RAMSES: An Operational Thematic EO-Application on Oil Spill Monitoring. System description

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Abstract. RAMSES (Regional earth observation Application for Mediterranean Sea Emergency Surveillance) is a web-based operational thematic EO Application System for oil spill detection and monitoring. Involving many geographically distributed resources and competences, the system had to meet strong requirements in terms of platform-independency and expandability. In addition, because thematic applications using remote sensing data share a lot of commonalties, the system has been designed in a modular way to ease modules reusability. The fulfilment of these objectives was largely supported by recent technologies such as CORBA and Java. After defining the actors and services, this paper presents the architecture of the system. It then outlines further improvements that can be considered for the oil spill application itself as well as further steps required towards a full multi-application support system.

Key Words: Earth Observation Application Systems, Web Application Server, Middleware, CORBA, JAVA, Oil Pollution

1 Introduction

The Regional earth observation Application for Mediterranean Sea Emergency Surveillance (RAMSES) project is funded by the European Commission (EC). Its goal is to develop and validate a **system** for **pre-operational** distributed oil spill detection and monitoring **services** based on Earth Observation (EO) products and meteorological/marine forecast geodata[1]. [MATRA, 1998] It intends to demonstrate the effectiveness of distributed EO environmental services as well as emphasise the benefits of EO data and geodata in environmental protection activities around the Mediterranean Sea.

[1] geodata = Spatially referenced data in a GIS format. Geodata is also known as "GIS data"

This ongoing project system includes a simulation of a sophisticated **business network** composed of data providers, value adders, business user intermediaries and customers as well as a prototype of a **distributed computing infrastructure** that supports their activities. Therefore, the RAMSES consortium, lead by MS&I (Matra Systémes & Information, St-Quentin-en-Yvelines, France), is composed of a balanced participation of project partners responsible for developing the infrastructure, providing data, processing and analysing data, supporting users as well as evaluating and exploiting system results.

An example of how the RAMSES business network interacts with the RAMSES distributed computing infrastructure is depicted in figure 1.

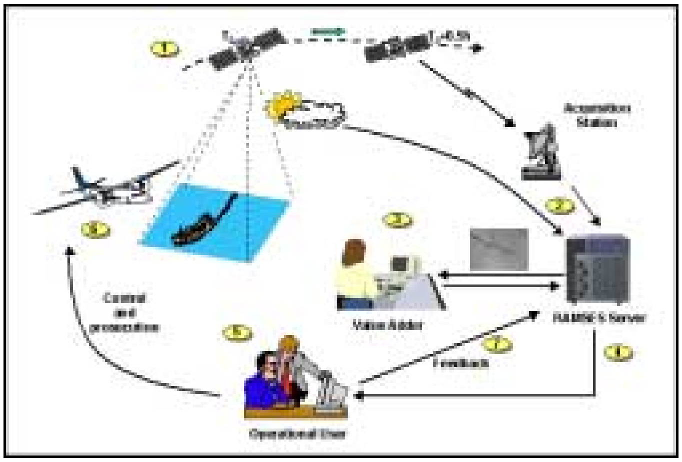

Fig. 1. RAMSES high-level business scenario

RAMSES relies on ESA‘s (European Space Agency) ERS-2 (European Remote Sensing Satellite-2) SAR (Synthetic Aperture Radar) products as the basic EO data resource for the oil spill detection and analysis. In case of "emergencies" high-resolution visible and infrared images from SPOT (Systéme pour l‘Observation de la Terre) are also requested. Thereby, not only is a higher observation repeat time provided but also the accuracy, reliability and quality is improved.

Presently, the monitoring activities are restricted to eight high-risk pilot areas. However, RAMSES is flexible enough to cover any area in the Mediterranean Sea. The present paper focuses on a system description of this project.

2 RAMSES actors and their roles

RAMSES actors are the "user-entities" involved in the RAMSES business network. Their primary role is to exploit EO data by interacting with the RAMSES infrastructure in order to detect, in near-real-time, oil spills in the Mediterranean Sea, and to initiate appropriate actions.

Since these activities more or less cover the whole chain of events of EO Ground Segments, RAMSES is labelled as an **End-to-End EO Application**. This type of application is characterized by actions beginning with the production of EO data and leading to the generation and dissemination of user-ready layered thematic products.

In accordance with [Moeller et al., 1999] EO Ground Systems and End-to-End EO Applications in particular are defined by means of three levels:

- **Data Level (DL)**: Generally composed of large-scale infrastructures, which handle the data acquisition from the EO satellite, as well as standard data processing and archiving.
- **Information Level (IL)**: Includes thematic processing infrastructures for creating higher level application-specific information products.
- **End-User Level (UL)**: Comprises user access infrastructures, which facilitate the application of such products in scientific, governmental, educational and commercial environments.

At each of these levels, appropriate user-entities are assigned. This classification is adopted and tailored to the RAMSES context as depicted in figure 2.

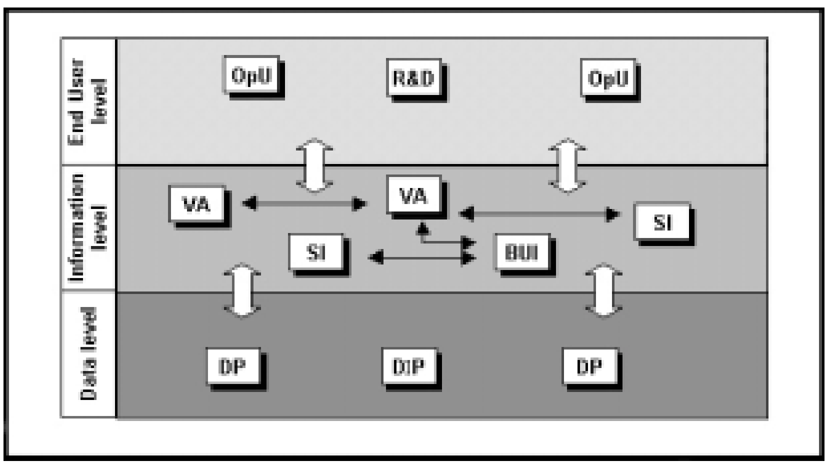

Fig. 2. RAMSES actors and their relationship

Data Providers (DP) are the entities, which deliver requested EO data and/or geodata to the system. Furthermore, they bring also their knowledge of the use and the transformation of these data (basic processing of the data, specific geometry issues, application involving large coverage, etc.).

Value Adders (VA) are GIS and image processing experts. They perform all the tasks involved in the processing and analysis of various DP products in order to serve their user community (i.e. customers). Therefore, they extract value added information of oil slicks and their movements from the imagery. This information is required for the generation of appropriate thematic products, which can be sent to the customers in near-real-time and in different formats.

Scientific Institutions (SI) are research and development entities specialized in satellite imagery and/or meteorological observation analysis and the development and promotion of new algorithms, models and applications. Their aim is to demonstrate the benefits of new research issues in order to integrate them into commercially viable EO-based services.

As the name says, **Business User Intermediaries (BUI)** have an intermediary role between the actors involved in RAMSES. Their work starts with the analysis of the satellite path in order to schedule RAMSES VA and SI activities, and ends with the evaluation of end user feedback. Furthermore, BUIs also have the task of supporting and fostering RAMSES users in any matter as well as advertising and promoting the RAMSES system and negotiating with potential new partners.

The **customers** are the end users of the RAMSES thematic products and services offered by the RAMSES system. According to their usage they are classified into two main types:

– The **Operational End User (OpU)** are those actors willing to use the thematic products in their operational decision making tasks related to oil slick emergencies. These users have a clear institutional or commercial role in the coastal or open sea pollution emergencies.
  Their main requirements are the provision of near-real-time RAMSES products in a predefined format. Most importantly, they want to use ready-to-use services, e.g. a warning message when a new oil slick is detected in their area of interest.
– The **Research and Development End User (R&D)** are the actors mainly interested in using RAMSES data for statistical and/or educational reasons. Furthermore, they use and integrate the RAMSES thematic information in their internal (research) analysis models/tools (e.g. models of the ecosystem, pollutant behaviour, fishery resources, etc.). Usually, R&Ds are governmental institutions (e.g. ecological departments, universities, etc.).
  Their requirements are different to that of operational users. In fact, they are not interested in warning services or a near-real-time delivery of thematic products, but in accessing the information available in the thematic catalogue (RAMSES product metadata, statistical information, etc.) without any time constraint of its delivery.

3 RAMSES services

As described in the previous chapters, RAMSES is a pre-operational system that aims to provide oil spill detection and monitoring services to operational and research users. This chapter describes the services in accordance to the three-tier structure of End-to-End Applications.

3.1 RAMSES DL services

In this section, the services provided by the RAMSES DL are specified.

- **Satellite path service**: This service specifies the orbits and tracks of satellites according to the date and time predefined by the user. On this basis, an EO product order table can be defined.
- **DP ordering service**: Through this service new DP product orders can be submitted. These orders can refer to different kinds of products: fast delivery EO radar data for the performance of preliminary oil slick analysis, high resolution EO data for ship detection analysis, optical high resolution data for oil spill monitoring, and meteorological/marine forecast geodata to estimate oil spill movement and its evaporation behaviour.
- **Ingestion service**: This service allows the system to register and store data products provided by DPs and on-site observations provided by customers. Consequently, this data becomes available to registered users.
- **Data handling service**: In addition to products, DPs also provide information about the (best) use of their data (e.g. basic processing algorithms, specific geometry issues, etc.).
- **EO notification service**: As soon as a DP product has been ingested, this service provides a notification to interested users (e.g. VAs, in order to allow the performance of oil spill analysis as soon as possible).
- **DP catalogue access service**: The DP catalogue consists of structured metadata of the EO data and geodata available in the system (i.e. products that have been ingested). This service provides several access mechanisms to the metadata.
- **DP catalogue maintenance service**: This service provides interfaces for the manipulation of the DP catalogue entries in order to guarantee its accuracy.
- **Modelling service**: This service provides meteorological and marine forecast geodata of different resolutions and areas. The user has to specify these parameters in advance.
- **Log and statistic service**: This service records the interactions (i.e. used services, errors, etc.) of users with the system. On this basis, simple statistical diagrams are produced. Furthermore, simple statistical diagrams are generated on catalogue entries.
- **Accounting and billing service**: In parallel to logging, the accounting service keeps track of any DP product and service provision to users. This information is the basis for the invoicing of the users.
- **User management service**: The user management service supports user registration, authentication and authorisation. It associates specific access rights to the user depending on which services he has subscribed to.
- **System maintenance service**: This service allows the maintenance of the system (e.g. start-up, shutdown, data backup, etc.) and controls the service availability.

3.2 RAMSES IL services

The IL is the layer that provides the most (important) services. The following list describes these services in detail.

- **Thematic analysis scheduling service**: On the basis of EO product orders, a timetable regarding oil spill analysis is generated. This service supplies appropriate schedules to VAs and/or SIs.
- **Thematic analysis service**: This service provides a set of scientific image processing tools for the professional detection of oil slicks on EO radar data. Furthermore, various GIS data (i.e. political boundaries, nautical maps, etc.) and meteorological/marine forecast data can be overlapped in order to include more information in the thematic products.
- **Thematic monitoring service**: This service allows the recognition and gathering of observations of the same oil slick. Once this is done, additional information can be extracted.
- **Information exchange service**: Through this service, thematic experiences and administrative information (e.g. regarding the organisation of a training session) can be exchanged between various actors.
- **Ordering service**: This service provides ordering mechanisms for RAMSES products and/or services. Hereby, the orders can be subscriptions (i.e. an order that remains open during a period of time and also refers to future available products/services) or on-demand orders (i.e. an order that refers to an available product/service and can be directly satisfied).
- **Thematic product delivery service**: As soon as a VA or SI has performed the analysis regarding a detected oil slick, appropriate thematic products are generated. The products can be distributed in a variety of standard formats including ASCII reports, postscript and GIS compatible (SHAPE) formats that best suits the needs of the different user community. They are sent to the interested user community using their specified delivery method.
- **Thematic catalogue access service**: This catalogue consists of structured metadata of the thematic products available in the system (i.e. products that have been ingested). This service provides several access mechanisms to the metadata.
- **Thematic catalogue maintenance service**: This service provides interfaces for the manipulation of the thematic catalogue entries in order to guarantee its accuracy.
- **Warning service**: As soon as an oil slick has been detected, this service delivers a warning message to interested users (e.g. operational end users like the Coast Guard). The reason for this alert is to reduce reaction times.
- **NULL warning service**: If after an EO data analysis no oil slick has been detected, this service delivers a NULL warning message to interested users. The reason for this notification is to stop possible operational interventions.
- **Help desk service**: This service‘s aim is to provide help with thematic products, services and processing algorithms to customers.
- **Model evaluation service**: In order to evaluate meteorological and marine forecast models this service provides tools to rate and validate their results.

- **Feedback analysis services**: This service provides feedback forms in order to collect comments, ideas, tips, advice, etc. from the user community.
- **User management service**: The user management service supports user registration, authentication and authorisation. It associates specific access rights to the user depending on which services he has subscribed to.
- **Log and statistic service**: This service records the interactions (i.e. used services, errors, etc.) of users with the system. On this basis, simple statistical diagrams are produced. Furthermore, simple statistical diagrams are generated on catalogue entries.
- **Accounting and billing service**: In parallel to logging, the accounting service keeps track of any product and service provision to users. This information is the basis for the invoicing of the users. Bills are regularly generated and sent to the appropriate user community.
- **Advertisement and promotion service**: This service provides information about the project and its results.
- **System maintenance service**: This service allows the maintenance of the system (e.g. start-up, shutdown, data backup, etc.) and controls the service availability.

3.3 RAMSES UL services

The RAMSES system doesn‘t provide any services in the UL. In fact, through the RAMSES infrastructure, UL actors take services from the other two levels (e.g. R&Ds interact with the IL thematic catalogue in order to get thematic information) but don‘t put any at the other actors‘ disposal.

UL services would be interesting only for UL actors who serve their own user community outside of RAMSES. For instance, with such an infrastructure they could get a thematic product from the RAMSES system, overlap some additional layers, and send these new products to their users.
Usually, these actors are already equipped with a processing environment of this kind. However, RAMSES does not offer it.

4 The RAMSES infrastructure

Chapter 3 described the services that the RAMSES system provides to the various actors. In order to perform these services in a professional and highly efficient way, automation and therefore a computing infrastructure is required. This chapter discusses technology considerations and the architectural design of the RAMSES infrastructure.

4.1 Technology Considerations

Most of the requirements of such an infrastructure can be met by a **component-based** architectural design. In fact, a component is a piece of software that covers a comprehensive function and has well-defined interfaces. These interfaces allow it to "plug" into a **component framework**, which is responsible for the communication between the different interfaces. Consequently, components can easily be replaced by competitive components with the same function and behaviour. Furthermore, other components can easily be added to the framework in order to increase the function and/or performance of the system. With such a component-oriented design, the foundations for these high-level requirements are laid.

Current implementations of **component models** are, for instance, OMG's *CORBA* (Common Object Request Broker Architecture), SUN's *EJB* (Enterprise JAVABeans), Microsoft's *COM+* (Component Object Model) and IBM's *DSOM* (Distributed System Object Model).

In RAMSES the OMG CORBA standard was chosen due to the following reasons: First, the RAMSES infrastructure is based on the former project (ISIS, Interactive Satellite Image Server)[2], which constitutes a prototype and proof of the functionality of a first European IL system based on CORBA. It responds to requirements of on-line access, selection, processing, reduction, compression and retrieval of EO image and GIS data and information, according to user-defined thematic and application-oriented specific criteria [Vizzari, Fusco, 1999]. Second, the RAMSES consortium has a particular interest in ensuring adequate design decisions that will ensure the compatibility of a future version of RAMSES with ESA standards. In fact, ESA uses CORBA as its distributed object model standard. Third, CORBA is not a product of a single company, but a specification of a consortium, called the Object Management Group (OMG). The OMG includes over 800 companies and it represents the entire spectrum of the computer industry. Therefore, there is no dependency on one company, as for instance with Microsoft's DCOM+.

4.2 Infrastructure Topology

Considering the list of services that the RAMSES system offers and the distribution of the actors, the infrastructure topology depicted in figure 3 was designed[3]. The large size of remote sensing data (e.g. 140 MB for an ERS high resolution image) was particularly taken into account. In fact, in order to reduce data transfers and alleviate network costs, it was decided to directly store and pre-process (e.g. stretching, flipping, etc.) EO products on DP premises. Only the relevant part of the images is transferred upon request to (remote) VAs. Therefore, the cost of the service is reduced by the fact that users do not need to buy the complete image.

The RAMSES infrastructure is a classical three-tier computing system consisting of a set of *graphical user interfaces* (GUI), an *application server*, and *database and transaction servers*.

The GUIs are the front-end applications of the infrastructure. They provide the display interfaces and tools that usually run local on users' personal

[2] Funded by the European Commission (HPCN/Esprit Programme)

[3] NB: Each server is connected to the Internet

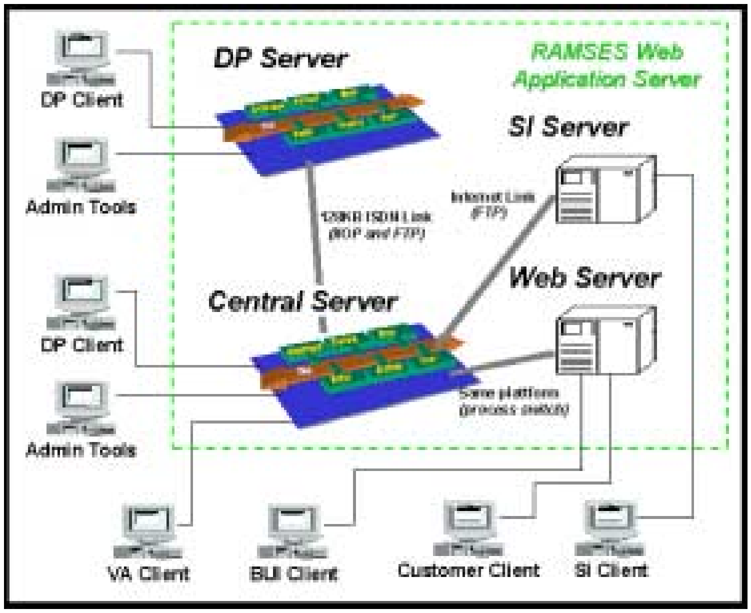

Fig. 3. Infrastructure Topology

computer or workstation. Each client application is associated to specific user-entities: the DP Client to DPs, Admin Tools to System Administrators, the VA Client to VAs, the BUI Client to BUIs, the Customer Client to customers, and the SI Client to SIs.
The middle-tier provides the business logic of the infrastructure. It is composed of an association of four servers: DP Server, Central Server, SI Server and Web Server. Since the application server includes a Web Server for the support of easy-to-create HTML-based front-end applications, this middle-tier is called *RAMSES Web Application Server*.
The database and transaction servers constitute the back-end of the infrastructure and are responsible for the storage of the data. In RAMSES, this layer is composed of a DBMS and ESA/ESRIN archive management system.
The elements of the infrastructure are described in the following paragraphs.

The **DP Server (DPS)** mainly contains ingestion, storage, post-processing and catalogue functions, limited to DP products provided by the related DP. The aim of this server is to allow DPs to ingest its own EO products as well as to maintain their own DP product catalogue.
The **Central Server (CS)** mainly comprises thematic processing functions for the analysis of DP products and generation of thematic products. Furthermore, it includes DPS functions for ERS-2 radar imagery and meteorological/marine forecast geodata as well as customer-oriented functions like ordering, delivery, advertisement, accounting and invoicing.
The **SI Server (SIS)** is mainly used for the execution of meteorological/marine

forecast generation models (i.e. atmospheric model, ocean circulation model, wind wave model with 4 km and 16 km resolution) and their validation algorithms.
The **Web Server (WS)** is mainly used to advertise and promote the RAMSES System to a wide community. Furthermore, it constitutes an efficient way to share project internal information between RAMSES partners (e.g. project status descriptions, satellite path specification, internal documents, etc.).

The communication between the SIS and the CS is across Internet. Each day in the early morning the generated set of meteorological and marine forecast geodata (ca. 2 MB) for the next 48 hours starting at 12 o'clock of the previous day is transferred by FTP from the SIS to the CS. On the other hand, the communication between the CS and the DPS is based on a 128KB ISDN link. Available DPS related products are directly transferred on request by FTP to the CS (max. 40 MB / product[4]). Administrative and catalogue data exchange is performed upon CORBA's IIOP (Internet Inter-ORB Protocol).

The set of clients uses the RAMSES Server functions and packages them in user-friendly GUIs (Graphical User Interfaces). Through them, actors can access the infrastructure and use it either for the accomplishment of system services, or for the subscription of services, or for further statistical elaborations.

Admin Tools embrace standard UNIX tools for the maintenance of the computing system and the backup of files. Furthermore, they include COTS maintenance tools, like an interactive SQL interface to the database or an access interface to the archiving management system.
The **DP Client** application includes ingestion and catalogue maintenance tools. Depending on the user login, appropriate screens are displayed.
The **SI Client** application embraces appropriate screens for the configuration of meteorological/marine forecast models and their evaluation.
The **VA Client** application is related to VAs. Since the VA Client intents to serve a user community strongly interested in near-real-time information availability[5], connections between them and the CS are especially important. However, apart from the expensive, analog telephone lines, Internet is still the sole terrestrial computing network that connects the countries around the Mediterranean Sea. ESA studies for a possible application of DVB (Digital Video Broadcasting) connections.
The **BUI Client** is mainly used for the management of users, customer subscriptions and catalogue accesses. It is related to BUIs. Since BUI operations mostly are not time critical and the average size of communication packages is not bigger than 100 KB, the Internet link is sufficient. The BUI Client is a JAVA applet integrated in a RAMSES web page.
The **Customer Client** mainly supports order and catalogue access functions for customers. It has the aim to penetrate in a wide user community and allow

[4] With the assumption that users never request more than 1/3 of the ERS-2 SAR high resolution image

[5] Communication-packages between VA Clients and the CS comprise sizes between min. 10 KB and max. 40 MB

registered customers to access the infrastructure from everywhere. Therefore, it is available as applet in an Internet web page. The Customer Client is a JAVA applet integrated in a RAMSES web page.

Admin Tools, DP Clients and SI Clients are always locally installed and used on the related server machine. However, VA Clients, BUI Clients and Customer Clients are remotely connected to the CS.

4.3 RAMSES Web Application Server Architecture

In this section the general architecture of the RAMSES Web Application Server core infrastructure is described.

4.3.1 DP Server Architecture

The DPS Architecture is composed of several server modules, as depicted in figure 4: Geo Data Server, User Manager, Image Product Repository, Image Processing Server, Ingestion Module, Subscription Manager, EO Notification Handler, Log & Accounting Manager.

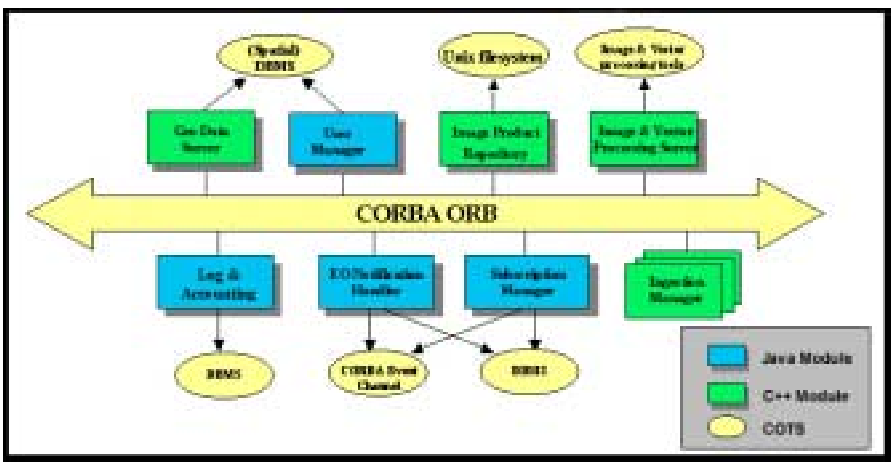

Fig. 4. DPS Architecture

The commercial product ORBIX 3.0 of IONA (Dublin, Ireland) is used as the **CORBA ORB**. It is applicable to a wide range of platforms and operating systems, and offers some *CORBAService* implementations like Naming, Event and Trader Service.

The **Geo Data Server (GDS)** is the RAMSES system *catalogue*. It contains descriptive data (i.e. metadata) of all ingested products (i.e. SPOTImage remote sensing data). Furthermore, it provides catalogue access and manipulation services.

For the storage of the metadata, the GDS includes the DBMS freeware product "PostgreSQL 6.5.2" of the Postgres Global Development Group. PostgreSQL is an object-relational DBMS that provides a spatial index for the efficient 2-dimensional data access. The DBMS is accessed by the GDS by linking the PQ library[6] in its C++ Code.

The **User Manager (USR)** module stores descriptions of registered users (e.g. name, organisation, postal and email address, etc.), privileges that are granted to them (e.g. right to use a client application or to access datasets), descriptions of registered groups, and a list of available client applications in the system. Furthermore, it provides information access and manipulation services. For the storage of this data, the same instance of the PostgreSQL DBMS is used. Since the spatial index is not required and the USR module is implemented in JAVA, the database is accessed through the JDBC facility of PostgreSQL. Therefore, an exchange of the DBMS can be performed without hardly any changes in the module code.

The **Image Product Repository (IPR)** is the RAMSES system *archive*. It holds all the remote sensing products that are referenced in the catalogue. The functions of this module are limited to the ingestion and retrieval of images.
This module is implemented in C++ and its related imagery is directly stored on the UNIX file system.

The **Image & Vector Processing Server (IPS)** provides common image and vector processing tools[7] that are needed during the ingestion of EO products (e.g. stretching, flipping, etc.) or are shared by more than one application (e.g. image compression, cropping images, etc.). Furthermore, it provides services for the monitoring of the progress of each processing chain (with a progress and/or execution report).
This module can be understood as the CORBA wrapper of the image processing engine "Multiscope 1.6"[8] developed and commercialised by MS&I and the freeware library "GD" of the National Imagery and Mapping Agency (NIMA). It is implemented in C++ and uses Multiscope's APIs and descriptor files[9] for the specification and execution of image processing tasks, as well as the GD library in for the processing of GIF images.

The **Ingestion Manager** imports various EO products and their metadata into the catalogue and also eventually into the archive[10]. The ingestion process consists of importing the data, extracting the metadata, computing a browse image and thumbnail, pre-processing the image (e.g. stretching, flipping, etc.), updating the catalogue and eventually the archive. Furthermore, it produces an "Event Description File" for eventual EO notifications (see EO Notification

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[6] The PQ library is part of the Postgres Software Developer Kit
[7] In the DPS, only image processing tools are used
[8] Including the IGN's GEOLIB library extension
[9] Multiscope descriptor files contain processing instructions and inputs for the control of the processing engine
[10] Only high-resolution remote sensing products of large sizes are referred to in the catalogue, and stored in the archive

Handler).
The ingestion modules are implemented in C++ and related to the ingestion of SPOT panchromatic and/or SPOT multispectral images, SPOTView and SPOT Vegetation images.

The **Log & Accounting Manager (LOGG)** allows server modules to record events (e.g. user accesses, EO product user requests and deliveries, etc.). These events can be converted to statistics and/or invoices.
Every event sent to the LOGG is stored in a database. Postgres is again used as the DBMS linking the PQ library to the JAVA code of the LOGG module.

The **Subscription Manager (SUB)** accepts different subscription requests (i.e. EO product subscriptions and EO notification subscriptions) and stores them in the subscription database. Furthermore, the SUB provides database manipulation and removal services. For the subscription processing this database is accessed by the EO Notification Handler.
This module is written in JAVA and relies on IONA's Event Service.

The **EO Notification Handler** is an event consumer. Each time an Ingestion Module produces a new "Event Description File", the EO Notification Handler checks the subscription database for eventual EO notification service subscriptions. If this is the case, the module sends an email to the subscribed users by specifying the ingested product. Thereupon, the user is allowed to access this data. The EO Notification Handler module is implemented in JAVA and relies on IONA's Event Service.

4.3.2 Central Server Architecture

The CS Architecture is composed of the same server modules as the DPS (for the management of ERS-2 EO products and meteorological/marine forecast geodata), and additionally of thematic processing functions (i.e. RAMSES Product Packaging and VA Application) and customer-oriented functions like ordering, delivery, advertisement, accounting and invoicing. Furthermore, it includes the Remote Request Manager, which coordinates the access of different DPS catalogues. The CS architecture is depicted in figure 5.

IONA's ORBIX product is again used as the **CORBA ORB**.

The logic of the DPS modules **GDS**, **USR**, **IPS**, **Ingestion** and **EO Notification Handler** is the same for the corresponding modules in the CS. The only difference is that they are no longer related to SPOTImage products but to ERS-2 EO products, meteorological/marine forecasts, customer onsite observation reports and RAMSES thematic products.

The **IPR** implementation is slightly different because instead of directly storing high-resolution EO products on the UNIX file system, the ESA/ESRIN AMS (Archive Management System) is used.

The **LOGG** module functions are increased by simple accounting and invoicing routines that simulate the commercial use of the RAMSES server. The related accounting information (located on each DPS) is gathered by the Remote Request Server.

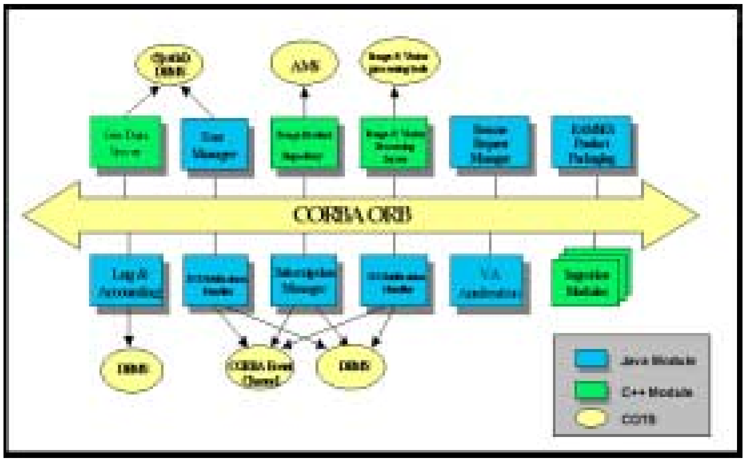

Fig. 5. CS Architecture

The **Subscription Manager** functions are increased by the possibility that OS notifications and thematic products in different formats can now be subscribed to.

Just like the EO Notification Handler, the **OS Notification Handler** is also an event consumer. Each time a VA confirms the detection of an oil slick, this module is activated. It checks the subscription database for eventual customers that have subscribed to the delivery of RAMSES thematic products in this area. If such a customer exists, it sends a warning message (only if the customer has also subscribed to the warning service) and activates the RAMSES product packaging and delivering routines.
The OS Notification Handler module is implemented in JAVA and relies on IONA's Event Service.

The **RAMSES Product Packaging (RPP)** module is responsible for the generation of RAMSES thematic products. It has to gather, reformat and tailor various data sources in order to produce the requested product. Currently, the RAMSES thematic products are *OS Observation* and *OS Monitoring* available in ASCII, high contrast image and numerical format. Furthermore, it ensures the delivery of these products using the customer specified method (i.e. email or FAX).
The RPP module is written in JAVA.

The **Remote Request Manager (RRM)** module unifies all available catalogues (GDS modules) into a virtual one. In fact, each catalogue request is first inspected by the RRM, which passes it onto the appropriate GDS module. The results are sent back to the client through the RRM.
The RRM also gathers accounting information from each DPS in order to make the CS LOGG module process a unique invoice for the customer.
The RRM module is implemented in JAVA.

The **Value Adder Application (VA Application)** module provides an adequate VA Client specific interface to the RAMSES server modules. Therefore, it supports services for the ordinary access to the infrastructure, the retrieval of available browse images in the catalogue in the time and region of interest, the selection of an image, the request of (further) high-resolution data, and the insertion of oil slick related information.
The RRM module is implemented in JAVA.

4.3.3 RAMSES VA Client Application

The purpose of the RAMSES VA Client application is to offer VA tools for the thematic oil spill analysis of radar and optical satellite images. The complete application is implemented in JAVA, allowing an easy distribution to users on many platforms. It remotely interacts with the VA Application module of the CS, which provides the entry point to the infrastructure services. In this section the current status of this application is described.

The first screen refers to the authentication of the user. In fact, users have to enter their login name and password, which are compared with the internal user access table. Only authorised users have access to the successive screens.

The next screen displays the Mediterranean Sea and specifies the RAMSES regions of interest. Furthermore, it allows the specification of the time of interest. Users have to choose one of these areas and define a time which they are interested in.

In the third screen, footprints, thumbnails and related textual information (e.g. satellite instrument, frame, track, acquisition date and time, etc.) of all available radar or optical browse images regarding the user specified area and time are displayed. Users have to choose the image they want to analyse.

The next screen displays the complete browse image in GIF format. At this level, the application provides basic tools like zoom-in/out, measurement of distances and display of the geo-coordinates of a specified point, and basic image manipulation tools like convolution filters, incidence angle correction and modification of the look up table. Furthermore, vectorial meteo fields like wind, pressure, and current (of almost the same time as the acquisition time of the satellite image as well as forecasts for the next hours) can be overlayed on the image. As soon as users find a spot on the image that they want to analyse in more detail, they have to select the area and either open the analysis tool or request the high-resolution scene of this browse image area.

The oil spill analyser is a collection of powerful tools for a professional, oil spill oriented analysis of satellite images in GIF format. These tools support users in specifying the oil slick contour and extracting parameters like perimeter, darkest point position and direction. Figure 6 provides a snapshot of this analyser tool.

After analysis, oil slick parameters are sent to the CS, which notifies interested users and generates/delivers appropriate thematic products.

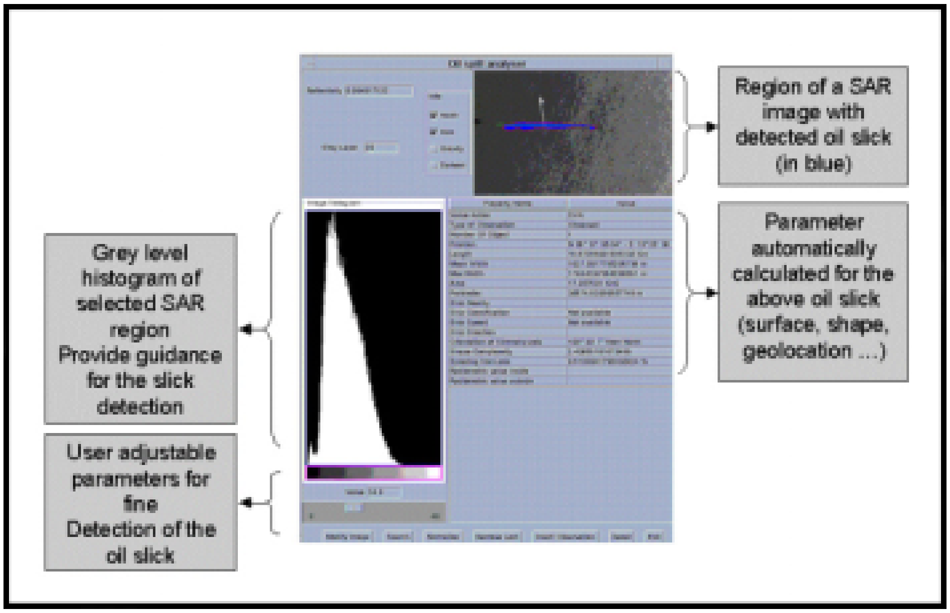

Fig. 6. Oil spill analyser

5 Recommendations for future work

In this chapter recommendations for future work regarding the current version of the RAMSES infrastructure are given. Generally, these recommendations can be considered at two levels: Improvements to the infrastructure and adaptation of the infrastructure to other EO systems.

5.1 Improvements to the RAMSES infrastructure

The first version of the RAMSES infrastructure is operational since January 2000. The first notifications of oil pollution have been successfully sent to customers. Nevertheless, in order to further improve the quality of the service, the conception and development of the following **scientific models** is foreseen:

- *Oil slick forecast and hindcast models*: Analysis of meteorological and marine forecasts, as well as of the understanding of oil slick behaviours and movements are still lacking.
- *Automatic oil slick detection algorithm*: So far oil slick detection requires human intervention. Initial works on a neural network approach for semi-automatic detection of oil spills in ERS-SAR imagery [Calabresi, et.al, 1999] were performed.
- *Ship and position forecast models*: Reliable models for the detection of ships and their trajectory, as well as forecasts of ship position after a specified time would be very useful in RAMSES. Research in these topics is ongoing.

From a technical point of view some improvements are required. In fact, in order to commercialise the RAMSES infrastructure, some of the modules implemented in this prototype have to be improved in terms of performance, reliability and security. Furthermore, some COTS have to be replaced by commercially supported de-facto standard products and some others have to be added (e.g. e-commerce systems).

Besides this, there is also a need to expand RAMSES with new concepts.

VAs often express the desire to complement the thematic information with proprietary information, like additional GIS data (e.g. regional ship routes) or drifting model outputs, which should be provided only to their regional customers. Furthermore, they would like to ingest new and only regionally available (radar) data as an additional thematic analysis source. Therefore, there is the need to provide VAs with their own, semi-autonomous **"branch" server**.
Branch Servers (BS) should include the same capabilities of the CS, limited and tailored to local requirements. Hereby, the concept of interoperation becomes fundamental.

Currently, the RAMSES infrastructure relies on standard terrestrial communication services like Internet and ISDN. Due to new telecommunication solutions and to the lack of high-speed connectivity in third world countries, further improvements are needed for future **network connectivity**. Examples for such networks are:

- *ADSL (Asymmetric Digital Subscriber Line)*, that enables to transmit digital information at high bandwidths on existing phone lines.
- The terrestrial R&D high-speed backbones that connect Europe (e.g. *GARR-B* in Italy, *Renater* in France, etc.) can also be used.
- *DVB (Digital Video Broadcasting)*, which could cover the gap of third world country connectivity infrastructures.

Reusability, expandability and scalability are big requirements in RAMSES and particularly in End-to-End EO application systems. In order to resolve these problems, RAMSES designed and implemented a modular infrastructure based on CORBA. The idea of CORBA is to let modules concentrate fully on their business logic, whereas, communication tasks between other modules or basic services are provided by the core.
Since this approach can lead to a thick middleware layer which can result in substantial performance losses, there might be a need to broaden the term "module". For instance, besides functional logic, modules could also integrate other aspects like security or semantics, so that the middleware could be reduced to a communication and coordination framework. This means that in such a **component approach** the middleware would be responsible for the semantic relationships between components, which could be maintained in a flexible and dynamic way. Furthermore, each component would be associated to its own semantic description, which would enable the exchange of components in a process chain.

5.2 Adaptation to other EO systems

RAMSES doesn't support any interoperability with external DP servers, like MUIS (Multi-Mission User Services - ESA's multi-mission distributed infrastructure, providing access to several EO-missions with a unified service concept including product and sensor guide), or INFEO (Information about Earth Observation - CEO's EO information access service system). Currently, data is ordered off-line at the appropriate DP service desk and then transferred via the network to the RAMSES Server. Studies are needed to apply a **standard EO catalogue interoperability** protocol like CEOS' CIP (Catalogue Interoperability Protocol) or ESA's GIP (Gateway Interoperability Protocol).
The adaptation of RAMSES to a DP interoperability protocol doesn't imply the deletion of the DL in the three-tier structure of End-to-End EO application systems. There is still a need to have EO product ingestion tools in order to ingest, for instance, customer on-site observation or private data.

Studies in RAMSES' former project ISIS have shown that individual IL functions may be applicable to more than one application domain and system (e.g. advertisement of available services, pre-processing functions of EO images, cataloguing and delivery of thematic products, etc.). Therefore, interoperation of these modules becomes essential. This idea of proper application partitioning into a **federation of individual IL service systems** is currently followed by the MASS (Multiple Application Support Services for Earth Observation) project, funded by ESA/ESRIN. Furthermore, MASS also integrates also DP aspects, which means that interfaces to DP systems are provided. An adaptability analysis of RAMSES to MASS would be fruitful for both projects.

Such an analysis can also be performed starting with a RAMSES approach. In fact, besides providing an operational system for oil pollution, the RAMSES system can also be used for the support of new thematic applications. Currently, RAMSES supports a flood monitoring application (Decide - ESA funded project). An analysis of the increase of the number of supporting thematic applications by RAMSES towards a large-scale EO application framework would surely yield interesting results.

6 Summary

European EO application systems are still in their beginnings. Initial research on their design and implementation has been performed and is still ongoing. Their main goal is to build prototypes in order to give a potential set of users (e.g. environmental departments, coast guards, etc.) an understanding of the benefits of space-based Earth Observation. Consequently, the use of space-based Earth observation data in various private-economic applications is encouraged. These first research projects are supported and funded by institutions like the European Commission and the European Space Agency.

RAMSES also takes part in this effort by setting up a prototype system for the oil spill thematic market using satellite based radar images. The goal of this project is to demonstrate the relevance of satellite imagery for the detection of oil pollution in the sea, even in emergency cases that require near-real-time processing. Therefore, a component-oriented three-tier architecture was investigated based on CORBA in conjunction with JAVA and C++. This architecture enables to allocate specific functions to different service providers (e.g. ingestion routines to data providers, modelling algorithms to scientific users) and to increase the number of applications interfacing with the same infrastructure.

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