

Classification of nuclear powerplants with eCognition

EARTH CASE STUDY

The analysis of commercial satellite images in the context of nuclear verification has been recently proposed by the International Atomic Energy Agency (IAEA) as an additional tool to verify the absence of undeclared nuclear activities within IAEA member states. Object-oriented and knowledge-based image analysis could have a variety of applications in the context of nuclear verification. In the present work we have suggested the classification of nuclear facilities through a defined semantic model.

Data

We used LANDSAT TM5 images over various nuclear power plants in Germany: Brokdorf (August 1984), Emsland/Lingen (August 1997), Kalkar (July 1985), Philippsburg (July 1984), Wuergassen (April 1984) and Muelheim-Kaerlich (July 1984). The LANDSAT TM5 images were registered with high-resolution KVR-1000 images from a CD-ROM which is commercially available (D-Sat2, Copyright 1997 Topware Mannheim). The KVR-1000 imagery dates from the early 1990's.

The first five images were used for the modelling of a semantic network in order to get a fixed training set for the classification, the last one (of Muelheim-Kaerlich) was assumed to be representative of images with unidentified objects and was used for the semantic classification.

The pressurized water reactor Muehlheim-Kärlich, located near to the Rhine north-west of the city of Koblenz, was put into operation in 1987 and stopped production in 1988. Presently, the reactor is shut down.

A-priori knowledge

First of all, we looked for characteristic features of (German) nuclear power plants that could be used as a-priori knowledge in the semantic modelling: Power plants have geometric forms

and are often surrounded by a fence. They normally include at least one circular cooling tower, that forms shadows depending on the sun angle azimuth and elevation. Thermal emissions can be observed depending on the operating status. Due to the cooling water circuit, the plants are often located near to bodies of water. They show a connection to a street and/or a railway and stand aside from residential areas.

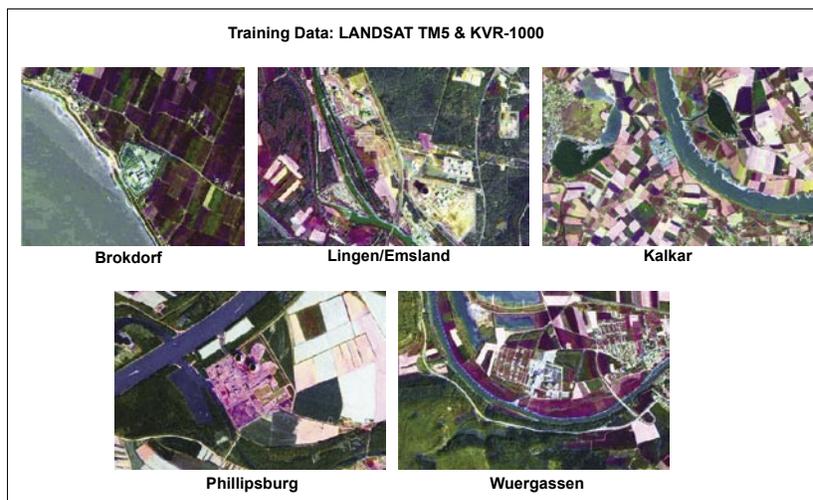


The five training set images were segmented at two different scales, so that the individual objects of the nuclear plant are extracted on a fine level (level 1), whilst a coarse level (level 2) contains the facility as one object. The individual objects in the level 1 are sub-objects of the objects in level 2. As input, we firstly used synthetic channels resulting from image transformations to enhance specific multispectral data information: the first three principal components, the first three components of maximum autocorrelation, the tasseled cap coefficients, the vegetation index NDVI and an index for man-made surfaces, the NDASI, in single weighting. In order to extract fine objects despite the lower resolution of the LANDSAT data we used it in conjunction with the high-resolution KVR-1000 image weighted by a factor of 50.

Based on the two segmentation levels we defined the object classes plant1 and plant2 (level 1 and 2), cooling tower and tower shadow (both in the level 1), waters1 and waters2 (level 1 and 2) by membership values of various object features: layer values, form, hierarchy. In addition to the above-mentioned input channels, the LANDSAT TM5 channels 1 to 7 and ratios of the channels 2/3, 2/4, 2/5, 2/7 and 5/7 were used for object description.

As class-related features we generated relations to neighbor, sub- and super objects, again in terms of membership functions: To be classified as plant2 in the coarse level, an object has to include the sub-object classes cooling tower and shadow and has to be located near to water. An object is not classified as plant1 in the fine level until it belongs to the super object plant2 and if it is not classified as cooling tower and shadow. Furthermore, the object classification of cooling tower and shadow requires that the objects exist within the class plant1 and that there is an object class tower or shadow in the neighbourhood.

The semantic classification of the training



data shows satisfactory results: The water areas were not classified completely but sufficiently in order to identify plants nearby waters. At least one of the existing cooling towers and one part of its shadow were detected. In all five cases the plants were correctly recognized.

The results of the training study were then applied to the segmentation and classification of the image of Muelheim-Kaerlich. As before, the synthetic channels were used for segmentation on two scales. Assuming that the image objects were unknown, we further used the homogeneity criteria from the segmentation of the training data. The fuzzy class description was provided by the defined object features.

Classification Results

Figure 1 shows the classification at the second (coarse) level without class-related features: aside from the correctly classified area of the plant Muelheim-Kaerlich some other objects were falsely marked as plants. The application of the class-related features improved the classification (figure 2): The nuclear power plant was well identified with the objects cooling tower and shadow in level 2.

The other objects previously classified as plants were no longer displayed, since they do not have the sub-objects cooling tower and shadow and/or are not located near to a water area.

Conclusions

The recognition of objects with medium-resolution imagery is limited by the resolution. Given the existence of high-resolution image data finer image objects can also be extracted in the segmentation. These objects can then be described by the medium-resolution imagery. If image objects such as nuclear power plants show specific characteristics, the use of these features will obviously improve the classification. In particular, the class-related features enable the classification of specific objects.

According to our results an object-oriented, knowledge-based procedure can be used for the recognition of undeclared nuclear activities. eCognition fulfils many requirements of the procedure: It allows a multisensorial analysis with the weighting of the input channels, provides different object features and enables the use of specific knowledge on nuclear plants by defining class-related relations.

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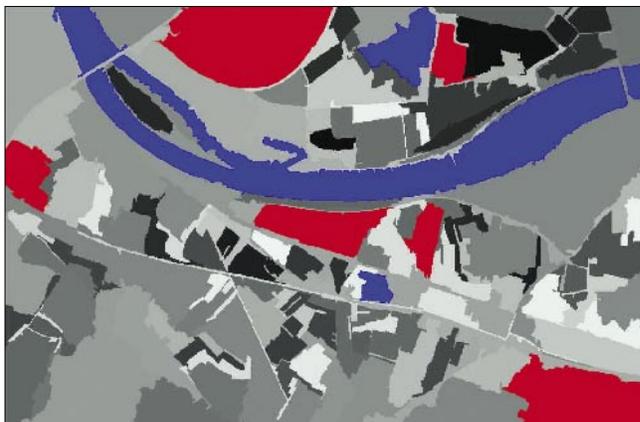


Fig. 1: Classification of level 2 without class-related features: Classes plant2 (red) and waters2 (blue)



Fig. 2: Classification of level 1 with class related features: Classes plant1 (red), cooling tower (yellow), cooling tower shadow (green) and waters1 (blue)

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