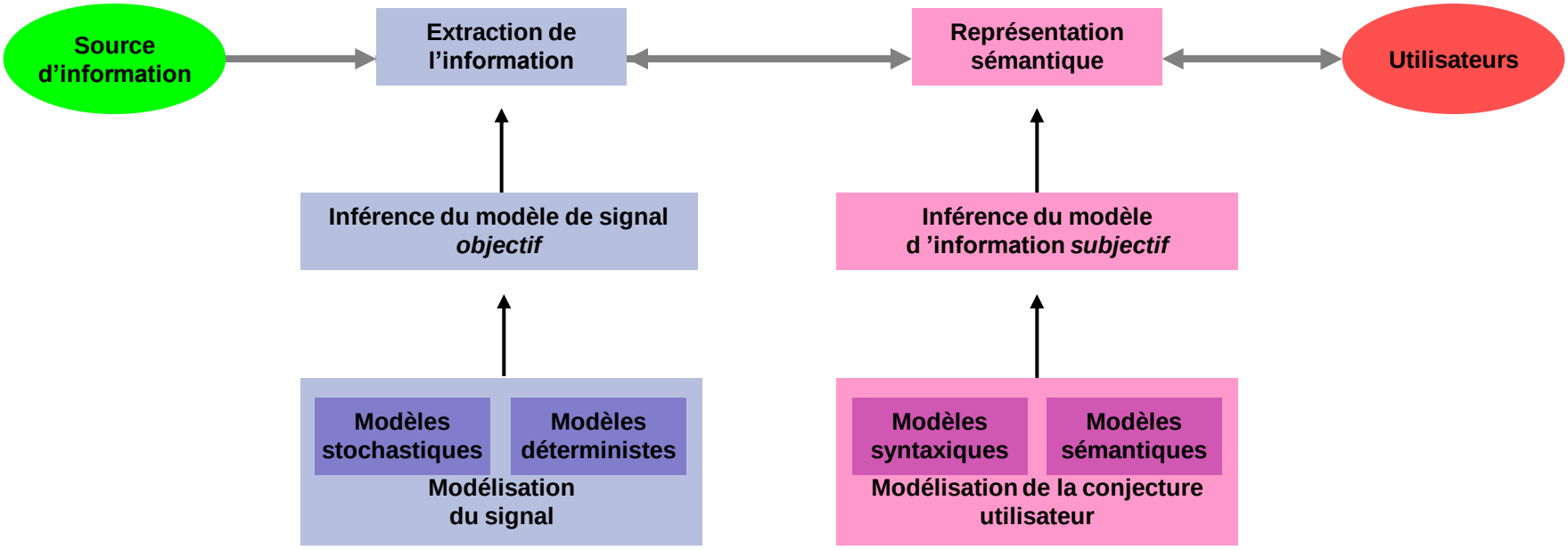
Semantic compositionality: the meaning of a hole is a function of the meanings of its parts and their mode of syntactic combination

PERFECT PRESENT

KIM hierarchical information representation: coding



CONCEPT DE COMMUNICATION AVANCE



The principle of semantic compositionality:

the meaning of a whole is a function of the meanings of its parts and their mode of syntactic combination

Coding

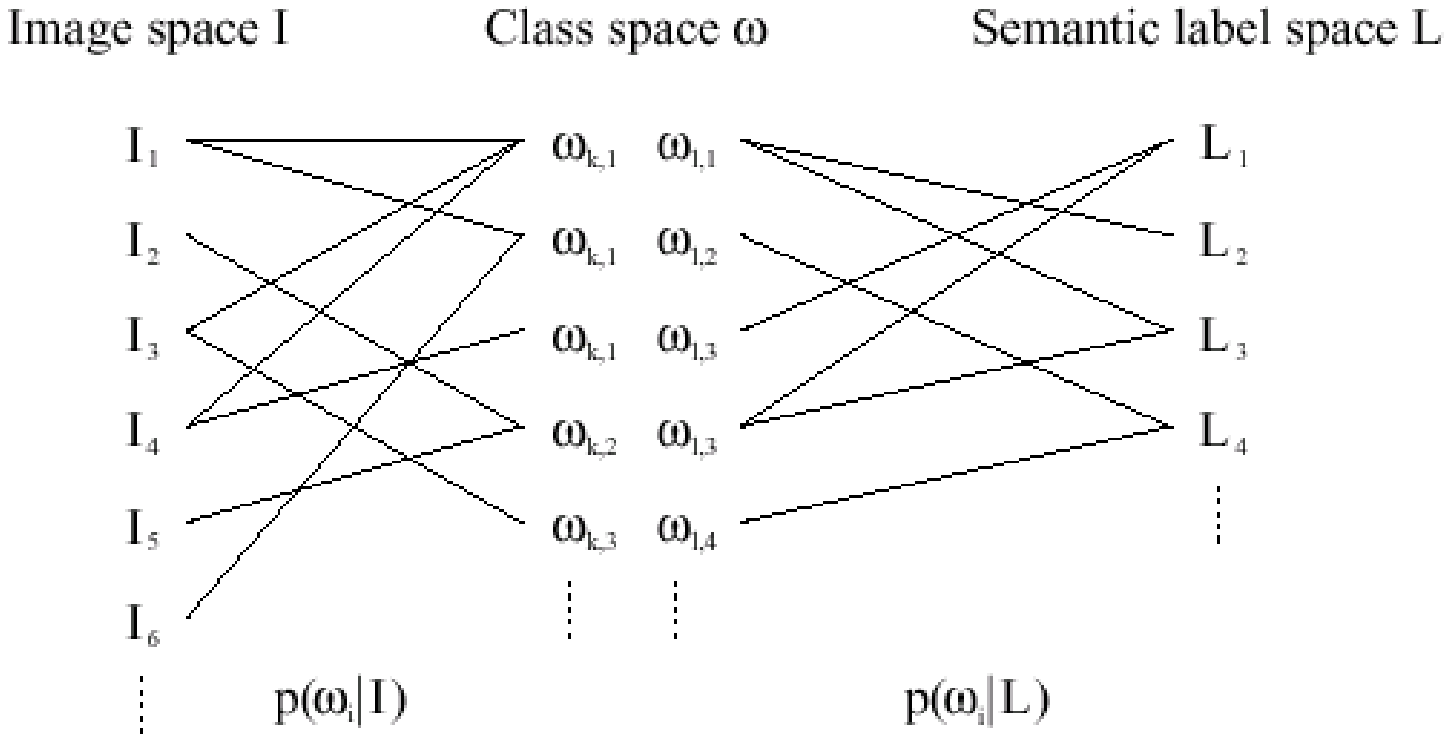
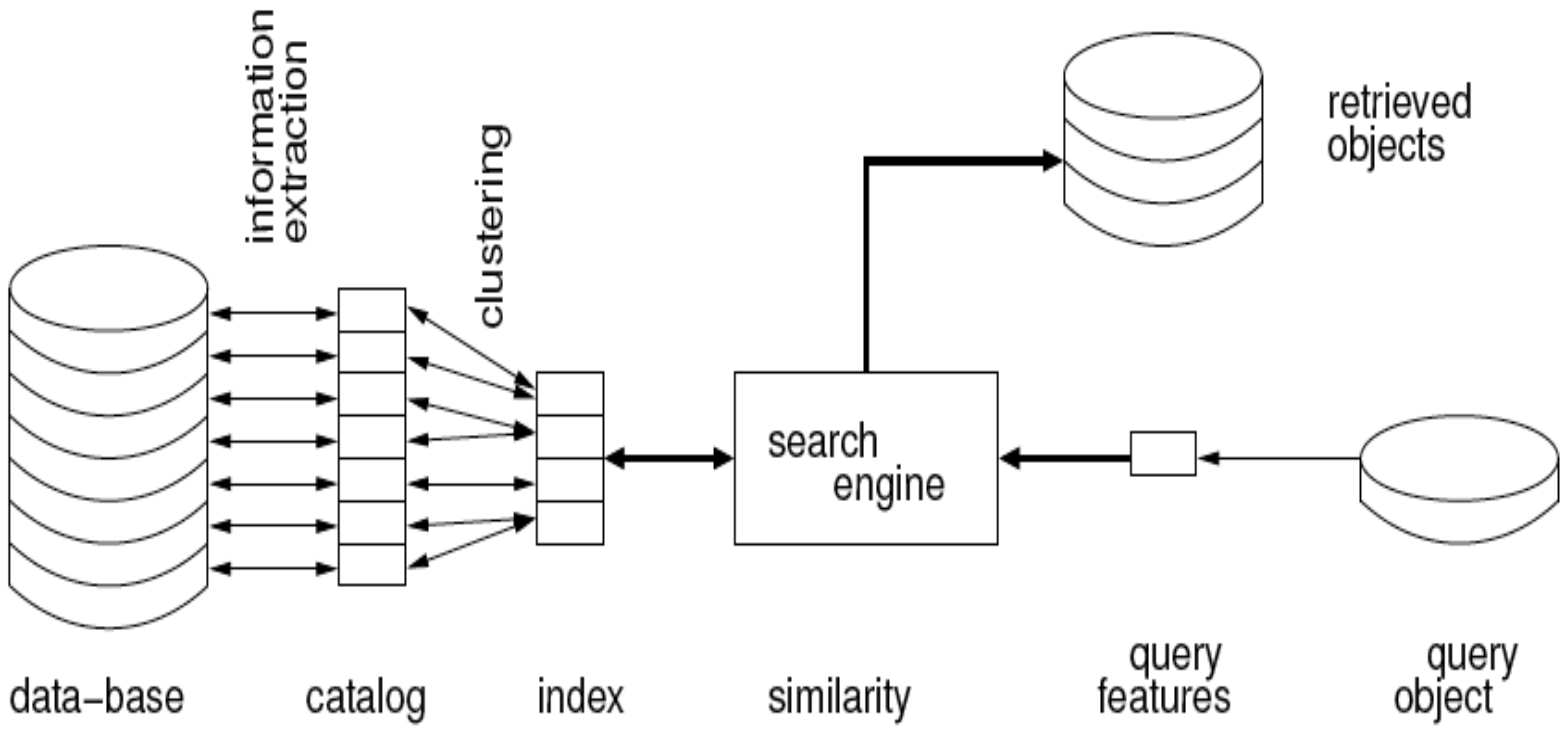


Image space I
Class space ω
Semantic label space L
I1
I2
I3
I4
I5
I6
ωk,1
ωk,1
ωk,1
ωk,2
ωk,3
ωl,1
ωl,2
ωl,3
ωl,3
ωl,4
L1
L2
L3
L4
p(ωi|I)
p(ωi|L)

Coding and Data Bases

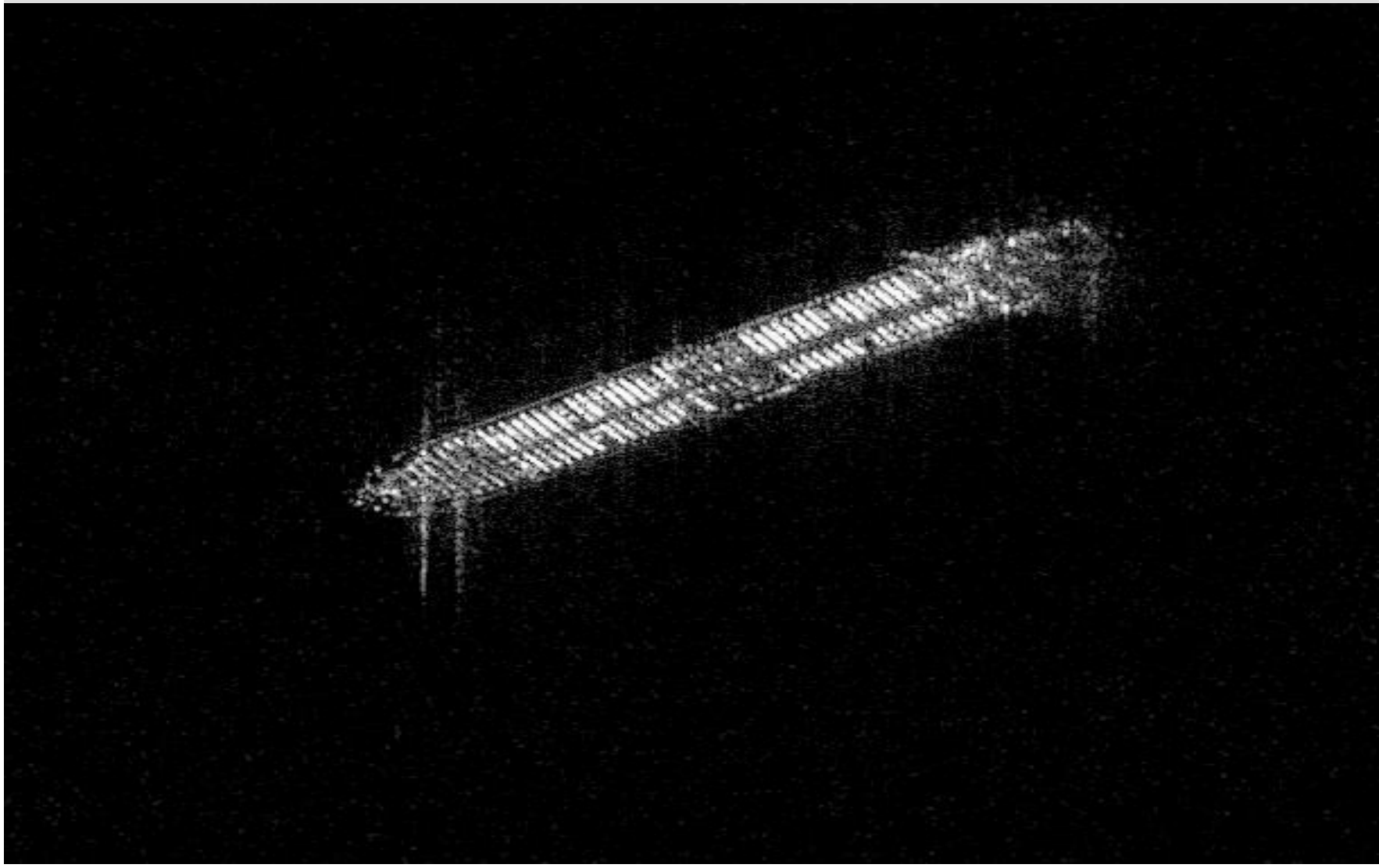


the structure of an indexed data-base and how the search engine uses this structure to find similar objects


TerraSAR-X: Urban analysis

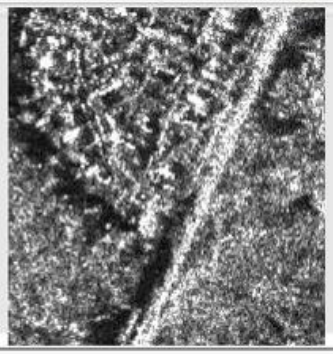
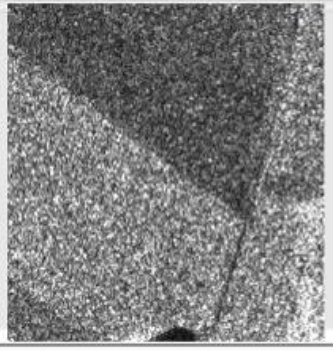
Oil storage tanks, Singapore

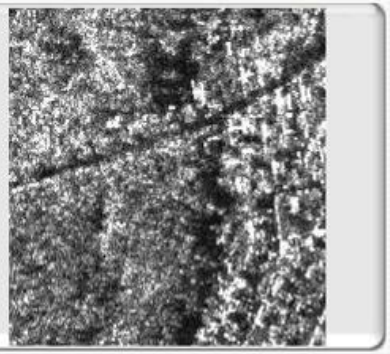
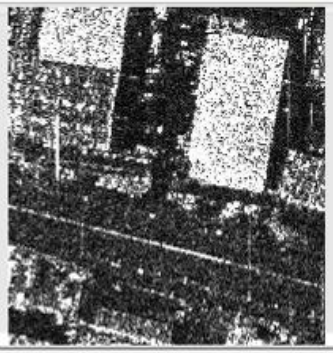
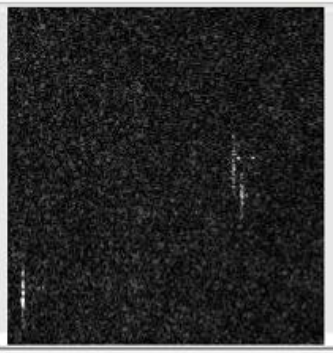
TerraSAR-X: Ship Recognition




TerraSAR-X: Moving Target analysis

Category based SVM/Bayesian Classifier - Training


Init | Run

Save as... | Classify... | Show classification

Results