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Work proposal for the Master thesis of Lorenzo Clementi

Inter-comparison of remote-sensing observations: a new relational metadata framework on support to meteorological R&D

Objective

The objective of the proposed work is to implement a flexible tool in form of database for organizing and characterizing meteorological data, coming from different remote-sensing sources, in order to support the use of different algorithms for meteorological purposes (key-word Nowcasting).

Abstract

Meteorological services have at their disposal large amounts of data coming from various measure instruments, like radars and satellites. Some weather-related applications – for example the “nowcasting”, that is the forecasting of specific weather events on the very short term – takes advantage of the combination of data coming from different sources in order to improve the estimation of the trend for the observed parameters. Throughout this procedure, called multi-source approach, great care must be given to the way in which different types of data are combined.

The goal of this work – carried out in collaboration with MeteoSwiss Locarno-Monti – is to design and implement an information system that organizes the data coming from different remote-sensing sensors, allowing to consistently combine them. The framework to be developed shall implement – as a proof-of-concept – some methods that allow to analyze data originating from distinct devices, taking into account all the details involved in their processing.

Background

The study of an environmental object like the atmosphere requires the use of a wide spectrum of observation types and processing techniques. Beneath well-known acquisition instruments like weather stations and radio-soundings, remote-sensing techniques have been establishing a well important and defined role in weather applications. It accounts of many active and passive instruments like weather radars, lidars and weather satellites (e.g. Meteosat, MetOp, NOAA).
The whole gathered observation flux is then used by the weather services (singularly or through international organizations) for very different applications, which account for numerical weather models for simulating the atmosphere over several days, climate applications for studying radiative balances over years, and very-short range weather predictions for monitoring and following of specific weather events (so called “Nowcasting”).
In all these fields it is at a certain point of the long chain (from acquisition to user) necessary, to apply a multi-source approach either for extracting new parameters or for simply presenting the results to the final users (e.g. the forecaster).

The applied researches work on back-stage for implementing new application or adapting old techniques to new data. In some cases, they developed refined instruments that, however, apply only to very peculiar inter-comparisons (like calibration between radar and rain-gauges or inter-satellite sensors). In other cases, overall relational databases for initializing big climate or weather models have been developed (e.g. ECMWF); their final result, however, represents a nearly completely independent dataset and/or projected into another space and time scale.

The proposed work aims to furnish to MeteoSwiss/Locarno-Monti a simple but flexible framework for characterizing and preparing the data, mainly coming from different remote-sensing sensors, in a best suitable way for subsequently apply comparison methods (physically or statistically based). The final goal of this instrument will be to optimize the R&D effort for inter-comparing several methods and several data, taking under control data-quality and the complexity of the problem.

Science and Techniques

Application example

In order to explain the proposed theme we illustrate the task of combining ground based weather radar measurements and satellite observations with the objective to attain a quantitative estimation of a precipitation field.

Both the radar and the satellite don’t directly measure the precipitation. However they are very important instruments to detect and quantitatively estimate the liquid water content of the atmosphere.

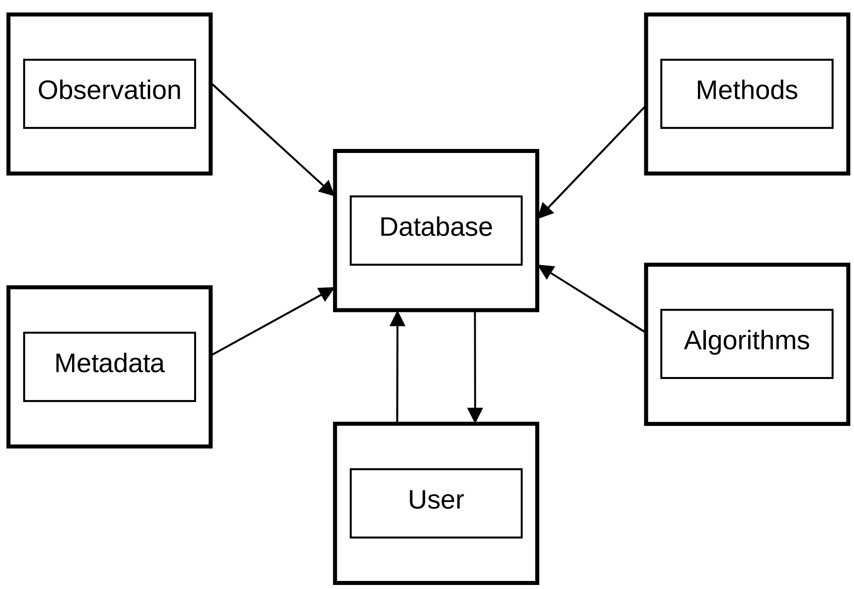
The surface based weather radar scans the surrounding volume along conic surfaces centered over the antenna with a predefined time schedule.

The geostationary satellite is placed around 36’000 km from the earth surface and scans the terrestrial globe with a known geometry and temporal schedule.

The physical processes involved in the transformation from the observed quantity (reflectivity for the radar and electromagnetic radiation for the satellite) to the target quantity (the precipitation intensity) are very complex but under scientific investigation since various years so that physical models are known to transform the observed into the target quantity.

Based on all these known aspects which should be present in the database of our framework we should be able to combine the measurements from our two instruments to given the best estimate of the precipitation field over a target zone.

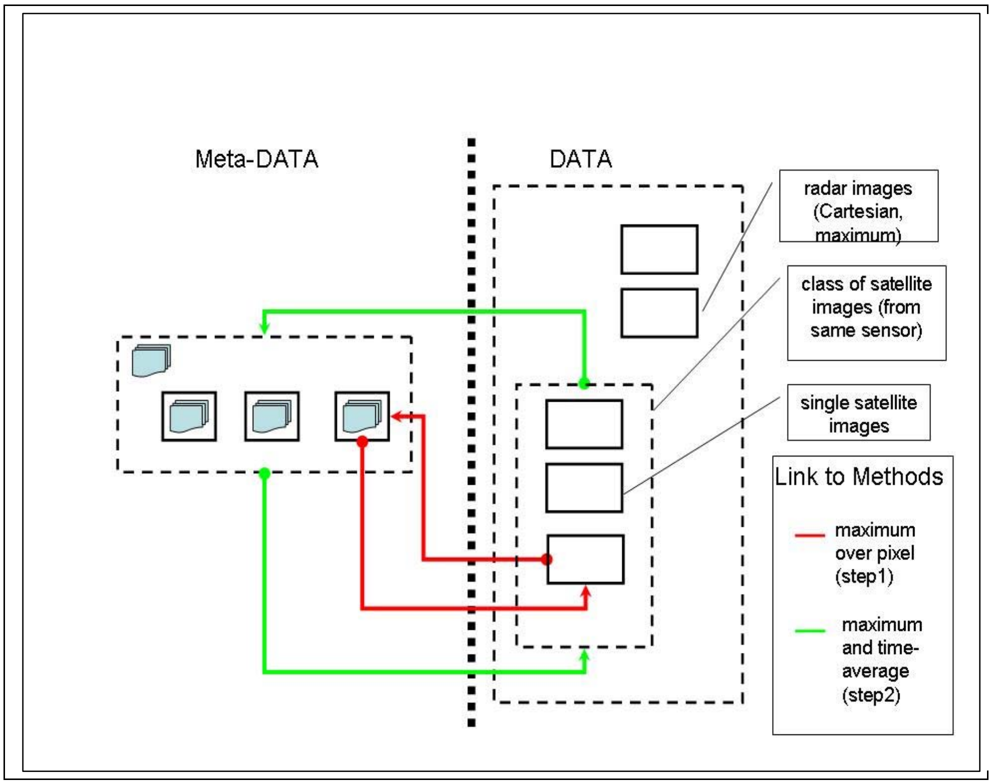
Conceptual scheme of the database



The database should combine in a systematic and consistent way data, metadata and methods to be applied to the data entities. The user may query the content of the database or request it to apply specific algorithms to selected data whose results are stored back in that repository.

The data model

The design of the database is centered on the data model which should be designed in consequence of the functionalities required by the framework.
One viable approach could be that of a hyperspace with dimensions space, time and observed parameters. As supplemental feature we could describe an observation on a specific point in the space as resulting from a convolutive operation: all elements contributing to the observed point are to be somehow integrated in the data model.



Instrumental characteristics

As stated in the introduction it is important to describe and model the technical and data processing characteristics that an instrument uses to deliver the quantitative value of an observation. This is a task that should be performed in the course of this thesis and that should be integrated in the framework to be constructed.
In form of an example we illustrate the processing steps behind a pixel of a Cartesian volumetric radar product:

– the volume surrounding a weather radar station is scanned by a rotating antenna

- the antenna performs a complete rotation at a set of fixed elevations
- the conic surface traversed by the sensing electromagnetic wave is electronically sampled at a spatial resolution of 1 degree in azimuth and 1 km in radius
- the Cartesian volume is subdivided in cubic elements of 1x1x1 km^3 (voxels)
- given a specific cubic element all collocated samples from the conic surface are associated to the voxel and their observed measurement values are combined through an arithmetic averaging operation to form the value of the voxel
- the starting time of the volumetric antenna scan, the scan geometry and the antenna velocity are known and therefore the time of all contributing samples can be calculated and the time of the observation of the voxel can be indicated.

Management

About MeteoSwiss Locarno-Monti

MeteoSwiss Locarno-Monti is a dislocated unit of MeteoSwiss with a long experience in R&D and operations with radar and satellite data. The radar research has an internationally well recognized position and accounts several researchers and a PhD student; for the satellite field Locarno-Monti is the focal point and is responsible for developing and operational implementing new algorithms for real-time meteorological applications and for international representing Switzerland within the reference international organization EUMETSAT.

Reference-Tutor: dipl. Phys ETHZ Igor Giunta, via ai Monti 146, CH-6605 Locarno-Monti (igor.giunta@meteoswiss.ch).

About the candidate

Lorenzo Clementi did a semester-work at MeteoSwiss Locarno-Monti between September and October 2006. During this stay he designed and implemented a product-catalogue with a related extendible product manager and an automatic ordering system. This allows users of MeteoSwiss to off-line re-process satellite data. His work fully satisfied our expectations.

Working-Approach

The working approach wants to take advance of the existing data and the existing algorithms on one side and the skills, the knowledge and motivation of the candidate on the other side. It is suggested to adopt the combined top-down and bottom-up designing approach. The framework will modularly build-up starting from very simple cases (similar sensors, simultaneous observations, very simple data comparison) to more and more complex inter-comparison cases.

Calendar and tasks description

The Master thesis work will begin on November 5, 2007 and will end on April 4, 2008. This corresponds to a period of 20 working weeks (plus 2 weeks vacations).

The work will be organized in three main phases, defined according to the presentations scheduled at the University of Fribourg. After the initial literature study, a prototyping and testing phase with true data will progress in parallel to the framework development.

1. First phase (from November 2007 until the first presentation)

   - Study of the literature and draft design

2. Second phase (from December 2007 until the second presentation)

   - Specification of the information system.
   - Beginning of the information system implementation.
   - First simple data-analysis: the development method – based on the combined top-down and bottom-up approach – should allow some simple comparisons even in an early stage of the implementation. For example, it should be possible to compare data sharing the same source, under cartesian geometry and simultaneous grid data, by applying simple arithmetic operations.

3. Third phase (until the final presentation)

   - Completion of the information system implementation.
   - Implementation of additional data analysis methods that exploit the available metadata to handle, for example, time synchronization or geometrical issues.
   - Documentation of the project.

Literature:

- UNIDATA project http://www.unidata.ucar.edu/
- EUMETSAT Satellite Application Facilities (SAF) – Nowcasting (http://nwcsaf.inm.es); several reports about visiting scientist activities on validation
- http://www.ecmwf.int/services/odb/odb_overview.pdf