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Remote Sensing Analysis Framework for Maritime Surveillance Application

Dr. E.N.Ganesh, Dr.V.Rajendran, Dr. D.Ravikumar, P.Sai Kumar, G.Revathy and P.Harivardhan

VISTAS Chennai

Abstract

Synthetic Aperture Radar (SAR) and high (HR) and very high (VHR) resolution optical satellite images are valuable sources of information for maritime situational awareness. The objective of the Maritime Security Lab Analysis Framework is to develop and integrate applications to support operational services based on those SAR and optical satellite images in near real time (NRT).. In the frame of maritime surveillance services based on satellite images, the German Remote Sensing Data Center (DFD), part of the German Aerospace Center (DLR), established a framework to support automated NRT processing of huge amounts of image data from different satellite missions provided by a network of ground stations and service providers. Developed at DLR's Maritime Safety and Security Lab Neustrelitz, the Processing Framework is intended to support operational maritime surveillance value adding services. Main components are the Processing System Management (PSM), embedded thematic processors and the Graphical User Interface (GUI). The presentation will describe the overall workflow of data handling, the interfaces and the operator GUI, which was implemented for operational use as example.

Keywords: Synthetic Aperture Radar, VHR, Near-Real Time processing, Ship detection, Oil detection

1. INTRODUCTION

Remote Sensing technologies are getting more and more used as main contribution in maritime situational awareness systems. Information required can be e.g. on marine environment, border surveillance, fishery control or for ice services. For maritime surveillance large areas need to be monitored, while the detectable items remain comparable small, thus requiring observations with large coverage and a possibly high geometrical and temporal resolution. Single satellite data can fulfill these requirements in parts, where a tradeoff has been made between coverage, geometrical and temporal resolution and as well specific characteristics, e. g. the spectral band width. A classical solution for targeted object detection involves Spaceborne Synthetic Aperture Radar (SAR) systems, which are weather independent and able to cover large areas with good spectral resolution. They provide information to different topics, e. g. manmade structures like vessels, buoys, on oil pollution, on icebergs or wave height. Optical images can offer valuable contribution in maritime surveillance domain as well, but due to possible clouds some limitations still remain. Nevertheless depending on their geometrical resolution, optical images can be used to detect objects and to recognize them (at least their types) in order to analyze the behavior of such objects. In combination with data from other sources it is possible to evaluate and to verify information from satellite data but also vice versa to support the verification of such data. E. g. integrating additional attributes acquired from Automatic Identification

System (AIS) extends these capabilities significantly and allows performing such tasks as AIS anomaly investigations or detection of malicious actions. For near real time applications it is important to shorten the time from data collection to dissemination as much as possible to ensure that the extracted information could be provided with respect to the user requirement and in the required time frame. All data required have to be collected from different sources simultaneously according to the time of the satellite acquisition. The workflow control of the processing system must ensure to perform this tasks in parallel, taking priorities into account and to be robust enough in case of error or missing data.

2. PROCESSING SYSTEM

2.1 Processing Management

Currently the framework [1] is deployed in a cluster of virtual machines, linked with a shared file system GFS-2. The Processing System Management (PSM) [2] is one of the main components of the Data Information Management System (DIMS) which is used in a multi mission context and composed of systems for ordering and production control together with a central archive. The framework of the entire processing system is managed by the PSM, which automatically schedules different processes (processors) according to the processing request in place or by the availability of the data required. All processors are triggered by thematic rules, added to the PSM control system which is calling all processing steps in sequence or in parallel. The general workflow is illustrated in figure 1.

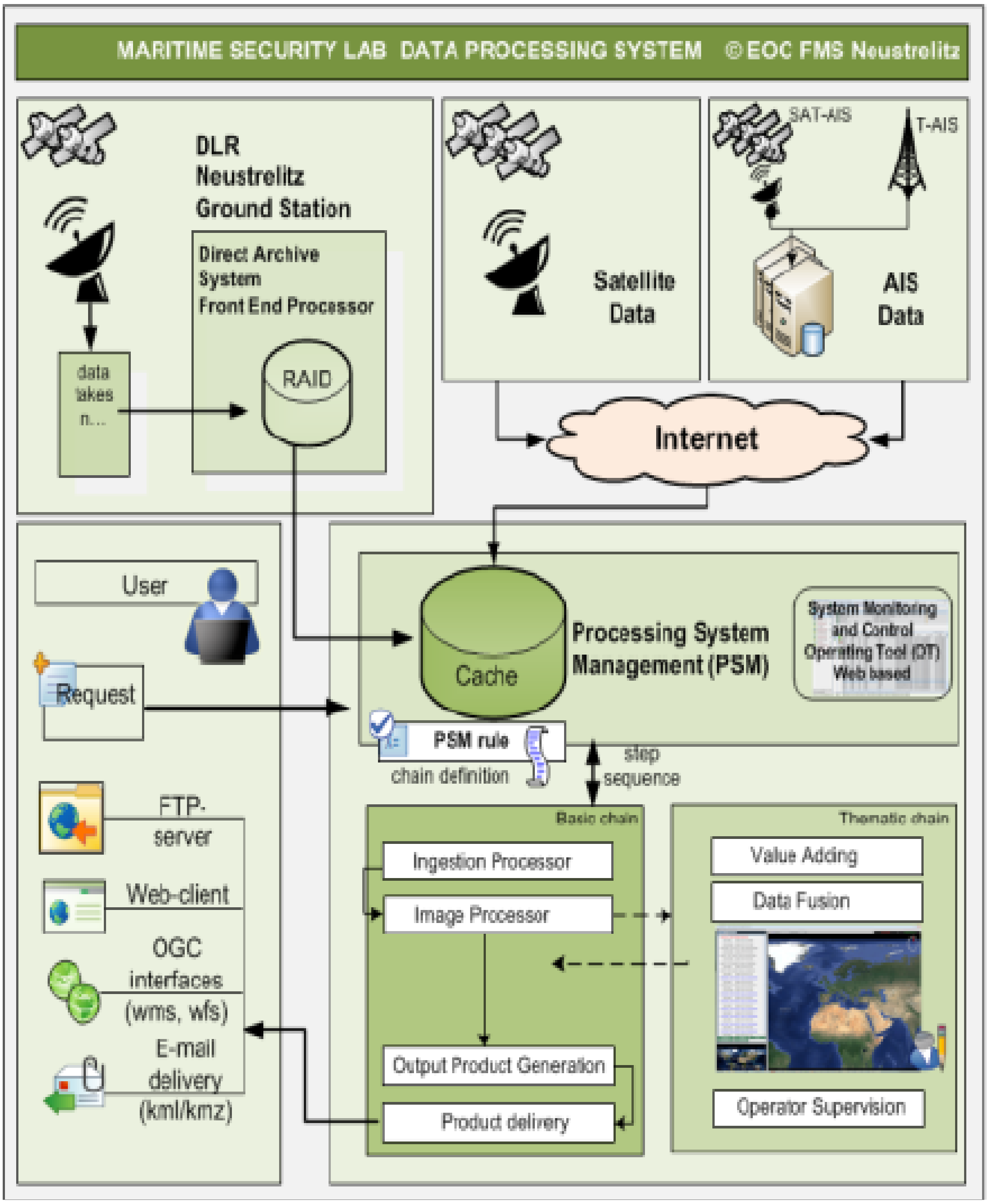

Fig. 1. Maritime Security Lab Optical Data Processing - framework architecture

Since images could be acquired at the same time by different satellites multiple PSM instances are implemented and configured to support different missions in parallel. Each single PSM and the individual processing requests are monitored and controlled with the Operating Tool (OT), a GUI which provides a set of views and allows operator interactions. Among others main processing modules are the "Image

Processing", the "Thematic Chain" and the "Product Dissemination". The image processing is the first main step and requires, with respect to the increase of image resolution and size, a high level of parallelization (hardware and software). For the thematic part every processing request contains at least one of the possible value adding types: e.g. Vessel Detection (incl. Wind and Wave), or Oil Spill Detection. Automatic Identification System (AIS) data are merged in accordance to the image extent and collection time. These data are acquired for the requested imaging time and coverage via real-time web interface based on HTTP protocol. Additionally an AIS plausibility check processor [4] is implemented. For some of these scenarios the framework requires human interaction during the processing. A second GUI in the frame of value adding based on the NASA World- Wind API has been developed and embedded to support these operator interactions The PSM communicates with this GUI via a Simple Object Access Protocol (SOAP) connection. In this way the results could serve automatically as an additional input before generation of the final products.

3. DATA AND METHODS

3.1 Image Processing

For near real time (NRT) response satellite payload data, consisting on instrument raw data, satellite attitude data and status information will be transmitted to a ground station within the visibility of the satellite. The first steps after data reception are quality checks, sorting, and assembly to create consolidated level 0 products. Depending on priorities and time constraints, instrument raw data might be pre-selected according to the timeliness applicable from the user request, since the following processing steps are very time consuming. In combination with additional calibration data sets and orbit information, this data will be processed to so-called Level 1 products, which for SAR products consist nominally of gray scale images for different instrument modes with annotated geo-information or images mapped to a geographic grid. Processing steps performed in case of SAR images are transformations, radiometric calibration, quality checks and geometric processing. The products generated are the basic input for thematic processing, so-called level 2 (L2) processing. In case of optical satellite image processing among others cloud processing is required to consider the cloud cover threshold from the user request. Basic imagery products like panchromatic or multispectral images could be handled and fit as input for the value adding L2 processing

3.2 Thematic value adding processing

Based on the L1B image product thematic processing can start, which might require additional input from external sources as well. In case of vessel detection the focus is to detect the objects of interest, determine their position, and if possible to determine the type and to estimate parameters.

In case of SAR vessel detection the SAR AIS Integrated NRT Toolbox (SAINT) [3] has been developed at the Maritime Safety and Security Lab Bremen, part of DLR's Remote Sensing Technology Institute. Beside vessel detection the software is used to perform iceberg detection, extraction of wind fields, containing information about wind speed and direction, as well as the detection of the sea state information e.g. the significant wave height (Hs). For monitoring areas like the German Exclusive Economic Zone (EEZ) generally known stationary objects are stored in a filter database and will be masked out. Other steps are filtering out ambiguities resulting from ghost images of large structures on sea or land. Information on detected objects will be merged with AIS information. The AIS information needed is retrieved in parallel to the image processing step, considering the imagery coverage and acquisition time. The AIS data is pre-processed and interpolated according to the image acquisition time if necessary. Both sources of information will be compared and matching information will be combined. The derivation of wind and wave information (SAR only) is based on geophysical model functions (GMF). For the wind field extraction in addition meteorological information on the main wind direction is needed, since the information based on SAR image solely is ambiguous. This input is generated by the Weather Research and Forecasting (WRF) Model [5], called as an additional pre-processing step. Running the different processors in parallel ensures that all extracted information is instantly available to the other information extraction processes. Processing optical images differs with respect to SAR image processing chain. One difficulty is dealing with clouds, which obscure the view in parts, but alter also the signal from ground due to shadows. For vessel detection there is also a need to obtain good geometrical knowledge on the object in order to recognize the shape. Depending on the geometrical resolution and the spectral characteristics of the vessel this information might vary significantly. Using deep learning algorithms it is possible to detect whether an object is a ship, and it might be possible to determine also the type of the vessel.

3.3 Product formats and dissemination

After running the L2 product generation different product formats are available in addition to the NRT L1b product. Among others the system supports kml/kmz, ESRI shape file, json and netCDF. In order to fulfill the variety of user requirements different dissemination options have been developed. This includes sftp/GridFTP or e-mail delivery, access over OGC interfaces (wms, wfs) enabling users to connect the data directly in GIS applications without having a local copy.

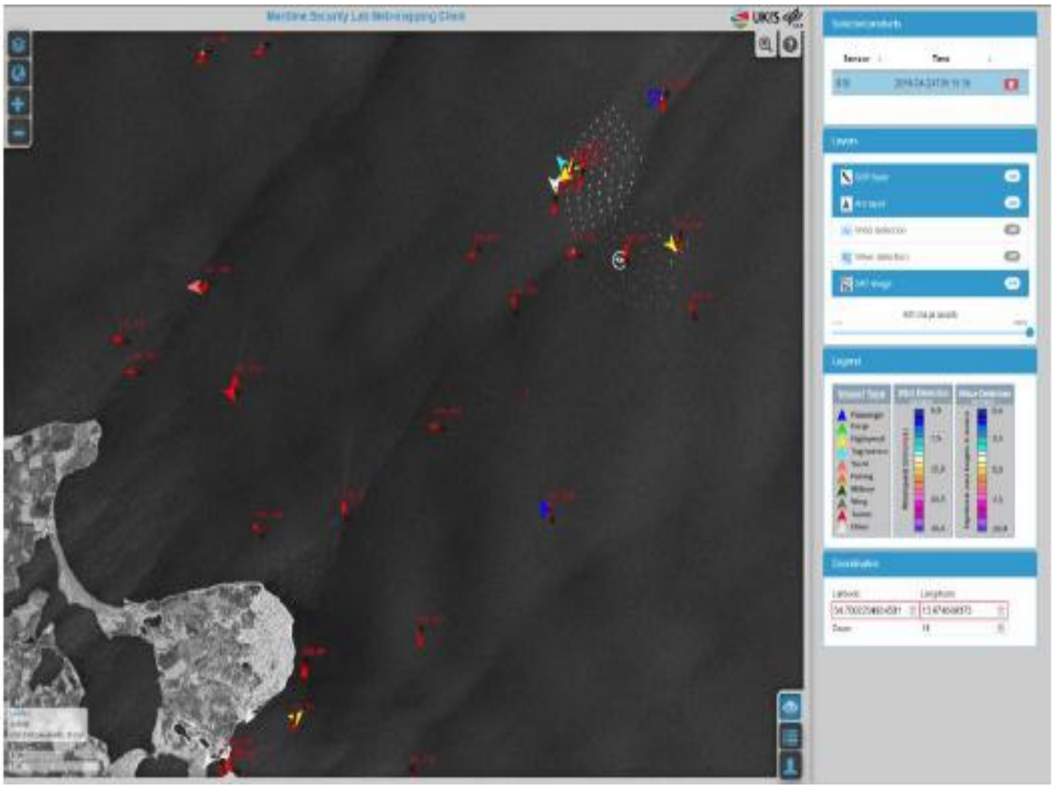

Fig. 2. Vessel detection product view using DLR's Web-mapping Client

Formats compliant to the EMSA CSN Standards are developed as well. Another alternative is a maritime web-mapping client developed, which requires the availability of modern internet browser only.

4. CONCLUSIONS

NRT applications for the maritime domain based on remote sensing satellite imagery have been successful implemented. Important for fast responses is the direct combination of data reception and processing. The combination of data from different sources is essential for value adding processing e. g. to refine the information, to avoid ambiguities, to get temporal and spatial context information. With upcoming satellite missions more satellite data with higher resolution will become available. This will increase the amount of data, but also the amount of smart data like the context information extracted. For automated data processing methods needs to be established, for selecting the correct data and considering interdependencies in order to control the distribution between sequential and parallel processing. Semi-automated processes need to be improved using deep learning algorithms as an aid for the operator.

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