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FASALSoft - An ISRO software framework for crop production forecast using remote sensing data analysis

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Abstract: In India, the procedure developed under Forecasting Agricultural output using Space, Agro meteorology and Land based observations (FASAL) Project is now accepted as operational for making multiple in-season crop production forecasts. Till recently, the processing was done using commercially available software. SAC took the initiative to provide automation intensive software solutions by developing an in-house geospatial software solution for crop production forecasting with a mandate to build from only fresh developments and free and open source software. This effort has culminated into a geospatial software framework called FASALSoft. This paper brings out details on the software framework realised by amalgamating and adopting available open source geospatial tools and fresh software developments which can perform the required image processing and geospatial operations in an effective way for a national level crop forecast tasks using single date optical data, multi-temporal optical data for winter crops as well as multi-temporal SAR data for monsoon crops. This software is operational at M-NCFC, Delhi since June, 2012.

Keywords: FASAL, FASALSoft, Geospatial Computing, Image Processing, GIS, Crop production forecast

1. Introduction

Pre-harvest forecast of crop production is important for planning and taking policy decisions. In recent years, Remote Sensing (RS) and Geographic Information System (GIS) have been accepted as indispensable tools in the field of agricultural inventory. Use of RS data in making crop production forecast has been actively investigated in India and many other parts of the world (Navalgund et al., 1991; MacDonald and Hall, 1980; Hanuschak et al., 1979; Sharman, 1993; De Roover et al., 1993; Dadhwal et al., 2002; Parihar and Dadhwal, 2002). The aim of Forecasting Agricultural output using Space, Agro meteorology and Land based observations (FASAL) project was to use remote sensing data to produce crop forecasts from early in the season with regular updates as the crop season progresses so that the information can be used effectively in decision making. Space Applications Centre has developed a reliable methodology for State-District as well as National-state crop production forecasting under FASAL (Parihar and Oza, 2006; Oza et al., 2002 and 2006; Chakraborty et al., 2006) and demonstrated its utility / performance over past 8 – 10 crop seasons. The FASAL procedure is now accepted as operational and Mahalanobis-National Crop Forecast Centre (M-NCFC) has been established by the Ministry of Agriculture with a mandate to perform the operational crop production forecast using the FASAL methodology.

A need to have automated software package to perform the tasks of crop production forecasting using remote sensing data was felt as early as in 1992. Partial successes were achieved with the developments of CAPEMAN (Anon. 1994), CAPEWORKS (RRSSC, 1996) and SARCROPS (Chakraborty, 1999) packages. The CAPEMAN and CAPEWORKS were applicable for use of single date data analysis and SARCROPS could be used for only for RADARSAT ScanSAR data. These packages were semiautomatic and their developments used COTS (commercial of the shelf) digital image processing software and their tool kit. SAC took the initiative to provide indigenous software solutions for RS and GIS data processing and analysis by developing an in-house geospatial software solution for carrying out FASAL analysis with a mandate to build from only fresh developments and free and open source softwares (FOSS), but not any COTS. The software so developed has been named FASALSoft (Anon. 2009).

This paper brings out details on the FASALSoft framework realised by amalgamating and adopting available open source geospatial tools and fresh software developments which can perform the required image processing (notably georeferencing, registration, classification and aggregation) and geospatial operations in an effective way for a national level crop forecast tasks using single date optical data, multi-temporal optical data for winter crops as well as multi-temporal SAR data for monsoon crops. The software also enables to build crop yield models using correlation weighted weather variables which are used to forecast crop production (Moorthi et al., 2011; Misra et al., 2010 and 2011).

2. Background concepts

The basic concept of FASALSoft is to have a reliable and data dependent system for in-season multiple forecasts at different crop stages from sowing to maturity using information from different sources like remote sensing, meteorology and land observations.

Information on current season weather condition is used early in the season and repetitive acquisitions of remote sensing data from middle of the crop season till end of the crop season for condition assessment and production forecasting. There are two types of forecast namely 'State and District Forecast (SDF)' and 'National and State Forecast (NSF)'.

In conventional workflow of FASAL procedure, an analyst started the processing by displaying data, checking for coverages and quality of the data before proceeding to perform geometric and radiometric rectification by employing various processing techniques in a COTS environment. This was followed by transferring ground information of various land use land covers on to image, creating training samples, classifying the image and generating classification report. For analysis, analyst depended on COTS tool box and was forced to do housekeeping jobs manually. Analysts wanted to automate the georeferencing and multi date image registration procedures. There was also scope for computing area statistics automatically after classification. Analysts preferred to have a mechanism to store results in an organised fashion for later scrutiny. Scope was seen for automating the processes and maintaining information about files and folders comprising results. These operational concepts were developed in the first phase of the project, which also influenced the development team to decompose the entire system into four sub-systems namely FASAL ADMIN, ARCHIVE, COMPUTE and QUERY. The data archive and the status monitoring were to be managed centrally with regional administrators and chief administrator.

User characteristics

FASALSoft system design is based on user hierarchy of analysts with specific tasks assigned to them. FASALSoft user characteristics are presented in table-1.

Operational environment and its characteristics

- ✓ Each FAN will have a networked PC based work-station with a common FASALSoft Compute Module environment installed on it as shown in FASALSoft Hardware Architecture (Fig. 1).
- ✓ Each FAN PC will have sufficient disk space for simultaneously processing at least 10 AWiFS scenes.
- ✓ Each Regional FASAL Administrator will typically manage a geo-spatial data server covering an entire State.
- ✓ The central geo-spatial data server will hold the entire input and output data sets used by ALL RFAs and all the FANs attached to each of them.
- ✓ The FASALSoft Admin, Archive and Query Module environment for each RFA will be identical to that of CFA, except for the area coverage.

3. Tool set for crop forecast studies

It needs to establish a geospatial approach to rationalize a competent methodology for quantifying parameters of study theme. Primary data source for these studies are multi date satellite remote sensing data such as Resourcesat-1/2 LISS-3/AWiFS, Radarsat-2 ScanSAR/Wide-2 and RISAT 1 MRS data suitable for the target crops. The essential geospatial tasks to be performed on the primary data sets are a) georeferencing, b) multi date image registration, and c) supervised classification. In addition, there are other geoprocessing tasks that involve raster and vector data layers together. Therefore the tool set meant for crop forecast studies should include these functionalities. Multi date image georeferencing and registration is required to bring multi date images in to geometric confirmation before going for any further processing of multi date image layers together (Moorthi et al., 2012 a and b). Image classification is a crucial task which assigns a pixel to one of the pre-defined land cover classes (based on similarity) for which training area are available (Anon. 2012). Beyond this point, processing steps are related to aggregating pixels based on attributes and conditions. This paper mainly elaborates on the software building experiment rather than the geospatial tasks themselves.

The FASALSoft comprises of functions for spatial analysis based on vector and raster data sets, database queries, image processing, as well as conventional and innovative image processing algorithms. This will cater to the need of present requirement of the application specific modules and also pave the way for development of the future modules. In this regard the software should give the power to visualize the images, spatial data (raster and vector) geographically for standard analysis, images and provide all the tools needed to download the data, perform image processing, classification, aggregation and give suitable outputs in an effective manner, solve the geo-locational and attribute based queries, present the results of work in the form of publication-quality maps and create interactive displays that link reports, graphs, tables, drawings, and other elements to the data. FASALSoft process workflow is shown in Fig. 2.

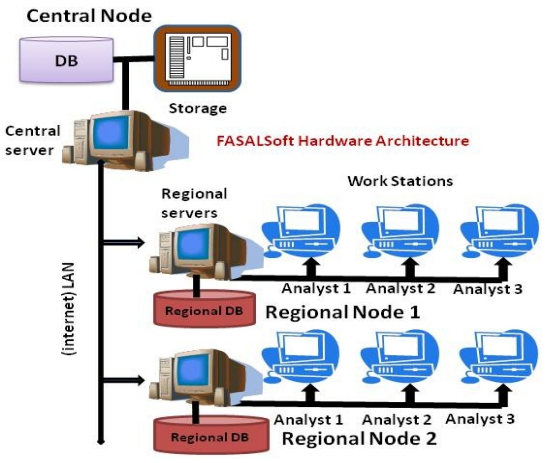

Figure 1: FASALSoft hardware architecture

Table 1: FASALSoft user characteristics

User	Description
CFA: Chief FASALSoft Administrator	A person who is the main administrator of FASALSoft system, who performs all operations related to administrating the central system (data fetching, user management, archive management, work flow management). One who initiates the FASAL processing for the current season by creating a work order. The work order will be split into regional work orders and assigned to regional FASAL processing centers. He/ She procures data, ingests them into master geo data server and manages the entire FASAL processing during a crop season.
RFA: Regional FASALSoft Administrator	A person who is the Regional administrator of FASALSoft system, who performs all operations related to administrating the regional system (data fetch, user, archive and work flow management). He/She belongs to a regional FASAL processing centre, where he accepts a work order generated for that work centre. He/She arranges data fetch into regional geo data server and converts work order into job orders for assigning to individual analysts for further processing. He/She has responsibility to deposit processed data and results into master geo data server.
FAN: FASALSoft Analyst	A person who is the FASALSoft Analyst. He/ She belongs to the regional FASAL processing center and responsible for entire processing of a particular scene that has been assigned to him. After processing the scene he asks the RFA to check the accuracy of the processed output. Once he completes his current job he moves to next that may be already assigned to him.
FEU: FASALSoft End User	A person who is the end-user of FASALSoft system. He/She is a distinguished user who will view the results on line, query the system for results and reports.

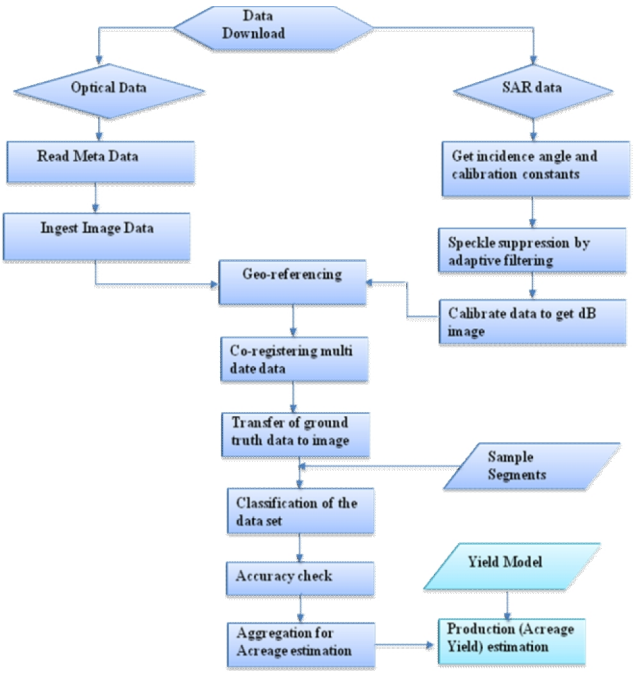

Figure 2: FASALSoft generic compute processes flow

FASALSoft architecture

FASALSoft is consisting of four major sub-systems

- ✓ Administrative System
- ✓ A Computing System
- ✓ One or more Archival Systems
- ✓ A Query System

Currently, FASALSoft solution runs on Operating System MS Windows 7 64 bit editions.

There are other sub systems which are relevant for dividing the work into sub tasks and achieve the intended task. FASALSoft has distributed application architecture (Fig. 3) with a common user interface and integrated applications. In specific, FASALSoft ADMIN/QUERY is a web application; an application delivers itself to the users over a network. Client/server architecture is well adapted in designing a web application. Web browser is the most common platform on which a client program is running.

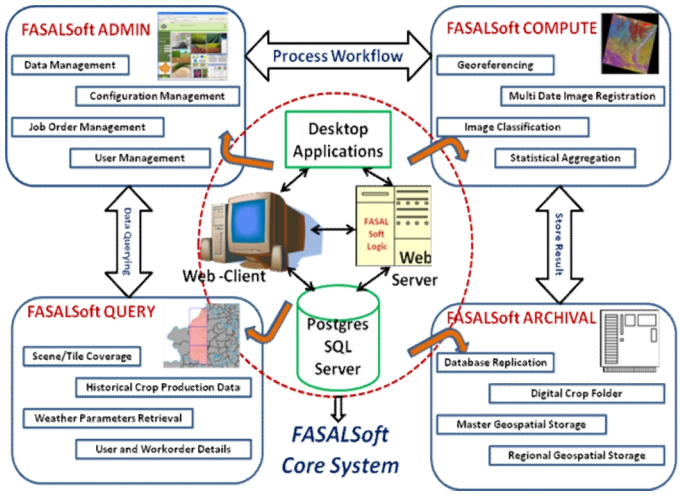

Figure 3: FASALSoft architecture

Composition and decomposition of FASALSoft application into sub systems, the technology choices are meant to connect crop scientist goals to what is built as FASALSoft. FASALSoft follows a minimalistic architecture philosophy. The architectural decisions were merely to go with the ability of the team. FASALSoft is a geospatial analysis tool box with a suggestive workflow implemented as a web application. The various tools and features available in FASALSoft package is shown in Fig. 4.

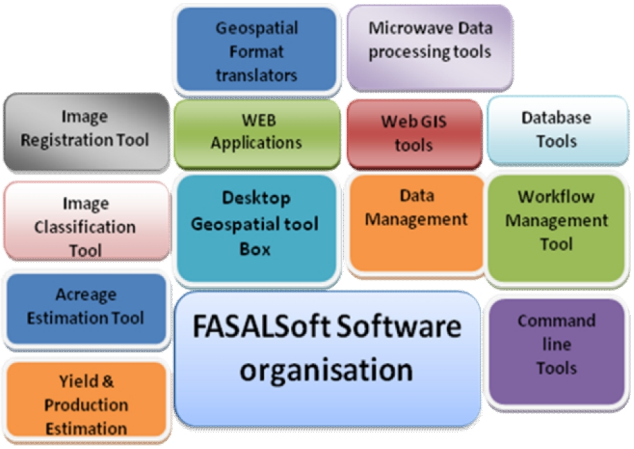

Figure 4: FASALSoft tools and features

4. FASALSoft components

FASAL ADMIN Module is a task execution and management layer built to facilitate image analysis task initiation and guiding workflow to achieve indented task. FASAL ADMIN has CFA/RFA/FAN components. While the CFA/RFA web modules provides functionalities to configure parameters for processing, start a project, data import, define workflow, tracking and monitoring functions, Report generation, Database, archive interface, administer the clients by way providing user authentication, the FAN components provide an interface on the FAN W/S to the main RFA. Also FAN web modules facilitate direct data transfer to local workspace. FASAL ADMIN functionalities no way hinder, restrict and modify the autonomous functionalities of the existing FASALSoft desktop tools at all workstations. Overview of FASALSoft web applications is given in Fig. 5.

User management

The first task was to identify the different users involved in the system and their role and responsibilities. Refer Table-1 for the users identified in the system.

Work order management

CFA initiates the FASALSoft workflow by giving year, crop and forecast type and number. A Master Workorder is created using these information and further split into regional workorders for the participating states for a particular crop. Each RFA further divides the regional workorder into scene or template based processing data units which can be allocated to a FAN, which is known as job order in the system.

Data management

CFA and RFA load the input data sets and sometimes partially processed data sets into system for FANs to carry out further processing. Each FAN analyses the data after fetching a local copy in his workstation that belong to the job order and uploads the processed outputs to RFA. RFA accumulates every FAN output results and uploads to CFA.

Process management

Workflow steps are divided according to the rank of the actor in the system. For example, major compute processes are all performed by FAN and aggregation step is with RFA. Every FASALSoft workflow contains a generic pattern and follows staff hierarchy. At top the workflow has CFA processes and it has two parts as pre-RFA and post-RFA steps. Next to CFA steps, RFA has two parts pre FAN steps and post FAN steps

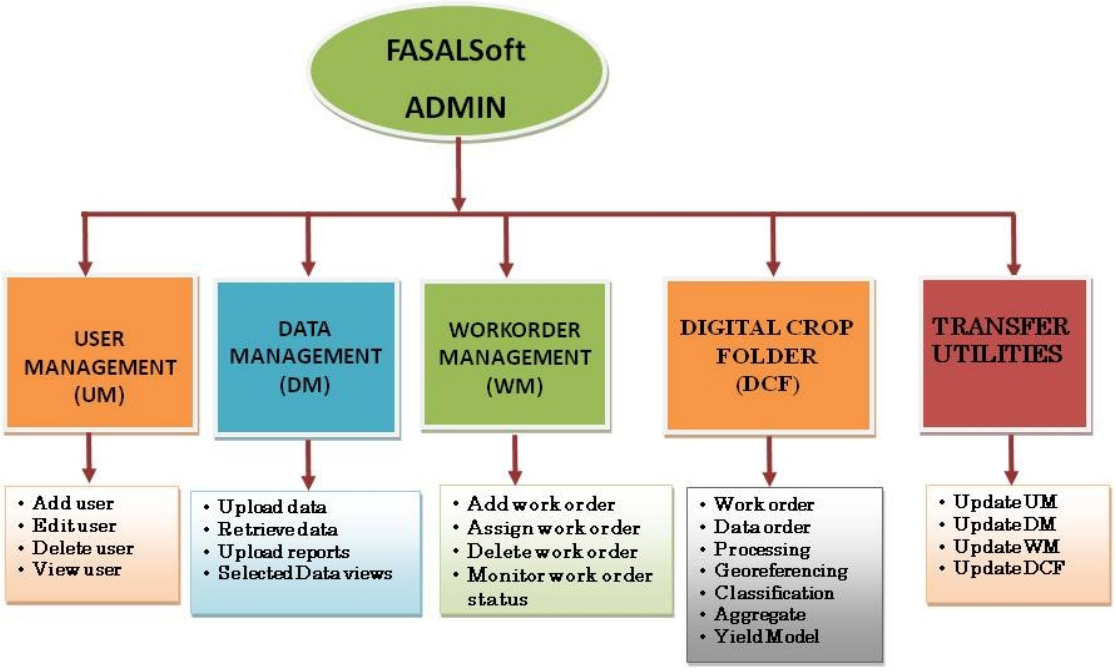

Figure 5: FASALSoft web applications

5. FASALSoft databases

FASALSoft is also a database centric application and has an elaborate database design mainly to manage details in geospatial analysis, work order generation and management, user management, database replication, and a unique database called digital crop folder.

The major databases are

1. CFA DATABASE (only one for the entire FASALSoft setup)
2. RFA DATABASE (one database per regional node)
3. Digital Crop Folder (results database)

FASALSoft has an elaborate database design to capture many parameters related to data sets, processing, workorders, users and results in systematic way so that they are available for further processing, knowing the status, generating reports and analysing the results. FASALSoft database design is shown in Fig. 6.

Database replication

The system is needed for RFA database replication system at the CFA end. Database Replication is a "master to multiple slaves" replication system supporting cascading and slave promotion. This system is intended for data centers and backup sites, where the normal mode of operation is that all nodes are available all the time, and where all nodes can be secured.

Digital Crop Folder (DCF)

FASALSoft workflow results in raster, vector and tabular outputs that are needed to be stored and queried for subsequent years. The processed information needs to be modeled and to be kept safely. The processed information in FASALSoft varies from metadata of the input data, crop calendar details, georeferencing information, classification output, and confusion matrix to say a few important details. All of the outputs need to be structured and kept in a database. Digital Crop Folder (DCF) caters to this need.

DCF captures all parameters, data details, and processing parameters and results specific to a Crop, Year, Forecast Type and forecast Number within FASALSoft software framework. The CFA digital crop database contains all the tables that are needed to populate the digital crop folder at Central FASALSoft Administrator level. While all metadata is stored in the database, the raster, vector, and graphics data will only be provided a link in the database. The actual datasets need to be accessed from the archive file system.

Weather/crop database

Meteorological data contains Meteorological sub division (MSDB) wise weekly information of weather parameters. Available weather parameters are rainfall, maximum and minimum temperatures. Historical crop data (acreage, yield and production) are taken from Government of India data sources.

The FASALSoft software takes care of issues ranging from handling data sizes, formats, data types, building process chains to taking advantage of batch processing capabilities and to put software processes in an integrated framework. Important items used and complexities handled in FASALSoft development are summarized in Table 2.

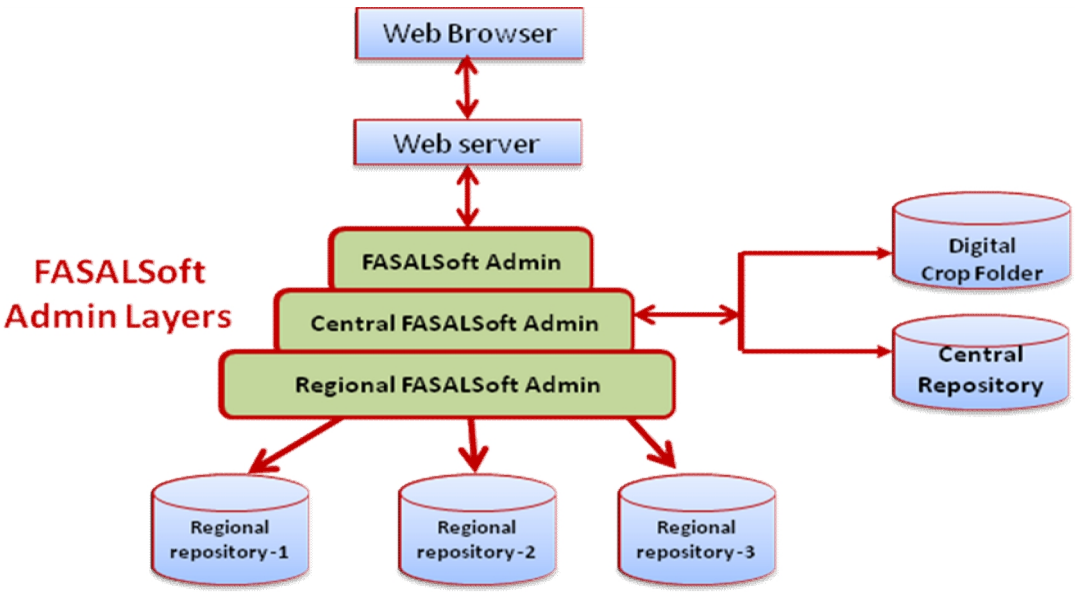

Figure 6: FASALSoft databases

Table 2: Important items used and complexities handled in FASALSoft

Item Description	Items used and complexities handled
Integrated software framework	National level geospatial data processing and publishing application. Distributed software & automation-intensive system for Forecasting Agricultural output using Space, Agro-meteorology and Land based observations.
Desktop Application	Geospatial data processing and analysis suite
FOSS used	GDAL/OGR, SHAPELIB,PSQL,GEOTOOLS
SAC Software Libraries for FASALSoft Processing	Map Projection Library, Resampling package, Georeferencing tools, model estimators, least square fit, feature extractors, image registration suite, image classification tool, microwave data preprocessing, registration and calibration packages, statistical aggregation, regression models for yield and production estimation utilities.
Real Time Database	Distributed Database Clusters with more than 75 tables
Remote Sensing data sets	Optical : Resourcesat-1/2 LISS-3, AWiFS,
	Microwave: Radarsat-2 ScanSAR and WIDE-2; RISAT MRS
Data Formats handling	More than 10 geospatial data formats (CEOS, GEOTIFF, and HDF etc.)
Configurable Web Workflows	Variable data units processing, workflow data modeling, workflow scripting
Subject Areas of expertise needed to realise FASALSoft	Optical & microwave Remote sensing data preprocessing, image processing, GIS, Computational Geometry, geoprocessing, Datum , Map Projections, linear algebra, non linear optimization, object oriented design, C, C++, JAVA, Machine learning algorithms, regression, curve fit, statistical procedures, Web application architecture, Real Time Database design, J2EE

6. Conclusion

FASALSoft is a "distributed & automation-intensive" and customized software system for performing sequence of steps based on FASAL methodology developed by SAC - ISRO. It is an in-house developed software solution to streamline the work flow in a processing chain in a common user environment for distributed operations with a central management provision and online archival and query options. FASALSoft geospatial processing toolbox has a framework with a common workflow comprising data preparation, analysis and presentation tasks taking raster and vector data of different size, data type and accuracy as inputs. This software takes care of issues ranging from handling data sizes, formats, data types, building process chains to taking advantage of batch processing capabilities and to put software processes in an integrated framework. National State Forecasts for various crops in the year 2012 -13 have been done with the use of FASALSoft. The software keeps track of all data used and results generated in each crop season. Improvements expected are in timeliness and performance characteristics such as speed, throughput and volume.

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