ARCHITECTURE FOR EARTH OBSERVATION AND FIELD SURVEY DATA EXPLOITATION FOR HUMANITARIAN CRISIS MANAGEMENT

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ABSTRACT:

A system's architecture has been designed to exploit earth observation and field survey data. This architecture has the task to combine, analyse and present information from earth observation sensors (satellite and airborne) as well as data from field survey. At the top architectural level, the system is decomposed in the following major subsystems: the mission planning system, the workflow management system, the information management system, the data ingestion system and data analysis system. An overview of the architecture is given with the data analysis described in more detail. One of the noteworthy aspects of the system is its compatibility with the ESA KEO architecture, allowing access to earth observation data and services. A prototype of this system will be deployed for the field trial in Angola. For the trial area there is a substantial lack of information and the little available data is described. Land cover classification is performed based on (freely) available satellite data land; demonstrating some the potential of the system.

1. INTRODUCTION

The STREAM system (Sahli, H., 2006) is an information system under development that is built to provide support for risk management for the mine action and humanitarian action community, see Figure 1-1. The STREAM system is developed within the STREAM project, which is an EU-funded project in the sixth framework. The project has completed its first phase of defining the system concept and designing the system and is currently working on the prototype implementation. This prototype is to be tested during the upcoming field trial in Angola scheduled for October 2006.

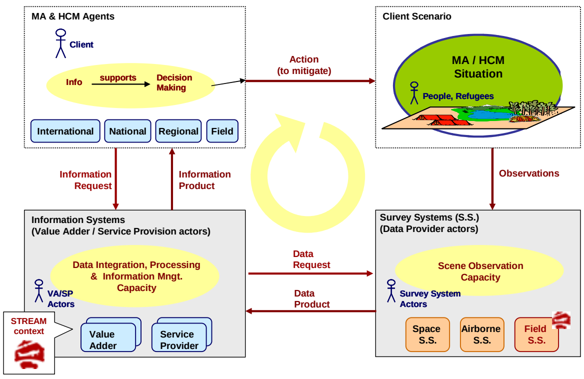

Figure 1-1: The STREAM system in its operational context.

In this paper, an overview of the architecture is given in Section 2. The system consists of several subsystems. The mission planning system (MPS), as described in Section 3, handles the incoming requests from the client and initiates other systems. The MPS is support by the Workflow Management System (WFMS), see Section 4. The data is stored in the Information Management System (IMS) which, as described in Section 5, also contains interfaces for exploitation of the data. Adding new data into the system is handled by the Data Ingestion System (DIS), see Section 6. To fully utilise this data, a Data Analysis System (DAS) is used for processing; described in Section 7. This also contains the high-level processing algorithms in the knowledge-based scene understanding subsystem. Emphasis is given on this part of the architecture.

A prototype of the STREAM system is to be tested during a field trial in Angola, a description of the trial area and available data is given in Section 8. Initial and example results of the data analysis are provided in Section 9. Conclusion and a discussion is presented in Section 10.

2. ARCHITECTURE SYSTEM OVERVIEW

An overview of the architecture is shown in Figure 2-1. The STREAM system architecture has been developed in close collaboration with the ESA KEO project. By aligning the architectures, future KEO services could be easily integrated into STREAM and future STREAM services could be offered to KEO and to the ESA's SSE, the service support environment (Achache, J., 2003). The STREAM system further interacts with IMSMA (Arnold, A. 2006) the mine action information system used by the national mine action centres and Humanitarian Information Centres (whenever a standard is established). Data is request (or procured) from survey providers: Field survey, airborne survey and satellite survey.

The main components of the STREAM system are:

- The Mission Planning System (MPS)
- The Workflow Management System (WFMS)
- The Information Management System (IMS)
- The Data Ingestion System (DIS)

- The Data Analysis System (DAS)

These systems are described in the following sections.

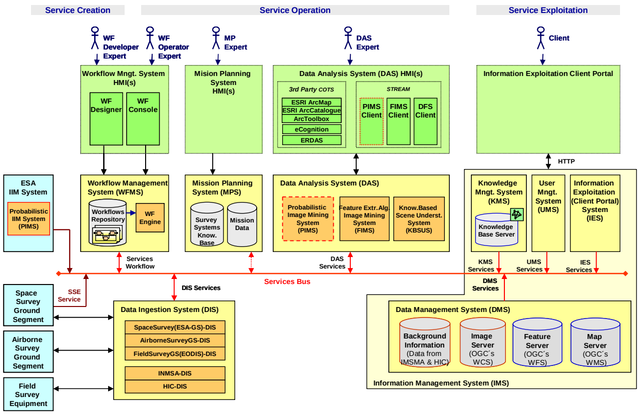

Figure 2-1: The STREAM system architecture

3. MISSION PLANNING SYSTEM

The STREAM system is though to be used by actors in the field of mine action and/or humanitarian action (which are called clients) to help them in the decision making and planning/monitoring process. By itself the system does not take any action. The system is triggered by a request for information from the client.

The Mission Planning System (MPS) is a tool that supports the STREAM Operator in order to:

- upon reception of a Request For Information (RFI) received from the client,
- having access to the knowledge about the survey system that can be invoked from STREAM (*STREAM Survey partners*) ,
- having *a level* of knowledge about the Scenario derived from previous Ingestions and Surveys

to define:

- (if the knowledge about the Scenario already gathered is not enough to fulfil the RFI) the type and characteristics of the scene survey missions that are needed to fulfil the RFI and draft the necessary Request For Data to the survey subsystems.

The RFI may results in one or several RFDs that are issued (after approval by the client) to the corresponding Survey System.

The specific mission planning for each survey operations is performed by the surveyor. The mission planning system only helps in defining the overall mission and the specific requirements for each of the survey missions.

The STREAM mission planner creates a survey report and defines the area that is to be surveyed. The planner writes any additional information, required by the surveyor in the description field of the report.

The concept of mission planner consists of several components and interfaces (see Figure 3-1):

- A Mission Planning Support Tool.
- A Data Repository with the Mission Planning definitions.
- Knowledge Base with all data related with the Mission Planning definition and execution.
- Knowledge Base with all data related with the Scenario definition.
- STREAM to Background Information Systems Exploitation Tools & Interfaces.
- Background Information Systems: IMSMA for mine action and the HIC (Humanitarian Information Centre) for humanitarian action information.
- STREAM to Survey Systems Interfaces.
- Survey Systems (Space, Airborne & Field Surveys).

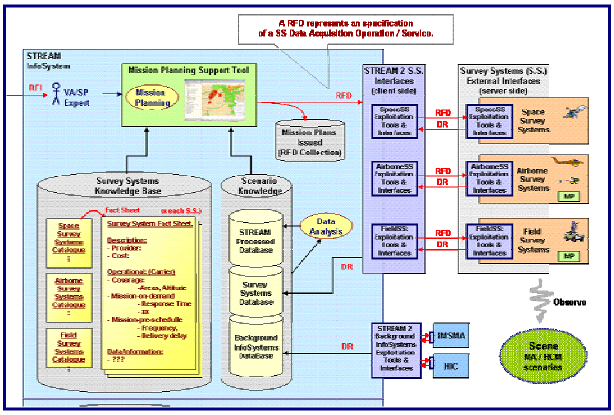

Figure 3-1: Mission Planning System Overview

The Mission planning is also a task in the chain of tasks to execute into the WFMS. Figure 3-2 depicts how the Mission Planning task is part of this chain. Different actors are involved according to their relation with a particular task.

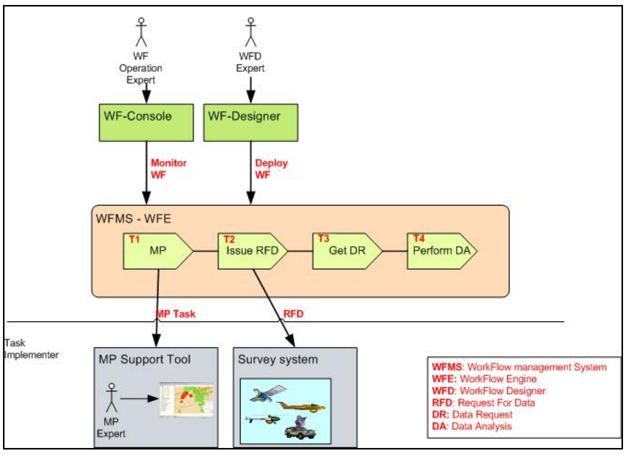

Figure 3-2: Interaction between the Workflow Management System and the Mission planning System.

4. WORKFLOW MANAGEMENT SYSTEM

The workflow concept is related to the automation of procedures where documents, information or tasks are passed between participants according to a defined set of rules to achieve, or contribute to, an overall business goal.

Workflow is a useful tool to chain different processes (Applications, Web Services, Manual Tasks…) being in one or in several servers or being executed by the same or different actors. Moreover, it is necessary to identify a mechanism to define processes for creating and storing Workflows and to define tools for reading and executing them correctly.

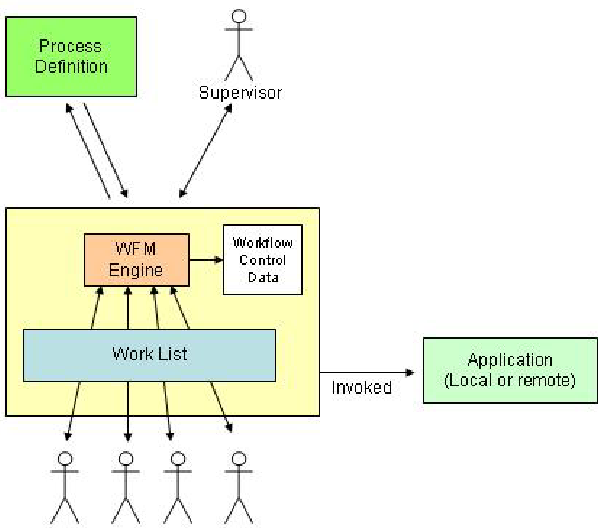

Figure 4-1: Workflow Management System Concept.

Workflow engines such as Oracle BPEL can be in charge of reading, monitoring and executing workflows defined in XML formats (BPEL mark-up language). The workflow engine in STREAM is responsible for managing all, or part, of the execution of individual process such as:

- DIS - Data Ingestion subsystem
- DAS – Data Analysis subsystem
- KMS – Knowledge management subsystem
- WFMS – Workflow Management subsystem
- MPS – Mission Planning subsystem

The flow of work may involve the transfer of tasks between different workflows to enable different parts of the business process to be enacted on different platforms or sub-networks.

The WFMS enables the automatic chaining of tasks, if these tasks are in an automatic process or manual process. The aim is to develop a system which allows the planning, conduct and control of the operational procedure with the following possibilities:

- describe a task,
- define its inputs/outputs,
- define the sequence of tasks,
- define the communication between tasks,
- control/verification of tasks,
- automatic processing of tasks (A task could be defined as a manual or automatic action).

Tools for integrating and automating system processes include:

- A Workflow designer: a visual environment for capturing processes as workflows.
- A Workflow engine: a runtime server for process orchestration
- A Workflow manager: a monitoring tool.

The WFMS is based on industry standard languages for the definition of Business Processes, such as the BPEL.

Based on these standards, STREAM Operational Procedures are formalized for an effective Work Flow Management.

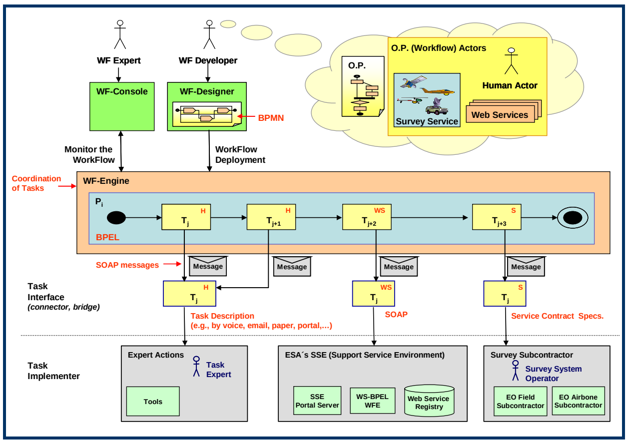

Figure 4-2: Generic Implementation Approach

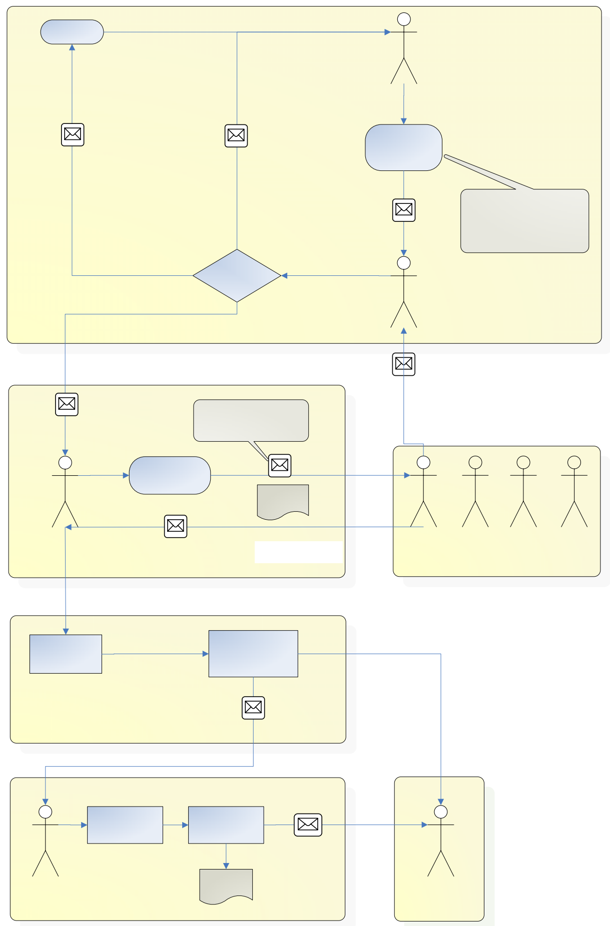

Figure 4-3: The reference workflow of STREAM.

The reference workflow for STREAM is shown in Figure 4-3. As stated in the MPS, see Section 3, the workflow starts with a request for information. If this RFI is accept by the STREAM manager, it is automatically transferred to the mission planner. The mission planner creates one or more requests for data (RFDs) which are submitted to the survey subsystem. Each request for data results in some data which is ingested in

STREAM after quality control. Once the data is ingested in STREAM it most likely needs some analysis before the information, as requested by the client, is extracted. This information is assembled in an information report and made available to the client.

5. INFORMATION MANAGEMENT SYSTEM

The STREAM Information Management System is composed of five main blocks which allow to the System to interact with the client and to store all geographical and non-geographical data:

- Knowledge Management System
- User Management System
- Information Exploitation Client Portal
- Spatial Data Storage System
- Non-Spatial Data Storage System

The non-spatial data is stored in the STREAM Data Repository and managed through a series of services. These services are accessed through a (Windows) application or through the STREAM Web Portal. Non-spatial data concerns for example:

- Field Survey team management
- Logistic Management

The Information management system should allow the STREAM HQ operator to perform the following tasks:

- Creating structured information e.g. Survey Team, Logistics, …
- Creating Form for field survey (e.g. Impact Survey Form, …)
- Insert new data.
- Get existing data.
- Update existing data.
- Delete existing data.
- Run predefined queries on existing data to extract data.
- Define custom queries on existing data

An overview of the architecture of the IMS is shown in Figure 5-1. The principle behind the design, and the one that makes the STREAM architecture comparable to the ESA KEO project, is that each component is connected through a service bus. This bus may be either SOAP/HTTP/JDBC or file system access, depending on the type of interaction and size of data.

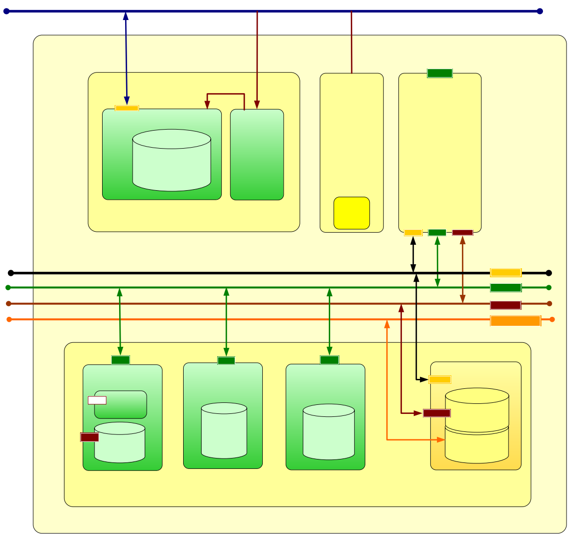

Figure 5-1: Overview of the information management system

Information Exploitation Client Portal Requirements

The Information Exploitation Client Portal is the part of the STREAM HQ that enables the exploitation of the Information gathered though external systems and captured during field surveys. The Information Exploitation Client Portal enables the Client to exploit the Information produced during STREAM system operation trough the STREAM web portal. The Web portal offers access to various compilations of data as well as querying and editing functionalities.

This idea implies a set of Graphical User Interface that is in charge to retrieve data existing into Information Management System and show it to the Client as a report way.

In the STREAM system there are different User interfaces implemented as web portals which could be merged, in a future, into a single integrated portal together with this Client portal having a common access interface (web-based) to the different user profiles.

The client server interaction is shown in Figure 5-2. For data ingestion, see Section 6, a special GUI is developed which allows packing of data and entering the meta-data before it is submitted to the server where the ingestion takes place. In the exploitation interface, it is also foreseen to give the client access to the geographical information system (GIS) component of the IMS. In this interface, the client can view additional information or different presentations than in the information report. For the first prototype it is foreseen that this viewer is based on commercial software and not available as web interface.

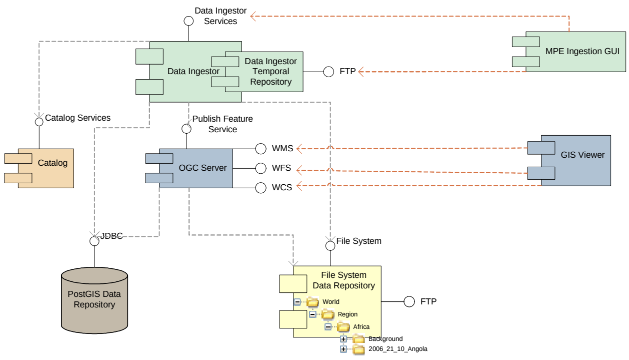

Figure 5-2: The server-client interaction between the IMS (left part) and the Ingestion GUI and GIS viewer (right part).

6. DATA INGESTION SYSTEM

Data Acquisition System represents the Interface between External Systems and STREAM Information System. This data acquisition is enabled through the definition of interfaces between STREAM with:

- Space Survey System (SSE System).
- Airborne Survey System.
- Field Survey System.
- IMSMA (B.IS. Sub-System) Info System.
- HIC (B.IS. Sub-System) Info System.
- Humanitarian Action agency
- EO Space Survey Value Adder / Service Provider (systems as SSE or WIN).

6.1 Data Ingestion from the Field Survey and the IMSMA Systems

The data acquired from IMSMA, an information management system used by national mine action centres, is imported to the STREAM Data Repository (Non-Spatial Data Storage System) through a number of services. Each service exposes interfaces that accept the data in *xml*, see Figure 6-1. The mine action information is exchange in the mine action XML (MaXML) format. A conversion tool of the data ingestion system converts this XML into GML (a XML format specifically designed for geographical information). The GML data is subsequently stored in the repository.

The mine action information that is acquired through the handheld devices of the Field Survey is also stored in the same MaXML format. Therefore the data is ingestion in exactly the same way as the IMSMA data from mine action centre.

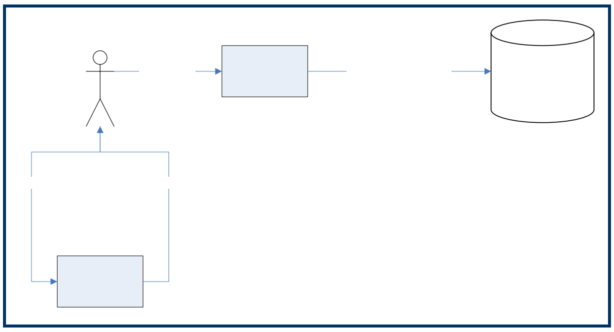

Figure 6-1: Ingestion of MaXML data, the MaXML data is converted to GML before it is stored in the repository.

For Field Survey data that contains humanitarian action information, special forms are used and the data is stored in a separate XML format, which we call HumXML. This data is ingested into STREAM in a similar fashion as the MaXML data: using a conversion tool to convert it to GML before storing it in the IMS.

6.2 Ingestion of other data

The ingestion of the other data is performed by the mission planning expert (MPE) using a client server approach, see Figure 6-2. The MPE uses a graphical user interface (GUI) to package the files that are to be ingested and to fill in all the necessary metadata (such as data source, geographical coverage, acquisition dates, etc.). The data is subsequently uploaded to the system into a temporal location. Once the data is uploaded a request is send to the data ingestor service to start the actual ingestion into the IMS. This request contains the location of the uploaded files. The process of packaging the data is shown in Figure 6-3 and the user interface for the client is shown in Figure 6-4.

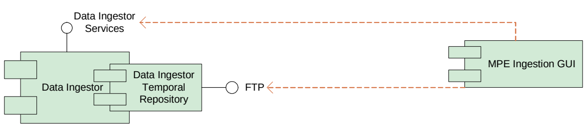

Figure 6-2: The client server approach for the ingestion of other (geographical) data

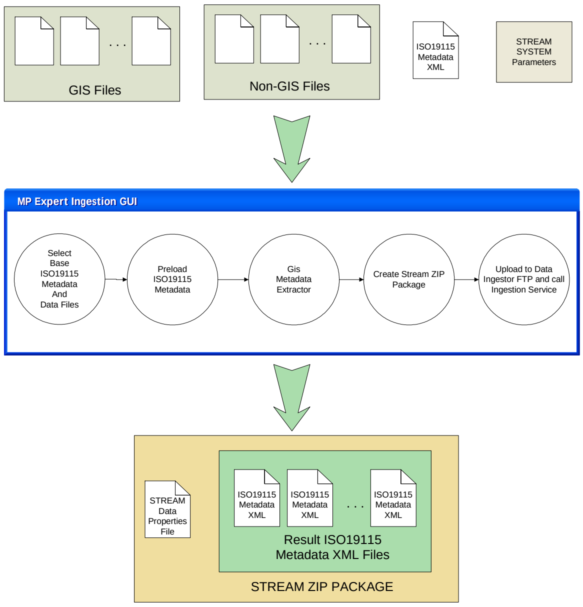

Figure 6-3: Packaging the data into a STREAM ZIP package with all the necessary metadata.

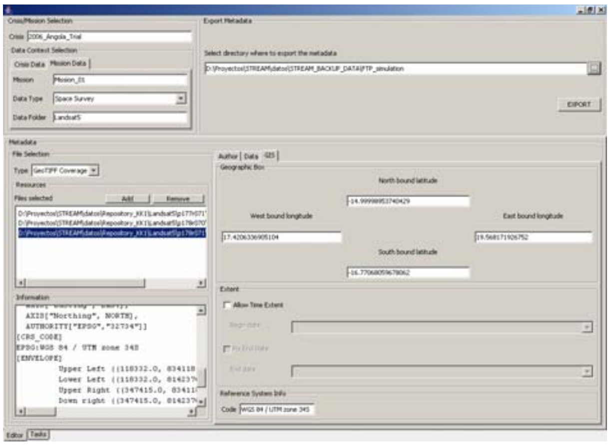

Figure 6-4: The MPE Ingestion user interface that is used for creating the STREAM ZIP package.

7. DATA ANALYSIS SYSTEM

The goal of image analysis is to derive a symbolic description of image data, which is suitable for a given task and often comprises objects detected in the scene along with their attributes and relations. A common feature of computer vision systems is that this transformation is accomplished within a hierarchy of abstraction levels, beginning with the raw data up to the desired symbolic description, where the control flow does in general not have to agree with the hierarchy. The main goal of this hierarchy is to explicitly represent the information inherent in the data with growing abstraction, making also use of the general or domain specific knowledge to a varying degree. Thus, the gap between raw data and high level representations like object models is bridged successively giving rise to a number of more simple modules interacting to achieve a perceptual ability.

To formalize the semantic content of the acquired images, the extraction of feature objects is organized hierarchically. Our guiding principle is to use a smaller number of high-level object detectors, coupled with mid-level visual observables, to interpret the scene. Edges, textures, interest-points, response to filter-banks, and segmented/classified regions are considered to be *direct observables* and therefore form the bases of the visual information hierarchy (Low Level). At the Intermediate Level, information derived directly from image observables is computed and characterized for object detection. Intermediate level feature objects are more salient, but generally requires additional context to be meaningful. This is done at the High Level information where semantic concepts and spatial relationships are included.

The Data Analysis System is closely interrelated to the other STREAM components as illustrated in Figure 7-1, e.g. with the (a) GIS for gathering *a priori* knowledge about the scene, as well as adding new features, (b) the Knowledge Based Scene Understanding, for extending the Analysis results to Interpretation Results, (c) the Workflow, to define processing sequences, etc … In summary, the following STREAM components are part of the Data Analysis:

- Workflow Management Tools.
- Data Analysis Tools
- GIS Desktop Tools
- The produced/collected data are stored into Operational Data Repositories for:
- Mission Data.
- GIS data.
- Scenario Information.
- Image Archive.
- Image Features.
- Data Fusion Features.

In this context, it is important to highlight an important element of the STREAM System: the ***Repository Registry*** that stores all metadata resources existing in the STREAM system and allowing the data Analysis.

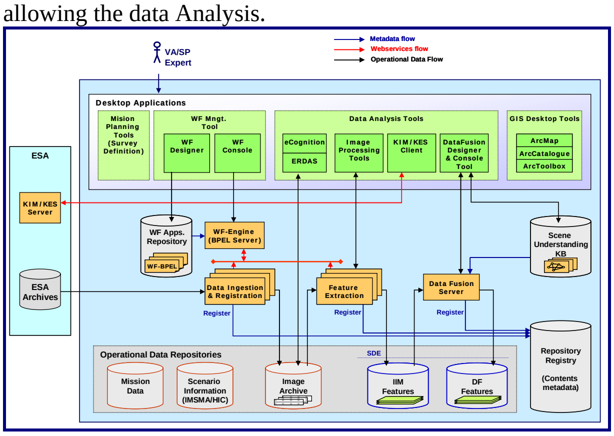

Figure 7-1: Data Analysis Concept

7.1 Feature Extraction

Image Analysis is the step to extract intended feature indicators for risk assessments and provide useful layers for synthesized maps. Intended indicators are defined according to problem definitions. The image analysis provides semantic information of the scene. The specificity of the application calls for methods that can exploit context, spectral information, vegetation changes, shape and structural information for identifying direct and indirect indicators allowing the production of thematic maps for the considered Humanitarian Emergency applications.

The main Use Case of Image Analysis is to perform an **Image Processing (IP) task** for the extraction of image features or semantic objects as depicted in Figure 7-2.

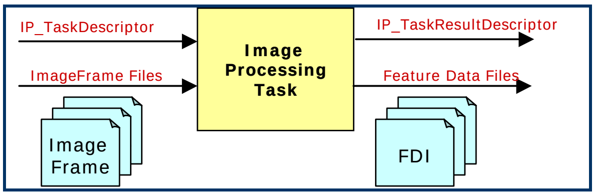

Figure 7-2: Image Processing Task

Each IP receives a task descriptor and a set of image frames. The output is a description of the results and the extracted feature data file. A feature data file is a shape file describing the extracted feature(s) or semantic object. The image files for STREAM have been standardised at GeoTIFF to preserve the geo-referencing of the images. The resulting shape files also contain the same geo-reference.

Land Cover Classification & Land Cover Changes: Land cover classification from multi-sensor imagery that provides first-hand up-to-date information on land use represents the first step of scene analysis. Certain land cover classes are indicative of whether an area is inhabitable (non cultivated land). For examples, water sources such as rivers and streams are important for displaced population; roads and paths describe the accessibility of the area. For high resolution airborne imagery, temporary refugee camps can be identified. Multi-temporal images acquired before and after the conflict can provide information on war activities, e.g. trenches, cradles created by explosives, destroyed houses and infrastructures, etc. Post-conflict multi-temporal acquisition can update the situation of reconstruction process. Indicators can be derived to represent level of reconstruction: new constructions of road, power lines, housing, cultivated land, etc. State of the art-techniques are used for land cover classification and land cover changes. For land cover classification the ESA-KIM system (Datcu, M., 1999; Datcu, M., 2002) is used. For land cover changes existing co-registration and fusion techniques are used. The interpretation work goes hand in hand with ground investigation and by correlated evaluation of information from the GIS. Delineation of landscapes as achievable by satellite image interpretation – e.g. according to CORINE nomenclature – permits the above mentioned assessment of human and economic value of hazard areas. The results support planning of airborne and ground surveys.

Structural information extraction: Map updating and scene understanding necessitate structural data extraction from high resolution images. Structural data in this context defines meaning full man made and natural objects, e.g. road, river, house. To detect objects using high resolution multi-spectral multi-sensors, low-level visual homogeneity criteria (like colour, texture, spectral, and so on) for segmentation do not lead to semantic objects directly. Hence, knowledge of the geometrical features of an object as shape (e.g. rectangular, oval, linear) and vertical dimension (e.g. height), as well as appearance are needed, these information represent the object semantic. Perceptual organization techniques are used to extract structural objects. Perceptual organization can be defined as the ability to impose structural/appearance organization on sensory data, so as to group sensory primitives arising from a common underlying cause. Perceptual organization assists an image understanding system in coping with unreliable low level processing, making it more resistant to minor changes in the input and achieving the much desired goal of graceful degradation.

Segmentation and Classification: refers to pixel-based or region-based methods for the classification of image pixels being a member of a given class or region based upon spectral, textural or homogeneity measure and class/object membership. Multi-scale decomposition, semantic models and gestalt laws and models associated with stochastic models (Markov Random Field) are used.

Disorder & Anomaly detection methods: Anomaly detection using multi-sensor, multi-temporal images refers to the detection of irregularity in the scene that appears unlikely according to a probabilistic or physical model of the scene, for example ammunition elements in a scene which is dominated by vegetation and soil. Most image analysis approaches focus on understanding "regularities", e.g. textures, geometrical patterns, configuration of objects, etc. The images to be analysed in the frame of this projects as for example the satellite images the airborne images of mine fields contain relevant information in "disordered" regions which have to be automatically characterised (Datcu, M. 2005).

We propose to analyze "anomalies" in images based on the application and novel extension of basic information theory. Information measures, both Shannon and Kolmogorov entropies, describe the information content of a code, e.g. the regularities in a binary string. Since the Kolmogorov entropy is related to the mutual information, and it turn the mutual information is used to define rate –distortion function, we propose to study the use the rate –distortion analysis to detect anomalies in images. The study aims at looking at image pixels, and clusters or image regions, obtained by the estimation of image parameters, as "codes".

7.2 Workflow of Data Analysis

Figure 7-3 shows both the conceptual framework of Image Analysis, as well as the process (workflow). In the figure:

- The input is represented by the Remotely Sensed Image (Satellite or Airborne), by the GIS data (e.g. existing maps, meteorological data, digital elevation map, already extracted features, etc.), by a knowledge base remote sensing topics (e.g. spectral/textural library – See KIM/KES description), and by a knowledge base on landscape (see Knowledge Based Scene Understanding).
- The output is given in the form of a thematic map of landscape elements with associated indicators derived from this map (e.g. anomaly, tents, ..), as well as an updated knowledge bases, in particular Models for geometrical and topological reasoning.

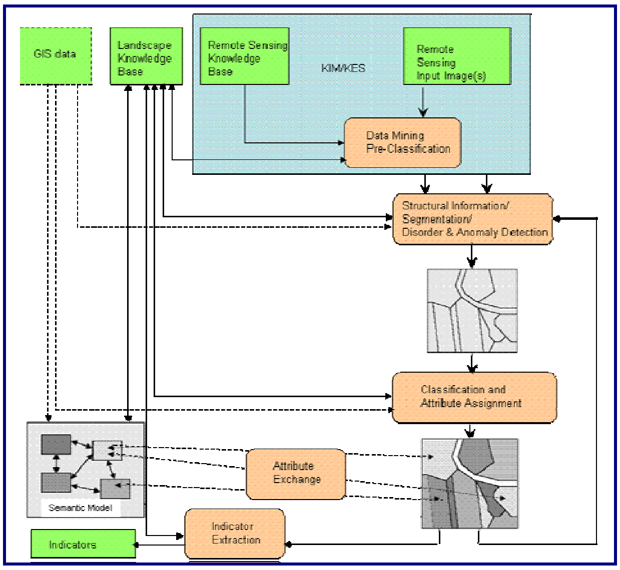

Figure 7-3: Image Analysis Process

The processing chain considers the following steps

1. Data Ingestion/Pre-Classification. Here we do not make distinction between satellite and airborne images; all data is ingested by the image mining system - KIM/KES for a pre-classification of the image pixels. The results of this step are classification maps corresponding to Land cover classes learned by the KIM/KES system, as well as the corresponding classes' prototypes.

2. Segmentation: this step corresponds to the process of partitioning the image into meaningful segments having significance in the real world. The segments should represent landscape elements or anomalies in landscape. Several algorithms for change detection, image classification, image segmentation, model-based structural information extraction, disorder/anomaly detection are used. Some of these processes use both the input image as well as the output from the data mining System. In general terms, the extracted segments are referred to as 'image features'.

3. Segmentation/classification: The requirements that image segments should represent meaningful landscape elements require the prior knowledge of the class of a segment. This prior could be inherited from the GIS, the landscape knowledge or the results of the image mining. The mutual dependence between segmentation/classification can be made by using an iterative process.

4. Interrelation Knowledge-Base Segmentation Classification: Segmentation and classification are influenced by GIS data, Landscape knowledge as well as remote sensing knowledge. This extra knowledge is used to constrain the classification and resolve ambiguities.

5. Spatial Models: Part of the knowledge based scene interpretation; spatial semantic models are used to relate segmentation/classification results to thematic

maps. Moreover, attributes, such as population density, land status, could be estimated.

6. The result of this process are indicators, corresponding to thematic maps, e.g. safe area, mine contaminated area.

From the architectural perspective, the above described modules are categorised as:

- Non-interactive modules; apply a data independent, or data driven algorithm, and require no interaction with the image analyst operator during the processing. The module can perform a supervised or un-supervised task. In case of supervised operation, the training phase is off-line.
- Interactive modules: effectuate a supervised processing of data, either data - or user-driven requiring on-line interaction with image analyst operator.

7.3 Knowledge Base Scene Understanding Approach

Figure 7-4 illustrates the proposed software architecture approach for the Knowledge Base Scene Understanding system (**KBSUS**). This components has the purpose of enabling the expert scene analysts to express their knowledge about the **assessment of the situation** (that is, the relationships between the available surveyed objects (semantic features), in a suitable user-oriented (but machine computable) language, in order to enable the automation of the application of these knowledge model templates to the new acquired data. In other words, it aims to enable the further exploitation of preliminary results (features) stored in the GIS Feature Server, which are obtained from previous Image Information Mining (IIM) processes, as well as other information sources.

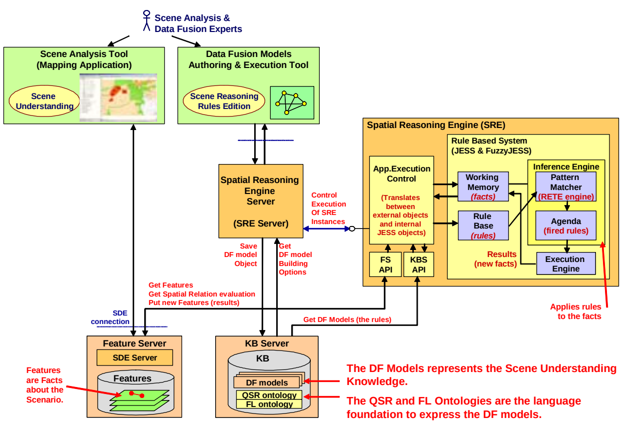

Figure 7-4: The architecture of the Knowledge Base Scene Understanding System

The KBSUS kernel is a software component developed by GTD referred to as the **Spatial Reasoning Engine** (**SRE**). The SRE approach is based on the following key technologies:

- **Ontology Engineering**: represent both: the basis for the knowledge representation language, and also the semantic grounded description of the features from the scenario
- **A Fuzzy Logic framework**: in order to deal with the uncertainty in the models expression (in the user mind) as well as in the scenario (in the facts).
- A **Rule-Based Engine** (augmented to deal with fuzzy logic algebra) integrated with the GIS feature server. That is, the models are computed (resolved) by a fuzzy-rule-based expert system. The engine uses fuzzy-terms and fuzzy-operators in the rules, and carries over the Certainty Factors accumulated along the evaluation of the rules, in order to provide a final figure of relevance that is used to rank and order the matching results.

This proposed approach follows the lessons learnt from the data fusion works performed in the baseline EC FP5 project ARC (Chan, J.C.-W., 2005). In the course of STREAM project, the following major areas of enhancement (over the work of ARC) are envisaged:

- Usability: user interface improvements, such as a help system.
- Robustness: Testing more complex models, performance benchmarks
- Functionality: SRE Language Expressiveness

8. FIELD TRIAL AREA DESCRIPTION

The selected trial area is in Angola, in the Cuando Cubango province. One of the partners of the STREAM project, MgM, is planning to start working in this area. To plan the activities and use of resources, it is needed to obtain prior information regarding the area.

The selected trial area is in the Cuando Cubango province in Angola. The two corner points are: (14.500 ºS, 18.216 ºE) and (16.186 ºS, 19.453 ºE). An overview of the area is given in Figure 8-1. During the 30 years of conflict, large minefields have been laid around Mavinga, Cuito Canavale and Baixa Longa.

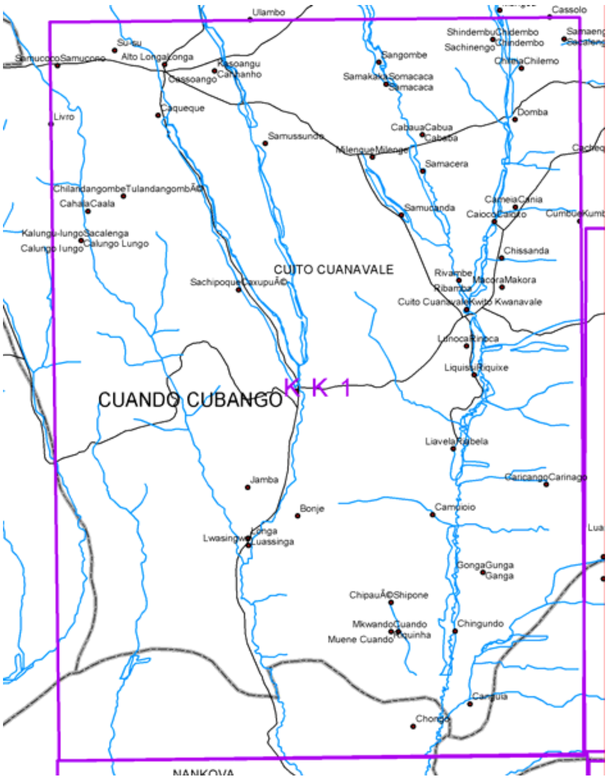

Figure 8-1: Overview of the selected trial area (KK1) in Cuando Cubango

From the area there is actually little information known:

- Roads and rivers and from VMAP0 (accuracy worse than 2 km)
- Settlements from GEONET name server (rounded to the nearest arc second)
- Administrative boundaries from famine early warning systems.
- Furthermore maps exist at a scale of 1:100,000, but these are more than 20 years old and there are maps of 1:1,000,000, which are not accurate enough.

From public sources, several satellite data sets are available free of charge. These data sets form the starting point for the processing. For practically any place on earth the following data is available:

- Landsat 1 – visible and near infrared
  - Resolution 57 m per pixel
- Landsat 5 – multi spectral visible – infrared
  - Resolution 28.5 m per pixel
- Landsat 7 – multi spectral visible – infrared
  - Resolution 14.25 m per pixel (panchromatic) / 28.5 m (other bands)
- SRTM2 – elevation data
  - Pixel size 100x100 m
- VCF – land cover: percentage bare, herbaceous, trees
  - Pixel size 1 x 1 km

For the KK1 area, we have found the Landsat data as listed in Table 8-1. This data allows for the first data analysis in terms of land cover classification and change detection. With the Landsat 1 data, although at lower resolution, we have the situation of before the conflict. From the Landat 5 and 7 data we can extract the land cover classification, where the latter gives the situation that should be comparable to the current situation.

Sat.	Path/ row	Acq.date	Bands	Res. [m]
1	190/070	18-09-1972	Red, green, NIR (2x)	57.00
1	191/070	27-07-1972	Red, green, NIR (2x)	57.00
1	190/071	18-09-1972	Red, green, NIR (2x)	57.00
5	177/071	10-04-1992	Red, green, blue, NIR, SWIR, TIR	28.50
5	178/070	15-04-1991	Red, green, blue, NIR, SWIR, TIR	28.50
5	178/071	12-04-1991	Red, green, blue, NIR, SWIR, TIR	28.50
7	177/071	30-04-2002	Red, green, blue, NIR,SWIR,TIR(2x), panchromatic	28.50 14.25
7	178/070	20-07-2000	Red, green, blue, NIR,SWIR,TIR(2x), panchromatic	28.50 14.25
7	178/071	04-04-2000	Red, green, blue, NIR,SWIR,TIR(2x), panchromatic	28.50 14.25

Table 8-1: Available Landsat data for the KK1 area.

One of the areas of interest within the KK1 trial area is the area around Longa. The VMAP0 data of this area is shown in Figure 8-2. The corresponding Landsat 5 and 7 images area shown in Figure 8-3 and Figure 8-4. Although the VMAP0 data gives an indication of where the roads are, at certain places the error (with the Landsat images) is more than 2 km. Consequently this data is useful for indicating where the roads and the rivers could be, but not for any practical use, like planning, monitoring and certainly not for navigation.

Furthermore in the Landsat images only the major roads are partly visible. The smaller roads, tracks or paths cannot be seen; similarly most buildings and houses area not visible. Also for anomaly detection the low resolution is not sufficient. Therefore high resolution imagery is ordered and is scheduled to be processed.

Figure 8-2: The available VMAP0 data of Longa, showing the roads river and places.

Figure 8-3: Landsat 5 data around Longa, using the SWIR colour representation (R=SWIR, G=NIR, B=green).

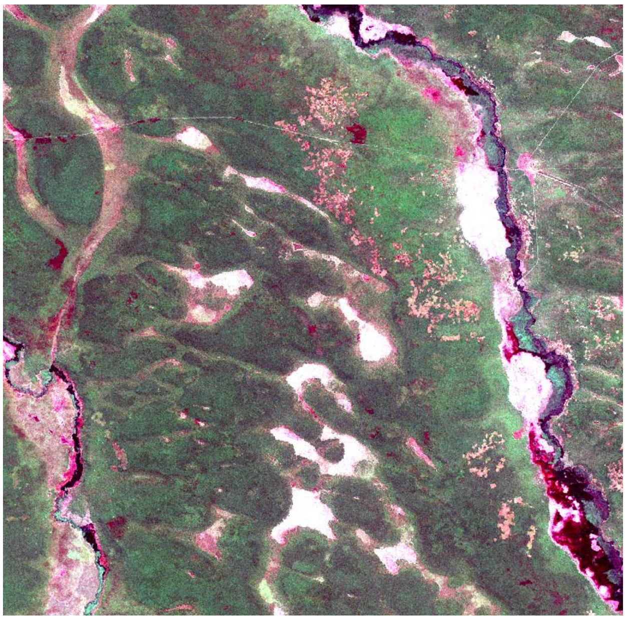

Figure 8-4: Landsat 7 data around Longa using the SWIR colour representation (R=SWIR, G=NIR, B=green).

9. INITIAL RESULTS

Using the existing and freely available imagery from Section 8 initial land cover classification has been performed. The land cover classification has, so far, only been performed on the Landsat 5 data set. This data set is pre-processed so that it can be ingested in the KIM system, using Erdas Imagine. The first step in this pre-processing is the layer stacking, since all bands were stored in separate GeoTiff images. For the layer stacking and display in KIM we chose the SWIR (short-wave infrared) colour representation with SWIR in the red channel, NIR (near infrared) in the green channel and green in the blue channel. This representation gives an image that is relative close to the true colour representation, but has more striking colours. So, the first three bands of the layer stack image are 7, 4 and 2. The other bands are stacked after that in the following order: 1, 3, 5 and 6; giving a total of 7 bands.

These layer stacking images are ingested in KIM. In this ingestion, one spectral and two texture features (at scale 1 and 2) are extracted. The original image is cut into image of 500 by 500 pixels. This is need so the user interface can easily display the image and resulting classification.

The KIM ingestion performs a pre-clustering based on the selected features. These clusters do not have any semantics attached to them. The semantic meaning is given in the user interface by giving examples and counter examples of pixels of a certain class (by means of clicking on the image). Using the pre-clustering, the system can quickly determine which clusters and thus which pixels have similar features. In this manner the user defines the meaning of certain clusters.

An example of the usage of KIM for the land cover of the Longa area is depicted in Figure 9-1. In the figure the jungle or forest is show in dark green, the short vegetation in light green, the bare soil in yellow and the river in blue. Unclassified pixels are shown in black. Obviously the classification can be improved by means of filtering, where pixels from one class fully surrounded by another class are re-assigned to the surrounding class.

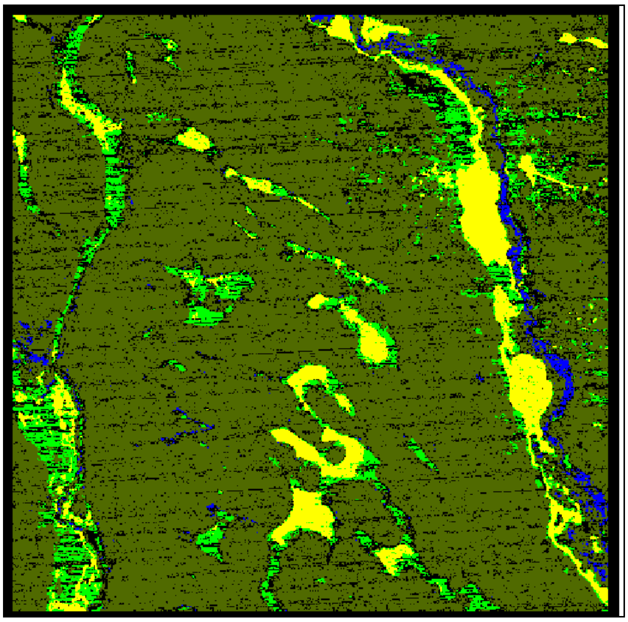

Figure 9-1: Classification results using KIM.

For comparison a similar approach has been followed by using unsupervised classification and re-labelling in Erdas Imagine. The results, see Figure 9-2, have been cleaned up using fuzzy clustering. The results are comparable to the approach using KIM. However KIM has better classification of the river and the forest. In both cases we were not able to distinguish between (apparently) agriculture area (near Longa) and either bare soil (like dry river beds) and light vegetation.

Based on the Landsat 7 data, we also performed a manual classification, see Figure 9-3. Here we only extracted the river, the roads, the air strip and some possibly marsh land. One thing that is noticeable is that the (suspected) agricultural areas around Longa seem to have changed and moved away from the settlement.

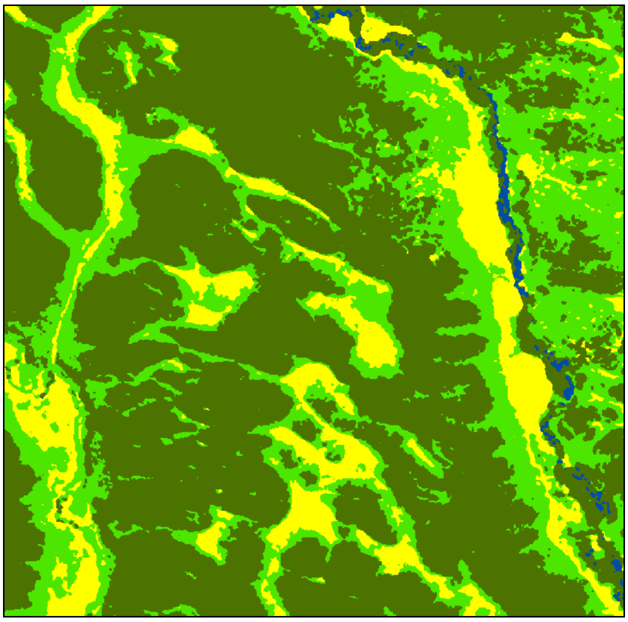

Figure 9-2: Classification results using ERDAS Imagine.

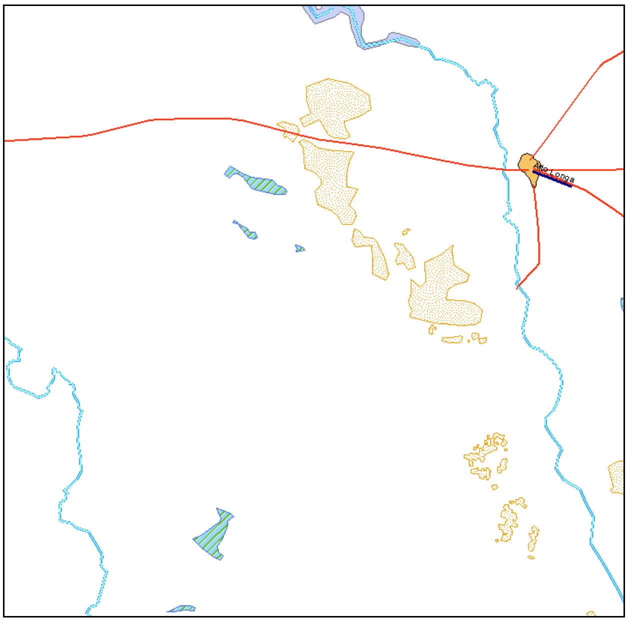

Figure 9-3: Manual classification of the Longa area, with in blue the river, in red the roads, in black the landing strip, in beige the agriculture areas and in striped blue the marsh lands.

10. CONCLUSIONS AND DISCUSSION

A versatile and unique architecture has been presented that allows the exploitation of a wide variety of data for the support of mine action and humanitarian action. The most important aspects of this architecture are:

- Wide range of data that is handled and integrated: from field survey to high resolution aerial survey imagery to satellite imagery.
- Close collaboration with ESA KEO allows future supply of data and usage of algorithms, through the service support environment.

Regarding the field trial area and the initial results the following observations are made:

- There is little known of the area of the field trial. This demonstrates the need for a information system to collect and provide the information for mine and humanitarian action.
- The land cover classification with Landsat 5 looks promising; however the agricultural area cannot be discriminated from bare soil or light vegetation.
- The land cover classification is a desktop study and depends on the interpretation of the image analysis experts. Field survey results are needed for confirmation and validation of the classification results
- Some of the needed geographical features (like roads, buildings and anomalies) cannot be extracted from the freely available satellite data. Therefore high resolution imagery is needed for the detection of the full road network.

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12. ACKNOWLEDGEMENTS

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