Six Years Operational Processing of Satellite data using CATENA at DLR: Experiences and Recommendations

Erfahrungen und Empfehlungen aus sechs Jahren operationeller Verarbeitung von optischen Satellitendaten mit CATENA am DLR

Thomas Krauß, Oberpfaffenhofen

In this article we present the fully automatic processing system CATENA developed at DLR together with experiences and suggestions from six years of operational use. CATENA has been developed since 2007 as a multi-purpose, fully automatic processing system for optical satellite image data. It is used in many projects for operational mass-processing and re-processing of similar satellite data for large coverages or long time-series as requested.

■ *Keywords: optical satellite data, processing chains, operational processing, CATENA*

In diesem Artikel stellen wir das automatische Prozessierungssystem CATENA des DLR zusammen mit Erfahrungen und Empfehlungen aus sechs Jahren operationeller Anwendung vor. CATENA wird seit 2007 als universelles Prozessierungssystem für optische Satellitendaten entwickelt und in vielen Projekten operationell angewandt, um den vermehrten Anforderungen nach (Re-) Prozessierung vieler gleichartiger Satellitendaten einer großen Abdeckung oder für Zeitreihen über lange Zeiträume gerecht werden zu können.

■ Schlüsselwörter: Optische Satellitendaten, Prozessketten, Operationelle Prozessierung, CATENA

1 Introduction

The uniform pre-processing of an increasing amount of satellite data for generation of complete coverages e.g. of Europe for one time or of time-series for one location covering many years is requested more and more. Such requirements demand for the processing of huge amounts of data which can hardly be handled manually. Thus, a fully automatic pre-processing environment was developed at the Remote Sensing Technology Institute of DLR in Oberpfaffenhofen since 2007. This processing environment named CATENA was designed for uniform, automatic general purpose processing of huge amounts of optical satellite data of similar type (e.g. same number of channels or processing level).

In this report we present the concept of the processing system, the framework and the decomposition of processing requirements into processing modules and processing chains. We give some examples for general purpose and project specific processing chains and provide an analysis of the performance and quality of the results. Finally the experiences of six years of operational processing and suggestions derived from them will be given.

The origin of CATENA was a system developed at the DLR Remote Sensing Technology Institute in 2006 for the ESA project "GMES Fast Track Land Services Image2006" (see e.g. Müller et al. 2008). This task included the preprocessing and ortho-rectification of two yearly coverages for 38 European countries of about 3500 IRS-P6-LISS3 and SPOT 4/5 scenes with accuracies below 1 ground sampling distance (GSD, here: 20 m). In addition a manual quality assurance of the images and delivery in one European and all national projections in only half a year was required (see Figure 1). Such huge amounts of data could no more be handled manually and so a fully automatic pre-processing environment had to be developed. The processing environment named CATENA was designed for uniform, automatic, general purpose processing of huge amounts of optical satellite data of similar type. The system was certified following the ISO9001:2008 standard in 2012. CATENA is based on the modular image analysis system XDibias which has been developed and still extended and improved at DLR since the late 1970s for scientific processing of satellite imagery. In this context e.g. high precision image correlation and ortho-rectification software was available for use in CATENA.

2 Preliminary Work

The processing system CATENA is based on the DLR developed image processing system XDibias (Triendl et al. 1982). XDibias is a collection of more than 300 modules for image processing tasks ranging from simple geometric transformations to complex radiometric adaptions and geographic manipulations.

In the frame of the ortho-rectification of two full European coverages for ESA project "GMES fast track land service 2006-2008" a system for this purpose was developed at DLR (Müller et al. 2008). This system implemented already a first kind of distributed automatic processing chain. In Müller et al. (2012) the method for the automatic ortho-rectification used in CATENA is explained in detail.

Almost every agency or company involved in remote sensing has built up mostly automatic processing chains for processing of their data. Examples are the Calvalus system of Brockmann Consult (Brockmann Consult 2014) or the processing of SPOT images (Spot Image 2014). But generally most of all these existing systems are tuned for the one satellite system they were developed for (e.g. Calvalus for the processing of EnviSat data like Meris or AATSR, the system of SPOT Image for SPOT images, and so on). In contrast CATENA was designed from scratch as multi-sensor and multi-purpose general framework to handle any type of remote sensing data ranging from aerial imagery with ground sampling distances of decimetres up to environmental satellites with GSD in the kilometer range.

3 System Architecture

The architecture of CATENA is shown in Figure 2. It is build up as a multi-purpose multi-chain processing-system allowing the specific definition of processing chains for many purposes or even for individual projects. The architecture was designed to run CATENA distributed on many nodes across a network, to minimize the repeated transfer of huge image data sets ("software to data"-principle). CATENA consists of three parts: The modules, the chains and the so-called framework. The processing chains are composed of modules which in turn wrap the software carrying out specific tasks ("Tool") as shown in Figure 2, top left.

The framework consists of a database storing the tasks and the software for ingestion (technical term for "submission") of tasks into this database, the scheduling and execution of the processing chains and of the corresponding modules and tools. One task consists of one or more input products and a defined processing chain which is requested for processing these product(s) together with optional task-specific processing parameters.

The chain is a simple definition of the order the required modules are executed and how they are chained together with input- and output-products. For an example chain-file see Figure 8. A module is a small script encapsulating a so called tool. The module provides standardized interfaces, reads and converts images and metadata to the format the tool needs, executes the tool and converts the results back to the standardized interface formats for usage with subsequent modules. The tool, finally, is a piece of software doing the scientific or administrative job of the module. Examples are the extraction of reference data corresponding to input data or the calculation of an ortho-rectified image or a cloud mask. For a concise definition of the CATENA components see Figure 3.

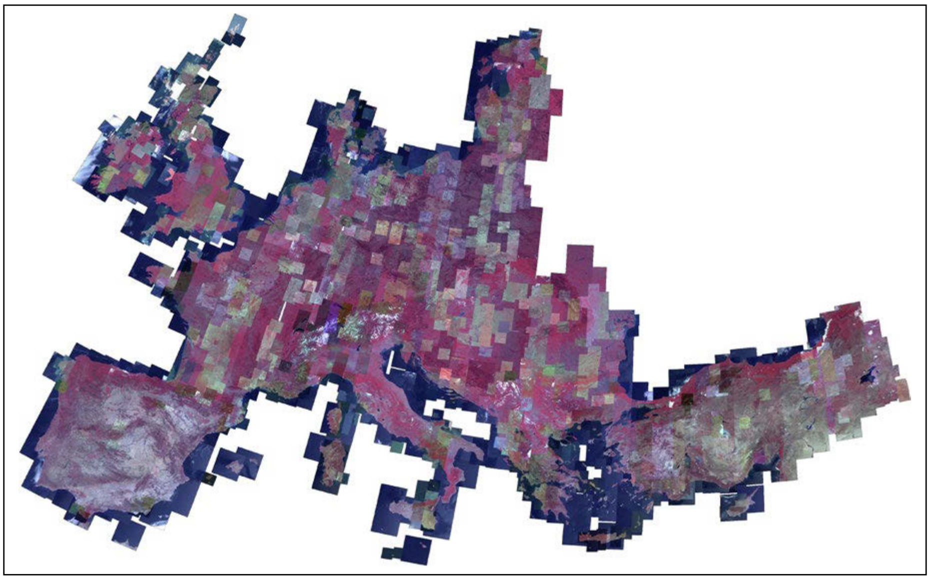


Fig. 1: European coverage Image2006 – 3500 IRS-P6-LISS3 and SPOT 4/5 satellite images of 38 European countries preprocessed and ortho-rectified to European and national projections in half a year

As shown in Figure 4 CATENA can be separated to two main parts: the Central Control Part and the Distributed Execution Part. The central control part contains the task database, the module repository, the chain definitions and also the web-interface. This part is necessary only once for a full CATENA system. In contrast the distributed execution part can be replicated on as much processing nodes as wanted. This part is responsible for the execution of a processing chain for a specific task. On each of the nodes running a distributed execution part a Task Scheduler fetches the next queued task from the database of the central control part, locks it and runs the task using the requested processing chain. The Task Execution in turn reads the chain file and executes the modules in the listed order with given parameters and input-/output-data.

The framework includes a web-interface as shown in Figure 5 to insert and control the queued, running and finished or erroneous tasks. The scheduled tasks may be shown as an overview list with many details of the actual processing or as an overview map.

For each of the tasks the status is easily visible in the web-interface. Each task is also assigned to an operator who ingested the task. Also individual tags (e.g. project

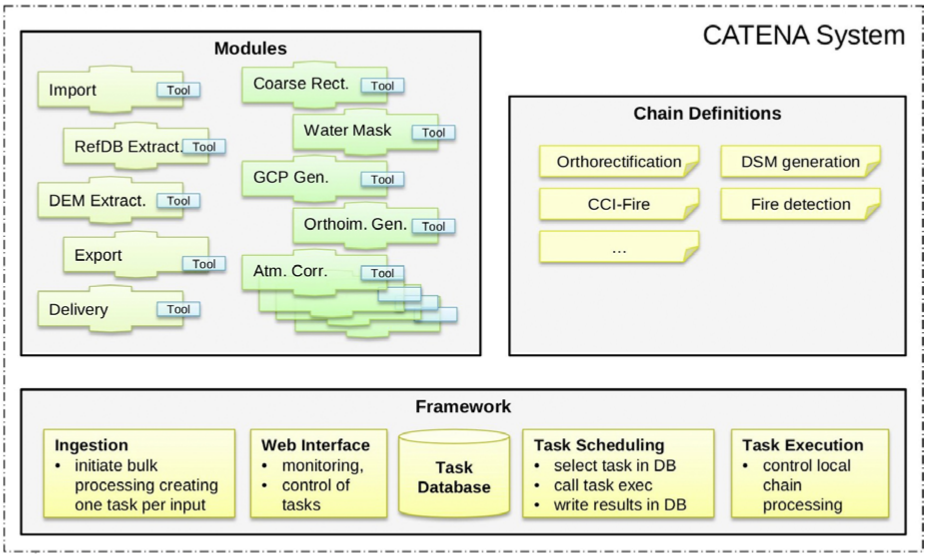


Fig. 2: Definitions of the Components of CATENA

Fig. 3: Two main CATENA parts: Central Control Part and Distributed Execution Part

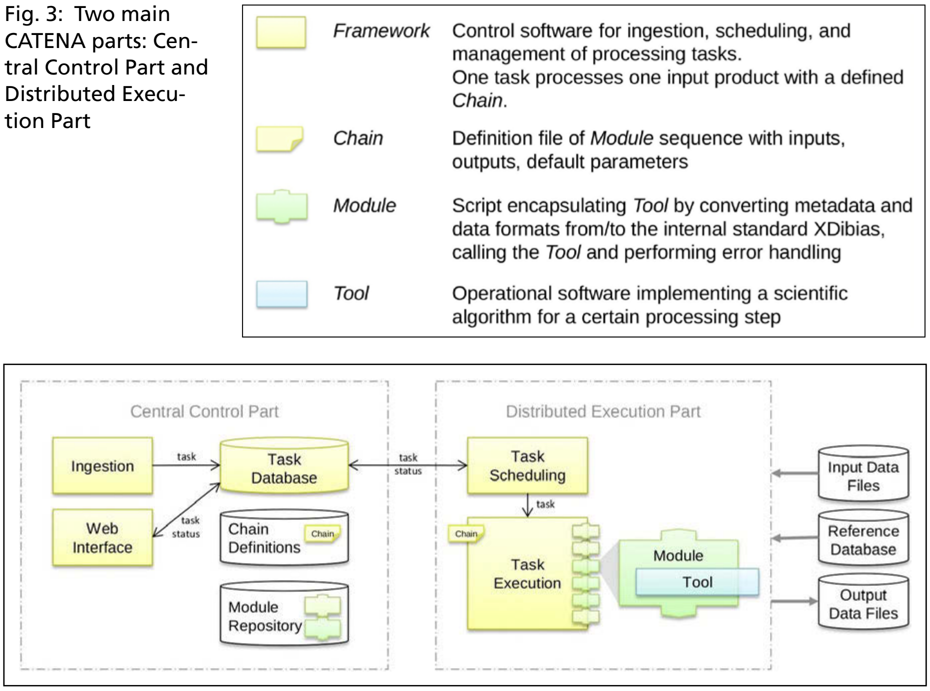
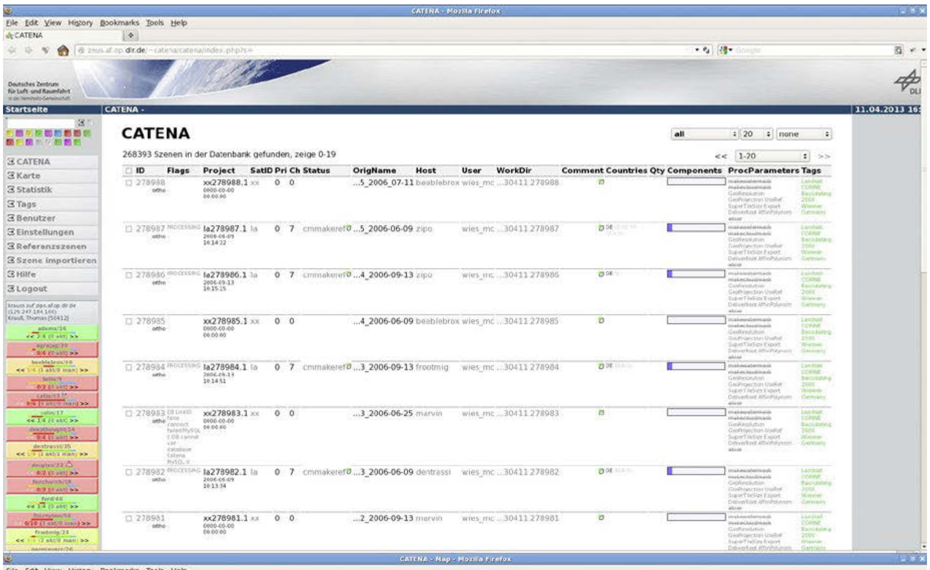


Fig. 4: CATENA web-interface to control the task database



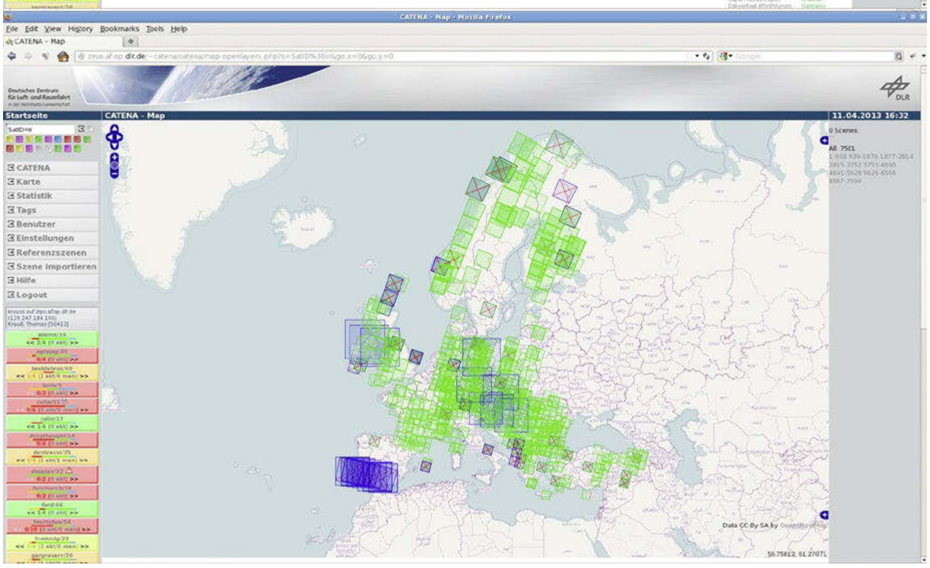


Fig. 5: Typical processing procedure in CATENA

names) may be provided to find specific tasks. A task has four states: *Queued* (input-data (OrigName), chain, user and requested processing parameters), *Running* (below Status the module actually executed is shown, under Host and WorkDir the node (Distributed Execution Part) running the task actually is shown), *Error* (below Status the module which drops the error is shown), *Done* (all fields are filled, Host/WorkDir are emptied again, under Flags "DONE" is shown).

In Figure 5 the web-interface also shows the nodes (Distributed Execution Parts) involved in the processing grid in the left bottom part. A host shown in green is free for new tasks. Yellowish green: the host already processes some tasks but has still free capacities. Orange: the host is fully loaded with CATENA tasks. Red: The host is disabled for processing in CATENA. For each host the number of cores is shown beneath the number of cores assigned for use with CATENA. Also small signs show if the host does not respond for a longer time or if the storage is full.

Figure 6 shows a typical processing procedure in CATENA. An operator ingests a new task to the task database on the central control node. In turn, each of the processing nodes queries the database for a new task (Task Scheduling) or a task ready for continuation already existing on this node. As many tasks as cores are enabled for use with CATENA on this node may be run in parallel. If one task is queued it will be locked and the processing chain requested in the task will be executed by the Task Execution on the input data. All work is done in a local workspace on this node (listed in the web-interface as WorkDir). The first of the module of a chain is normally the import which converts the proprietary satellite data formats of the providers to the standard interface format used throughout the processing chain. For converting proprietary Level 1 satellite data together with all needed metadata a large amount of import modules exist already for e.g. Landsat, SPOT 3/4/5 HRG/HRS/Vegetation, IRS-P6 LISS3/AWiFS, Cartosat, ALOS AVNIR/Prism, Landsat, RapidEye, Formosat, KompSat, DMC, ERS/EnviSat ATSR2/AATSR/Meris, Modis, Ikonos, GeoEye, QuickBird, WorldView, ZY-3, Pléiades. Level 1 satellite data as used in this context consists of coregistered and radiometrically calibrated bands of image data. The required import procedure will be chosen automatically. The last module in the chain is normally the export creating the requested results. The processor system uses for exporting the results the GDAL (Geospatial Data Abstraction Library, GDAL 2014) system to create output in many established geocoded image formats (e.g. GeoTIFF, BSQ, JPEG2000, HDF, netCDF, . . .).

4 Examples

4.1 Ortho-Chain

As first example the standard ortho-processing chain as shown in Figure 7 will be described. This is the standard pre-processing chain for all optical Level-1 satellite data. After importing the proprietary Level-1-satellite-data a section of a reference image database covering the area of the satellite image is fetched. An image matching procedure generates a list of conjugate points between the satellite image and the reference image which can be used as ground control points (GCPs) since they bear the exact geographic coordinates from the reference and the image coordinates from the satellite image.

Using the best subset of these GCPs the physical sensor model of the image can be corrected. Applying this corrected sensor model to the satellite data and projecting these data onto a reference DEM (digital elevation model, also extracted from an existing database) yields the correct ortho-rectified image in the requested output projection and resolution.

Additionally a cloud- and watermasking procedure, as well as an atmospheric correction of the data using ATCOR (Richter et al. 1990) will be applied afterwards. The fully automatic processing chain allows also the insertion of an optional quality check step in which an operator is requested to do the manually quality check of the results. Only after acceptance, the delivery process of the results will happen. If the quality check fails the operator can change processing parameters (e.g. measuring GCPs manually) and restart the processing at any step.

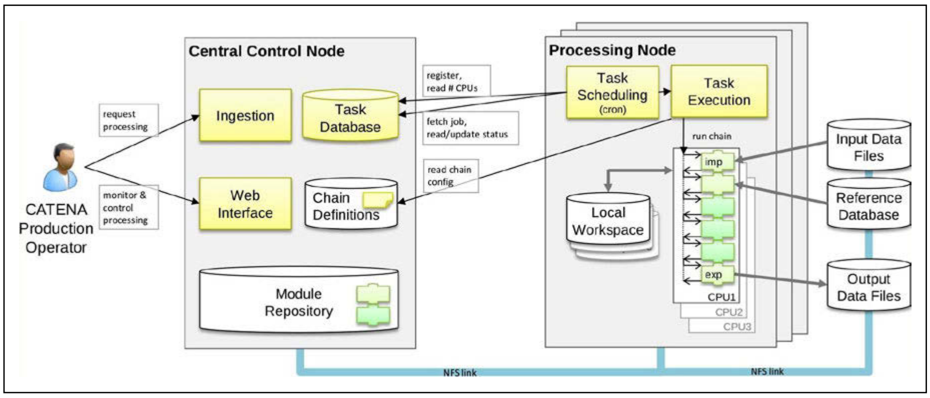


Fig. 6: CATENA ortho-processing chain

A typical chain file is shown in Figure 8. The chain consists of settings of standard parameters (in the example one main parameter "Export" listing all requested images which should be exported for default) and the chain itself. The chain is a list of modules together with the input data required for each module and the resulting output data. Each module can have any number of inputs. These do not have to be only images. Any file can appear as input. The module is only executed if all needed inputs exist. After execution the module creates the listed outputs which are mostly used as inputs for subsequent modules. The output, module and input are separated by colons (":"), each input and output file are separated by commas (",").

The Task Execution takes this simple chain description and generates from it the JobOrder.xml file as described in the Generic IPF Interface Specifications (ESA 2007). Each module is started with exactly one argument – this JobOrder.xml file. From this file the module fetches all information it needs: Its processing parameters, the input and output files. Afterwards the module executes the embedded tool for each of the inputs to generate the required outputs.

If an error occurs the module will exit with a non-zero exit code. The Task Execution will fetch this error-code together with all output of the module to an information log, which can be inspected by the user. In the stand-alone version of CATENA this information is fed to the database, so the operator can easily see which module for which task failed and what were the outputs of the module, which in general should contain a meaningful description of the error which occurred. In this framework also the runtime for each module is recorded and in the web-interface the whole log-history of all modules executed for a specific task can be checked.

The ortho-chain is in operational use since 2008. The chain implements the import of more than 25 native satellite data formats as already described in section 3. The input data has to be Level-1A/B data. This means the delivered bands have to be co-registered correctly, a sensor-model (mostly orbit and attitude data or a generalized type like rational polynomial coefficients (RPC)) has to be delivered and the data has to be calibrated radiometrically.

The chain was mainly in use for the follow up projects of the above mentioned ESA projects Image2009

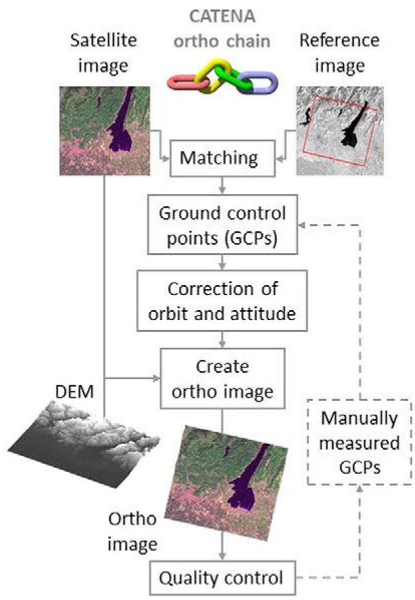


Fig. 7: Example chain file of the ortho-chain

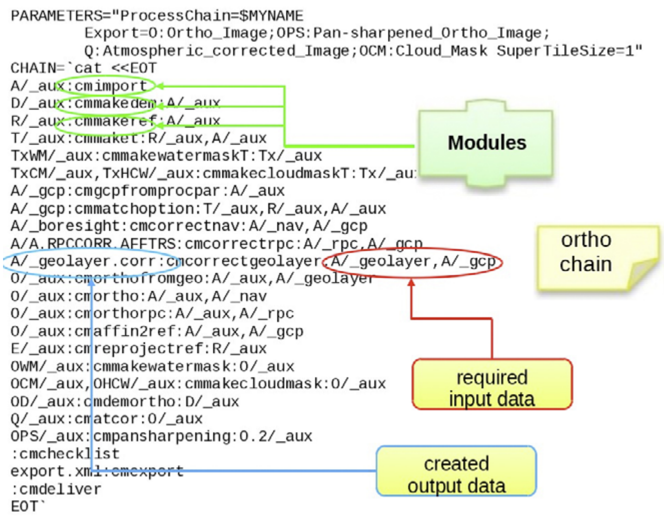


Fig. 8: CATENA multistereo-processing chain

and Image2012. For these projects the complete CATENA processing system was licensed to EuroMap in Neustrelitz who operate the European receiving station for the indian IRS satellites. In these projects two coverages of 38 European countries composed of IRS-P6-LISS3 and SPOT4/5 images with ground sampling distances (GSD) of about 20 m have been created. As reference for automatic selection of the ground control points (GCPs) and independent control points (ICPs) the previous coverages (for Image2009 the coverage from Image2006, for 2012 the one of 2009) were used. So the images as well as the references had the same GSDs. For each scene about 600 of the best points resulting from the matching process were selected to determine the correct sensor model parameters and ortho-rectify the data. The remaining (mostly somethousand) ICPs were used for quality assurance. The RMSE from these points give mostly values of about 10 m or half the GSD. In general the accuracy of the ortho-chain can be expressed as:

RMSE=max{GSD_data,GSD_reference}/2

The ortho-chain was used in the last five years for successful processing of already about 15.000 satellite image scenes.

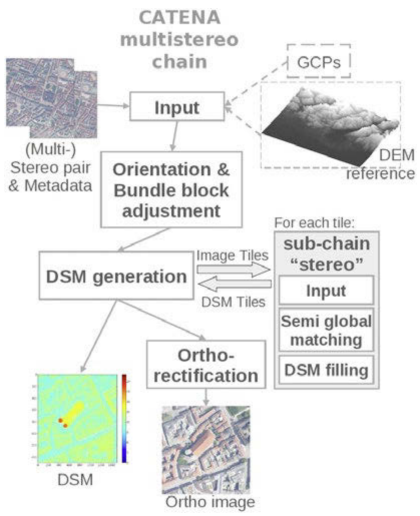


Fig. 9: Quality of multistereo-DSMs; left: ortho image of area around the central station in Munich, DSMs generated in the area of the Munich main station from WorldView-2 images using two images with 24° and 12° stereo-convergence-angle or three or all four images in parallel for the DSM generation. Using narrower convergence angles or more scenes reduce the occlusions (areas not visible in two or more images, shown in blue) drastically.

4.2 Multistereo-Chain

As second example we like to present the so called Multistereo-Chain as shown in Figure 9. This chain is used for the creation of digital surface models (DSMs) from two or more (aka "multi-") satellite stereo-images of the same region of the world.

The multistereo-chain starts with reading Level-1-A/B optical stereo satellite images. All of these images are bundle-adjusted to correct the sensor models relatively. Afterwards the input images are tiled and overlapping pairs of tiles are fed to the sub-chain "stereo". This chain does the calculation of the DSM of a given pair of images using the semi-global-matching (SGM) method (d'Angelo and Reinartz 2011, Hirschmüller 2005). This sub-chain processing is done by an automatic injection of new tasks for each of the tile-pairs into the CATENA task-database. The task-scheduling does afterwards the automatic distribution of these many small jobs over all available machines. The main task executes in the mean time only a module waiting for finishing of all sub-jobs.

After the creation of all tiled stereo-DSMs these will be collected, fused to a full DSM and optionally filled using a provided DEM. After this DSM creation step all input images will be ortho-rectified using this DSM and exported together with the DSM and some quality-layers.

The multistereo processing chain is operational since 2010. Also a more specialized version for stereo imagery from the Indian Cartosat-1 is licensed to EuroMap in Neustrelitz for the generation of a DEM with a GSD of 5 m for whole Europe (Euro-Maps 3D, 2013). The multistereo chain allows the fully automatic generation of high quality DSMs from a variety of high resolution stereo sensors like ALOS-Prism, SPOT-HRS, Quickbird, Ikonos, WorldView1/2, GeoEye, Pléiades or the Chinese ZY-3. Using this chain already nearly 2000 high resolution DSMs and associated true ortho images were produced. The experiences based on these huge amount of test cases show that best cost-benefit ratio can be achieved using in-orbit triple stereo imagery with one nadir and two scenes acquired with off-nadir angles of plus/minus ten to twenty degree (see Figure 10).

4.3 Other Processing Chains

There are many more processing chains ranging from more general chains like the ones mentioned above to specific processing chains for specific projects. Examples are shown in Tables 1 and 2.

5 Distributed Processing

The CATENA task scheduling framework is based on a distributed infrastructure of processing nodes. The system was created to utilize unused computing capacities of existing personal workstations running Linux CentOS-5. For each of the four- to eight-core systems available in the department each of the users may give some of the not needed cores free for CATENA processing (cf. Figure 5). A cronjob on each workstation (processing node) implements the Task Scheduling. This will check every 10 minutes the main database for new or restarted tasks, fetch one or more of these tasks for the processing node and executes the Task Execution for each of them.

To integrate a new workstation as processing node to CATENA just the creation of a local working directory (e.g. /Catena) with access for a functional account "catena" and access to the NFS shared home-directories and reference-databases is needed. Afterwards installing the cronjob for the Task Scheduling on this machine will do all other tasks: On the first request for a queued task the scheduler will detect that the machine is not yet registered in the Hosts database, it will query the capacities of the machine (cores, disk-space, memory), create the new Hosts database entry for the machine and activate automatically all minus one cores for usage in CATENA.

The distributed processing is optimized for minimal data transfer. Usually only the first module executed by the Task Execution – cmimport – will fetch the original data from any storage place in the network or via ftp. All processing is done in a local workspace on the machine. Other modules like the get-DEM or get-reference will also request data from reference databases over the network. But these data are normally relatively small. At the end the cmdeliver module will put the created export data set again on any defined network or ftp location. Further data transfer optimization will be possible if e.g. original data is stored directly on a processing node and during the task injection a specific host is assigned directly to the task associated with these data. But such an approach will disable the automatic Task Scheduling for this task, since the task is bound directly to a defined host.

6 Experiences from Errors and Recommendations

An analysis of the most frequent errors encountered in the last six years is shown in Table 3. This analysis has been done on over 270.000 scenes processed from 2007 to 2013. All of the errors did get finally solved automatically or by an operator. If the first scenes of a sensor passed the requested chain and optional processing parameters are tuned, in general about 90 to 95 % of all scenes pass the automatic processing without any manual intervention.

The most frequent error occurs in the atmospheric correction using the common tool ATCOR. Since this tool is written in IDL and needs a license for execution often the request of a processing node for a floating license fails and the module drops this error. For automation a cronjob checks regularly all errors regarding cmatcor for a log-entry containing a message regarding a missing license. In this case the error is just cleaned and the Task Scheduling will restart the Task Execution at this module again.

The second most frequent errors are related to the image-to-image-matching (cmmakegcp and cmmatchoption). If the input scene and the requested reference database does not fit quite well none or only few GCPs may be found and the internal (very rigid) quality check of these modules will drop an error. Mostly this is due to a scene containing much clouds or water in large areas of the scene. In such cases an operator has to decide if the found GCPs are good enough for further processing and may overwrite the rigid quality criteria. There are also cases

Fig. 10: CATENA system architecture

Chain	Purpose
ortho	Ortho-rectification of general optical satellite Level-1-data
multistereo	DSM-generation from (multi-) stereo imagery
isurf	Derivation of impervious surface areas from multispectral data
atcor	Atmospheric correction of multispectral optical satellite/aerial data
bundlerad	Radiometric bundle-block adjustment

Tab. 1: Examples for general purpose processing chains

Chain	Purpose
image20xx	GMES fast track land service Image2009/12
ccifire	Preprocessing for ESAs CCI Fire Disturbance (Günther et.al., 2012)
gioforest	Preprocessing for GMES Initial Operation Forest
p5	DSM-generation for Indian Cartosat-1 (IRS-P5) for whole Europe

Tab. 2: Examples for project specific processing chains

%	Module	Reason
28	cmatcor	IDL License missing
17	cmmakegcp	None or too few GCPs found
15	cmchecklist	Manual quality check failed (e.g. too much clouds in scene)
12	cmmatchoption	Matching failed (e.g. too much clouds, water, ...)
8	cmmakeref	Requested reference data does not cover scene
8	cmimport	Error in input data (e.g. wrong path, not readable, …)
5	cmmakedem	Requested reference DEM does not cover scene
3	cmdeliver	Requested deliver directory full or not writeable

Tab. 3: Most frequently errors occurring during processing; the module names are the actually implemented IDs from CATENA

where big land cover changes between the reference and the current scene allow no more automatic matching. Starting a new processing with new sensors or new reference sensor may also lead to such errors until a good fit of correlating bands and resolutions is defined.

All remaining errors (cmimport, cmmakeref, cmmakedem, cmdeliver, ...) are due to wrong operation of the system. Mostly input data is not readable, wrong paths are given or output directories are full. Also the references which should be used for cmmakeref and cmmakedem may be given. But then it is in the responsibility of the user to request databases covering the scenes which should be processed. The fully automatic processing strongly depends on the quality of input and reference data.

Analyzing the errors leads us to the following experiences:

- No software needing licenses should be used in modules/tools
- For each new sensor a new import module is necessary – the development of such an import may need from 1 day to several months (if the documentation of the sensor is incomplete or contradictory)
- The chains rely on standardized and complete data – wrong input will lead definitively to errors. Often incomplete or wrong inputs occur if data is delivered on non-standard ways like rapid delivery e.g. in the International Charter on Space and Major Disasters (Charter 2013)
- A strict and simple standard interface for all metadata and image data between modules is strongly required
- Training of operators is still necessary
- Checks of input/output storage areas should be done
- Checks of validity of requested references or parameters should be done
- If an error occurs a meaningful instruction what to do should be given to the operator
- Fully automatic processing systems like CATENA are only useful in processing mass-data of the same sensor(s)
- Often disk-space and network-capacity are the most limiting factors

7 Conclusions and Outlook

In this article we presented CATENA developed at the Remote Sensing Technology Institute of DLR as a typical processing system for mass-data from optical satellites. The system allows the definition of multi-purpose processing chains executing modules with common interfaces. These modules encapsulate the scientific or organizational tools. Typical processing chains are the presented ortho-rectification chain or the multistereo-DSM-generation chain. Actually more than 25 proprietary sensors ranging from ground sampling distances (GSDs) from 1 km like AATSR or SPOT-Vegetation to high resolution sensors like IRS-P6 or SPOT down to very high resolution sensors with GSDs of 1 m and below like WorldView-2, GeoEye or Pléiades are implemented. An automatic Task Scheduling and Task Execution utilizes unused capacities of standard workstations for efficient background processing. The experiences from six years of processing of more than 270.000 scenes leads to the main recommendation for such systems: The best application is mass-processing of similar input data, e.g. for creating large area coverages like in the Image2009/2012 projects or consistent time series from the same sensors. Also the experiences show that one strictly defined smart and simple interface covering all necessary image- and meta-data for the whole processing chain must be used for all processing module to guarantee interoperability of all modules. Furthermore licensed software should be strictly avoided to prevent the system from errors due to missing licenses. But the main conclusion is that in spite of such an automatic system still experienced operators are required. CATENA was certified following ISO9001:2008 in 2012. Further developments will include more thematic processing chains and more user-friendly instructions what to do if an error occurred. Also continuously new sensors will be inserted, old modules extended and new modules developed to fill up the tool-box of knowledge.

References

Brockmann Consult, 2014: http://www.brockmann-consult.de/calvalus/ (accessed 02/2014)

d'Angelo, P. and Reinartz, P., 2011: Semiglobal Matching Results on the ISPRS Stereo Matching Benchmark. In: International Archives of Photogrammetry and Remote Sensing, XXXVIII-4/W19, 79-84

ESA, 2007: Generic IPF Interface Specifications. Technical report, ESA. MMFI-GSEG-EOPG-TN-07-0003.

Euro-Maps 3D, 2013: http://www.euromap.de/products/prod_008.html (accessed 12/2013).

GDAL, 2014: www.gdal.org (accessed 02/2014)

Günther, K. P., Krauß, T., Richter, R., Müller, R., Fichtelmann, B., Borg, E., Bachmann, M., Wurm, M., Gstaiger, V. and Müller, A., 2012: Operational pre-processing of MERIS, (A)ATSR and VEGETATION data for the ESA-CCI project Fire-Disturbance. In: EGU General Assembly 2012.

Hirschmüller, H., 2005: Accurate and efficient stereo processing by semi-global matching and mutual information. In: IEEE Conference on Computer Vision and Pattern Recognition (CVPR), IEEE Conference on Computer Vision and Pattern Recognition (CVPR) (2005), volume 2, pp. 807–814.

International Charter on Space and Major Disasters, 2013: http://www.disasterscharter.org/.(accessed 12/2013).

Müller, R., Krauß, T., Lehner, M., Reinartz, P., Schroeder, M. and Hörsch, B., 2008: GMES fast track land service 2006-2008 – Ortho-rectification of SPOT 4/5 and IRS-P6 LISS III data. In: International Archives of Photogrammetry and Remote Sensing, Vol. 37, pp. 1709–1805.

Müller, R., Krauß, T., Schneider, M. and Reinartz, P., 2012: Automated Georeferencing of Optical Satellite Data with Integrated Sensor Model Improvement. In: Photogrammetric Engineering and Remote Sensing (PE&RS) 71(1), pp. 61–74.

Richter, R., 1990. Atmospheric Correction of Landsat TM, MSS and SPOT Images: ATCOR User Manual. Technical Report 552-14/90, DLR Oberpfaffenhofen.

SPOT Image, 2014: http://spot4.cnes.fr/spot4_gb/acquisit.htm (accessed 02/2014)

Triendl, E., Lehner, M., Fiedler, R., Helbig, H., Kritikos, G. and Kübler, D., 1982: DIBIAS Handbuch. Technical report, DFVLR Oberpfaffenhofen. NE-OE-14-9-82.

Acknowledgements

We would like to thank Stephan Kiemle (DLR) for the creation of the diagrams and also Mirco Tegler (DLR) for many valuable discussions and help with the implementation of CATENA into DIMS.

Über den Verfasser:

Dipl.-Phys. Thomas Krauß ist Gruppenleiter des Teams "3D und Matching" am Institut für Methodik der Fernerkundung des Deutschen Zentrums für Luft- und Raumfahrt (DLR) in Oberpfaffenhofen bei München. Er ist verantwortlich für die Entwicklung des automatischen Prozessierungssystems CATENA. Seine Forschungsschwerpunkte umfassen neben der Automatisierung der Ableitung höherwertiger Informationsprodukte aus Fernerkundungsdaten vor allem die Ableitung von Höhenmodellen und Stadtmodellen aus Satellitendaten.

Manuskript eingereicht am 15.1.2014, nach Review angenommen am 20.2.2014