KAOS 2.1
A guided tour and tutorial through the new KEO System client application

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Abstract
The KEO System [1], outcome of ESA KEO Project’s phase II [2], nevertheless being the successor of the prototype developed during project’s phase I, overcome to substantial improvements over its predecessor in both architectural and usability aspects [3]. The KAOS client application specifically addressed the usability aspects, dramatically enhancing the GUI tools developed for previous KES, KIM and KIMV projects [4, 5].

On 2006 and 2007 ESA/ESRIN started two projects [6, 7] to further improve the ESA/ESRIN KEO System installation and extend it to handle satellite image time series [8]. These projects led up to more than one hundred of improvements and as many bug fixes on the KAOS application, releases ad interim in version 2.0 in May 2009, and now ready to be officially released this month in version 2.1.

This article will explore the new interfaces and features of the KAOS 2.1 application, dwelling mainly on time series and the new processing component modules that will allow interaction with the image information mining subsystem [5, 3].

Introduction
Earth Observation (EO) products provide a valuable support to a certain number of human activities as change detection, global monitoring, disaster management, understanding of global phenomena or decision-making processes [9].

Image Information Mining (IIM) is one of the elements in the direction of empowering users with the capability to identify relevant information from EO data by interactive or batch processing of images. Examples of goals to be achieved in the long term via intuitive interfaces can be the identification of desertification trends, the forecast on iceberg routes, the global changes in chlorophyll concentrations [1].

As a step in the above direction, ESA started the project Knowledge-centred Earth Observation (KEO, [2]), to support more automated extraction of information from EO images:

• coping with the increasing size and complexity of EO images and archives,
• reducing and simplify the IIM steps,
• fostering cooperation through knowledge sharing and reuse,
• making complex programming and processing capabilities easily accessible also to non EO experts.

KEO System implements a distributed component-based programming and processing environment (Algorithmic Image Processing – AIP), supporting extraction of information from EO images by permitting to [10]:

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Introduction

- easily and visually create Processing Components (called FEPs – Feature Extraction Processors), also from interactive training (no code writing),
- semantically catalogue Processing Components,
- semantically discover Processing Components suitable for a specific task,
- start systematic or occasional execution of Processing Components against EO images to extract information and to store the results into OGC servers [11, 12, 13].

The KEO System is build upon five main components (see Fig. 1):

KEO CATALOGUES used to store IIM data and FEP modules descriptions,

INGESTION CHAIN in charge of the extraction of Primitive Features used by IIM [5],

KARISMA the web application used to interface the outer world with the IIM subsystem,

KAFE the web application used to interface the outer world with the AIP subsystem,


The KEO Application Operating on Services (KAOS) client interacts with the various parts of the system (see Fig. 2) permitting to browse the KEO catalogues, to define Feature Labels through IIM, to create and chain FEPs for feature extraction through AIP. All these activities are supported by a semantic knowledge subsystem simplifying user interactions and permitting discovery of available modules as well as automatic chaining validation by the system.

KAOS architecture is based on the idea of specialized plug-ins that are loaded at run-time, providing modular, easy to implement and to deliver extensions to the factory features built in the program itself.

The main tools available in the application are:
- The Image Browser that will allow user navigation inside the KEO Image Catalogue;
- The Image Info Viewer that will allow to view an image and inspect its characteristics;
- The Feature Label Designer that will allow expert users to define Feature Labels by training the IIM system with positive and negative examples;

Fig. 1: KEO System main components.

Fig. 2: KEO components topology.
Major Improvements

The FEP Designer that will allow users to graphically design their FEPs and run them through the AIP.

Many administration tools are also available as plug-ins:

- The Collections Manager will allow creation, removal and maintenance of KEO Collections;
- The Modules Manager will allow ingestion of “primitive” modules and the execution and management of “primitive” and FEP modules;
- The Types Manager will allow creation, removal and maintenance of FEP data types;
- The Users and Projects Manager will allow creation, removal and maintenance of KEO Users and Projects;
- The Tools Manager will allow creation, removal and maintenance of Ingestion Hosts, Rolling Archives, Web Map Servers and Classifications.

KAOS is a pure-Java application [14] running on different platforms (MS Windows, Mac OS X and LINUX) and uses the last Java technologies to provide a professional and easy-to-use graphical user interface for the KEO system. Its server counterparts (KARISMA & KAFE) are Java web applications (J2EE, [15]) running on the open-source glassfish application server.

Major Improvements

The KEI and IIM-TS projects [6, 7] required some changes in KEO System and many improvements and extensions to the KAOS client application.

Most of them are related to handling time series data and accessing the IIM subsystem from the AIP one, and will be discussed later. However, many other changes were done and will be addressed here.

KEO Servers Connection

One of the more important improvements in system’s usability and reliability is the possibility to contact KEO servers (KARISMA and KAFE) also via an authenticated system proxy: when KAOS discover the need to authenticate a proxy access, it will open a dialog for user’s authentication.

Image Browser

The new KAOS version will allow to display existing Feature Labels for the selected Collection in the Image Browser, by selecting it in the corresponding drop-down menu just over the Primitive Features/Feature Labels list (see Fig. 3).

The Primitive Features checked for Feature Labels creation are now displayed using a color code and their relative order. Moreover up to four Primitive Features can now be selected for classification purposes (see Fig. 4).

The tiles list can now be sorted clicking on the interested column’s header (see Fig. 5): the header will be displayed in bold font and with an icon on its right, indicating ascending or descending order.

Feature Label Designer

Many changes were made to the Feature Label Designer.

The Primitive Features contribution bars on the
Major Improvements

Fig. 5: Sortable tiles list.

Fig. 6: Contribution bars and color chooser.

The editor’s toolbar will now contain up to four bars, depending on the number of Primitive Features used to define the Feature Label. Near the contribution bars, a color chooser will allow to change the color of the over-the-threshold pixels of the a-posteriori-map (see Fig. 6). The same chooser was added in the Product Explorer’s toolbar, and will change the over-the-threshold pixels of Feature Label’s mosaicked a-posteriori-map.

One of the more voted feature change request was the possibility to substitute the tile quick-look with a Primitive Feature map, to improve the training clicks. In KAOS 2.1 not only this is now possible, but an RGB image can be created on the fly using Primitive Feature maps as color components (see Fig. 7). This feature has a highly improved user’s interaction in Time Series Designer, allowing a Primitive Feature color component to be dragged into the composite builder, a GUI component specifically built (see Fig. 8).

During the IIM-TS project, users requested the possibility to record training clicks to be able to reproduce a training session on Feature Labels built with different Primitive Features sets. The current implementation consists of import/export of
training clicks history from/to XML files, and the possible display of the training click positions by means of colored pins (green for positive and red for negative training clicks, see Fig. 9).

Another important feature that was added to KAOS 2.1, is the possibility to change on the fly the training radius, by means of special purpose menu items, allowing for finer or coarser label definition during the same training session. The new training radius will be displayed as a differently sized yellow finder cursor (see Fig. 10).

World Wind Viewer

The viewer based on the NASA World Wind for Java [16] was introduced in KAOS ver. 1.2 as an alternative WMS viewer. The new KAOS version has a better integration with the various designers and viewers, allowing to display static or animated (see later on) footprints (quick-looks and/or maps) over the world (see Fig. 11).

Moreover, new display controls for a better and easier interactivity were added.

Time Series

ESA has been setting up the Image Information Mining on Time Series (IIM-TS) project [7, 8], making the KEO System capable of providing final users with the analysis and navigation of multi-temporal data sets.

In KEO terminology a multi-temporal data sets is a Collection of tiles taken at different times and covering the same spatial area. Changes where made in the system and in the corresponding KAOS tools to create such time series container collection and to identify it when browsing the system (see Fig. 12).

The Time Series Designer (see Fig. 13) was created to give the user a unified interface to work with time series. It preloads all tiles and, thanks to the hugely improved performances in IIM algorithms$^1$, will allow to design, browse, filter and refine multi-temporal Feature Labels in real time, on the client’s computer$^2$.

Once a multi-temporal Feature Label is designed, a movie can be created using the time series’ quick-looks or the label’s a-posteriori-maps (see Fig. 14), viewed and exported as a QuickTime movie file.

The same movie can be projected on the earth and run in the World Wind Viewer.

Finally an interactive 3D viewer based on JOGL (the Java bindings to OpenGL, [21]) was developed to allow a three dimensional browsing and understanding of time variations in a multi-temporal Feature Labels.

$^1$ The improved IIM algorithm was also used on the server side – KARISMA – to give better performances on the legacy Feature Label-based search.

$^2$ The real time design, filter and refine capability made this designer suitable also for working with non-multi-temporal “plain” Feature Label. This is also the basis of the groundbreaking new streamlined user’s interface proposed for the KLAUS project [17].
FEPs

Many improvements were made on the FEP Designer, the Modules Manager and the Run Module dialog, the most striking being the new processing graphs look and feel (see Fig. 16), made to be more appealing and effective.

Other changes in the FEP designer made to improve productivity and ease of use include:

- modules pop-up menu triggered by clicking the right mouse button into the sketchpad;
- full screen editing;
- import of images inside the graph for documentation or aesthetic purposes (see Fig. 17);
- new modules to interact with the IIM subsystem from a FEP processing graph (ingesting products and classfiles, getting quick-looks, classfile and histograms, searching the IIM catalogue; see Fig. 16 for few examples).
Conclusions

On the management and execution side the most important changes are:

- the Run Module dialog is no more a modal one, allowing to continue working with KAOS while a FEP module is running;
- more than one Run Module dialogs can be opened at once, allowing more FEPs to be run concurrently;
- new FEP Export function to bulk export more than one FEPs at once;
- introduction of Ingestion FEPs: processing modules with a well specified interface and attached to a given Collection, that will be automatically executed every time a product is ingested into the Collection itself.

Future Enhancements

Nowadays a new project is about to be started by ESA/ESRIN: KEO demonstrator with models for land use management (KLAUS), whose aim is, among other [17];

- to consolidate the KEO prototype into a demonstrator, including improvements in availability, reliability and performance (in particular for the ingestion modules and chain);
- implement new Processing Components;
- define possible IIM enhancements.

The envisaged enhancements of the KEO System will include:

- improved performance of the servers as well as the KAOS client application, including the transfer of large files;
- improved import/export of FEP and CLI modules using a unified file format allowing for exhaustive and possibly recursive graph description;
- the monitoring of modules execution progress directly from the KAOS client application;
- the possibility to tie a module’s execution down to a specific actuator, maybe notifying the need for a user’s intervention (attended execution);
- a graphical debugger of a FEP processing graph;
- the possibility to batch execute FEPs and retrieve results also some days after their successful execution;
- extension of the FEP’s visual language to include flow control metaphors (if, while, for, ... [18, 19, 20]).

Conclusions

The new ESA/ESRIN KEO System installation will be available for the preliminary test this month, full of more than one hundred improvements, such as the handling of satellite image time series [8] and the new AIP modules to allow FEP interaction with the IIM subsystem.

The KAOS 2.1 client application was highly enhanced to support the new KEO features, exploring new UI paradigms in the image time series domain, and improving the usability and visual appealing of the processing graph designer.

References

Conclusions


[6] KIM Extensions and Installations (KEI), ESRIN/Contract No. 20345/06/I-EC.


