THE EFFECTIVENES OF SPECTRAL FEATURES FOR BUILDING EXTRACTION USING GEOGRAPHIC OBJECT-BASED IMAGE ANALYSIS (GEOBIA)

Athaya Atsir Frishila (1), Muhammad Kamal (1)

[1] Departement of Geographic Information Science, Faculty of Geography, Universitas Gadjah Mada, Yogyakarta, Indonesia 55281
Email: athaya.atsir.f@mail.ugm.ac.id; m.kamal@ugm.ac.id;

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Abstract: Mapping and inventory of building objects are very important task in urban areas to provide baseline for census, urban planning, tax valuation and disaster mitigation. Therefore, a systematic, accurate, and repeatable method is required for identifying and mapping building objects. Building objects are relatively hard to map using pixel-based classification approach due to the high variation of building roof and shape. Object-based classification approach (GEOBIA) was developed to address the classification of complex object such as building, using spectral, spatial, morphology, contextual, and temporal aspect of the object. This study aims to (1) examine the effectiveness of spectral features in GeoEye-1 pan-sharpened image (0.5 m pixel size) to identify and map building objects, and (2) assess the accuracy of the mapping result. The location of the study sample was in parts of Padang City, West Sumatra, and the image used was GeoEye-1 acquired on January 2018. Image segmentation was done by multi-resolution segmentation method to delineate candidate segments for building objects. Each segment was then assigned into building and non-building classes by applying a rule-based classification algorithm. Several spectral features were incorporated in discriminating the objects, including several band ratio that involve all bands in GeoEye-1 (Blue, Green, Red and near-IR), iron oxide indices, mean value of red and NIR bands, border contrast of red and NIR bands, HIS, Quantile of the bands, etc. The map result indicates that building and non-building object could be separated using spectral features of GeoEye-1 image. However, there are some classification inaccuracy mainly for the densely populated urban areas where buildings objects are close to each other. An area-based accuracy assessment shows that the use of spectral features provides an overall accuracy of 68.7%. The results from this study show that (1) the selection of the right image segmentation parameters plays an important role in providing precise delineation of building objects from GeoEye-1 image, and (2) the use of spectral features only was not enough for classifying building and non-building in urban area. Future work will be aimed evaluate the role of geometry and contextual features, in addition to spectral features, in building extraction.

1. INTRODUCTION

Object Based Image Analysis (OBIA) method or in geospatial science terms better known as Geographic Object Based Image Analysis (GEOBIA) (Blaschke, 2010) has been widely used in various mapping with various objects of interest, one of them is building objects. Building information can be extracted by using this method with various features that can be utilized in building rule-sets. The unique characteristics of each object make it necessary to examine object features that contribute to the object acquisition process in object-based classification with rule-based classification algorithm, one of which is for the extraction of building objects. The GEOBIA approach comprises of two main steps (Figure 1): image segmentation and object classification (Baatz et al., 2004; Mathieu et al., 2007).

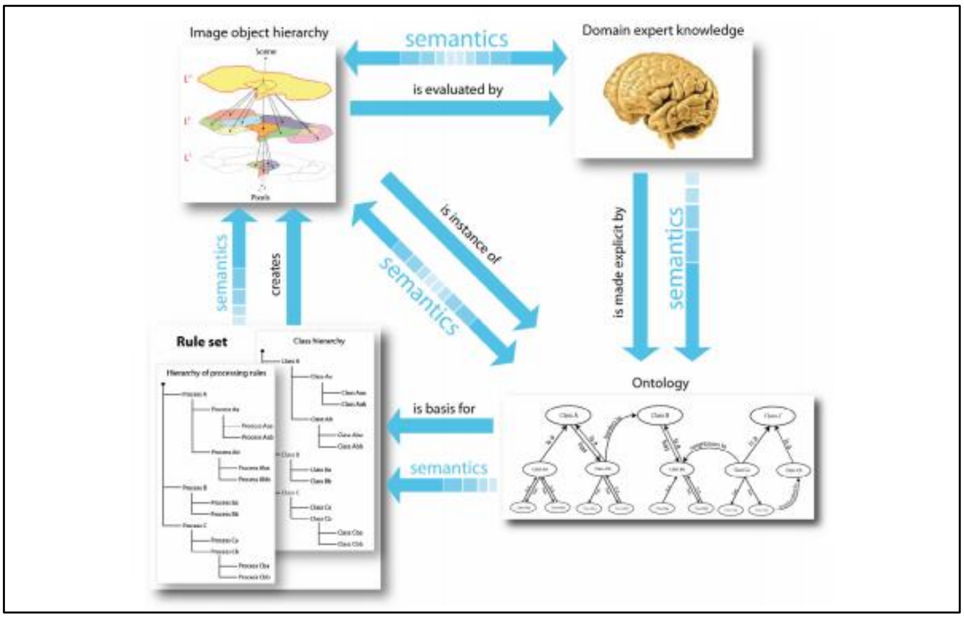

Figure 1. GEOBIA workflow.
(Blaschke, 2014:10)

Object feature is a representation of object condition contained in images at various scales and is commonly used in object-based classification (Navulur, 2006). In general, various features that can be involved are spatial, morphological, spectral, contextual and temporal features (Navulur, 2006). One feature that can be utilized is the spectral feature which is a feature related to the spectral value of the pixel or to a certain area obtained based on multispectral and panchromatic bands (Navulur, 2006). Jin and Davis (2005) used a variety of object features in their research namely structural, spectral and contextual features. The three features were extracted independently first and then the results of each extraction were tested for accuracy and compared with the results of building extraction which was used as a reference for ground truth. The research used IKONOS imagery. The test results obtained that the extraction with spectral features showed the best results after the test results from the integration of the three types of structural, spectral and contextual features. The geometry accuracy value was 72.7% from the result of feature integration and the semantic accuracy value was 58.8%.

Because of the role of an image spectral value on the process of classification methods with GEOBIA, this research will examine how the role of spectral features in the extraction of urban buildings so that relevant rules can be identified and can be utilized. In addition, the purpose of this study was also to determine the accuracy obtained when extracting urban buildings with GEOBIA, especially focusing on the use of spectral features in using the rule-based classification algorithm.

Buildings, especially in urban areas, become one of the important objects to study because they continue to experience changes and additions as urban areas develop, these changes can affect aspects of planning in urban areas (Salehi et al., 2012). The building is not only of economic value but also a place to live for residents who are still survivors of the disaster (van Westen et al., 2009). Building data is useful as information for programming, planning, controlling, and evaluating building construction (Minister of Public Works Regulation No. 17, 2010). The results of building extraction with rule-sets on spectral features were tested for accuracy by using an area-based accuracy assessment approach. Area-based accuracy assessment performed by assessing accuracy based on the position, size, and shape of objects geometrically, as well as semantic aspects (Zhan et al., 2005).

2. METHODS

2.1 Study site and Image Data

The data used for this research was the GeoEye-1 image of part of Padang City, West Sumatra Province, Indonesia. GeoEye-1 image is a DigitalGlobe product. The image was recorded on January 2, 2018, with the correction level "Standard2A" which still needs radiometric correction before further use. This image consists of a panchromatic (450 - 800 nm) band with 0.46-meter spatial resolution, and four multispectral bands with 1.84 meters spatial resolution, this includes blue (450 - 510 nm), green (510 - 580 nm), red (655 - 690 nm) and near infrared (780 - 920 nm) bands, while image radiometric resolution is 16 bits. The study site was shown in Figure 2, located at 649815.36 mT to 650952.95 mT and 9901164.17 mU to 9900459.82 mU (UTM 47 M zone).

Figure 2. Study site at Padang, West Sumatera, Indonesia (true color composite of GeoEye-1 image).

GeoEye-1 image which is used as a material in this study is at the standard 2A correction level, so it is necessary to do radiometric correction before further process. The stage of radiometric correction in this study was important because the process of selecting object features for extracting buildings will be performed with image spectral analysis. One way to involve spectral images is by testing a number of useful spectral transformations. Mathematical transformation requires absolute radiometric correction of the image used before being transformed (Danoedoro, 2012).

This study used the Gram-Schmidt Spectral Sharpening method because according to Laben et al. (2000) this correction method is able to maintain the authenticity of the spectral value of multispectral images so that the resulting display will be better. The advantages of the Gram-Schmidt method which maintains the spectral value of the image are considered beneficial for this study because, in the process of selecting object features, it will be involved in the utilization of spectral values of objects for example to perform spectral transformations.

2.2 Segmentation

The Multiresolution Segmentation algorithm was developed by Baatz and Schape in 2000 with the aim of reducing heterogeneity in the image so that it forms object segments with good results even though they are carried out at various scales and various types of data. Multiresolution

Segmentation is image segmentation that produces object segments based on consideration of scale, color, shape, smoothness, and compactness parameters. These parameters are combined to produce a variety of objects in accordance with the objectives of the operator, thus the five input values will greatly affect the results of the segment formed later. One of the things behind the development of the Multiresolution Segmentation Algorithm by Baatz and Schape (2000) is that interesting or unique objects generally appear at different scales .

2.3 Classification with spectral features

Building object extraction with spectral features in this study utilized the customized feature space and layer values that an image has. Customized feature space is used to make an arithmetic calculation of the layer or image band used so as to produce an index value for each segment. The making of index in this study includes existing and commonly used index as well as new index while still taking into account the spectral characteristics of building objects. Building index in this study involved two to four bands (read, green, blue and near-infra red) in the calculation.

Reviewing the spectral characteristics of building objects is important in utilizing the spectral features of objects to obtain building objects accurately because they provide input on band that should be used for indexing. The building object in the image is recognized by the reflection of the roof or rooftop. The study area of research includes several types of buildings with different types of roof so that their spectral reflection characteristics differ. In general, spectral reflections of objects such as buildings have similar characters to land objects where the intensity of reflections occurs at high wavelengths and tends to absorb waves at low bands such as blue band. Therefore, in this study several indices involved, for example the highest band (red and NIR) and the lowest band (blue) so that significant absorption differences can be observed.

2.4 Area-based Accuracy Assessment

Area-based accuracy assessment overcomes the limitations of the accuracy assessment method by using a confusion matrix where the error matrix is only able to assess the correctness of classification based on location without considering the correctness of the geometry of the object being classified. To test accuracy by considering thematic and geometric aspects generally use reference data for assessment, reference data can be in the form of visual interpretation results that have been validated through field Kamal and Johansen (2017) used the area-based accuracy assessment approach to measure how similar the results of object-based classification with reference data through various aspects namely overall quality (OQ), user's accuracy (UA), producer's accuracy (PA), and overall accuracy (OA). Following are the formulas of the four aspects.

$$\textit{Overall Quality} = \frac{|C \cap R|}{|\neg C \cap R| + |C \cap \neg R| + |C \cap R|} \quad (1)$$

$$\textit{User's Accuracy} = \frac{|C \cap R|}{|C|} \quad (2)$$

$$\text{Producer's Accuracy} = \frac{|C \cap R|}{|R|} \quad (3)$$

$$\text{Overall Accuracy} = \frac{|C \cap R|}{|C \cup R|} \quad (4)$$

Where C is the area of the classified object and R is the area of the reference object. C ∩ R is the intersection between C and R, ¬C ∩ R is the area of R that is not covered by C, C ∩ ¬R is the area of C that is not covered by R, and C U R is the area covered by both classified and reference objects.

3. RESULT AND DISCUSSION

3.1 Utilization of Relevant Spectral Features

This study examined some calculations of the mean value of the image band to obtain spectral building objects, from various calculations obtained several ratios that are able to extract buildings properly, including (Red/Blue) or known as the iron oxide index, (Red-Blue)/(Nir-Red), (Red/Green), (Blue-Red), (Red-Blue)/(Red + Blue). Some of these ratios have been used previously in research by Fan (2016) and can extract buildings, especially residential buildings at a certain range of values that are not much different from the values used in this study, while the ratios (NIR-Blue) and (NIR/Blue) can be used for extracting building objects in the form of buildings with greater area and sparse density. Other ratio tests were also carried out involving green band, but the results obtained were biased towards road objects and parking lots so that in this study for the extraction of building objects, this ratio was not included.

The involvement of blue, red and NIR bands in most indices was made due to the variety of types of building roofs covered in the study area. Generally the roof of a building will have a low reflecting value in the blue band and high in the red and NIR bands, but in some cases such as building roofs made of clay tile, the reflection value will decrease in the NIR band due to the role of water content or clay that make it up. Therefore, in this study, several arithmetics tests that involved division and normalization operations were tested. Each index has its own characteristics in its ability to extract building objects, especially for residential buildings with small to medium size and high density. The appearance of costumized feature space window is shown in Figure 3.

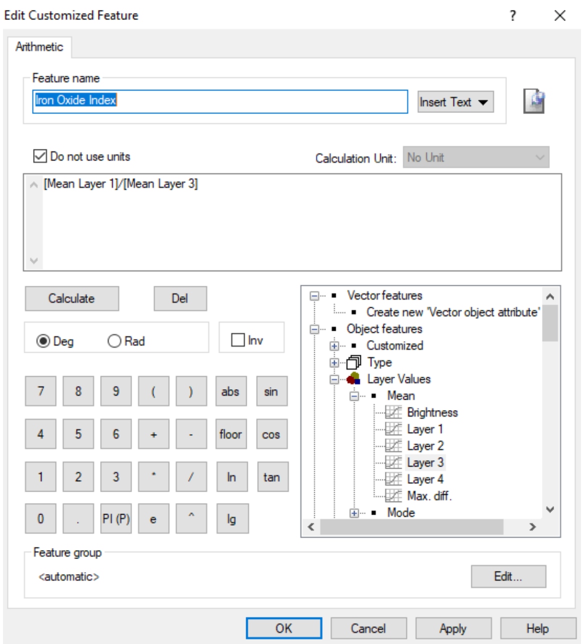

Figure 3. Customized feature space windows in eCognition.
(Source : eCognition Developer)

In addition to compiling calculations and ratios between bands, the use of object spectral features for the extraction of building objects also utilizes other spectral values that are owned by segments that have been formed. The brightness value, for example, which is the brightness value that is owned by a segment, is very important to identify buildings with brightly colored zinc roofs (Figure 4.) which were found in buildings with a fairly large area. The building with that roof was less effective to be identified by band ratio so the brightness feature was used to identify the building based on the brightness value which tends to be high compared to other objects.

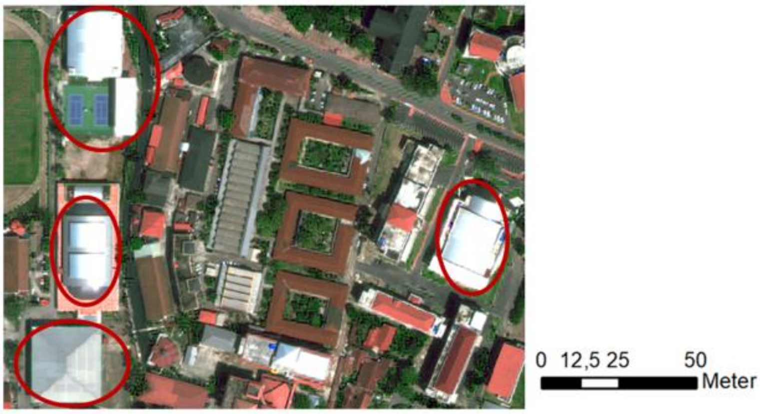

Figure 4. Buildings with high brightness value (indicated by red circles).
(source : Processing, 2019)

Building objects in the study area of this study included objects that were easy to recognize and observe in plain view because the colors are clearly different from the surrounding area. The building objects observed especially in the building complex can be seen clearly the difference in color both with the road or the parking area around it and with the vegetation next to the building object. This principle then underlies the use of border contrast features to recognize building objects in the form of buildings. The use of border contrast involves the contrast of a band to recognize building objects, and the results of tests and observations obtained that the border contrast of the red band and the border contrast of the NIR band can extract buildings based on their contrast with the surrounding area.

Building object extraction by utilizing spectral features if observed visually can be used for the extraction of building objects especially for residential buildings and buildings including sports buildings. However, special cases are found in military building objects. Spectral features that have been tested previously did not show effective results for the extraction of military building objects (Figure 5). The spectral character of military building objects is identical to the characteristics of vegetation objects, especially in the military area in the study area of this study, military buildings tend to be surrounded by vegetation around them, making it very difficult to distinguish and extract by using spectral features only. The extraction of military building objects was carried out using the mean value of the NIR band although it was only able to identify a few parts and was less accurate.

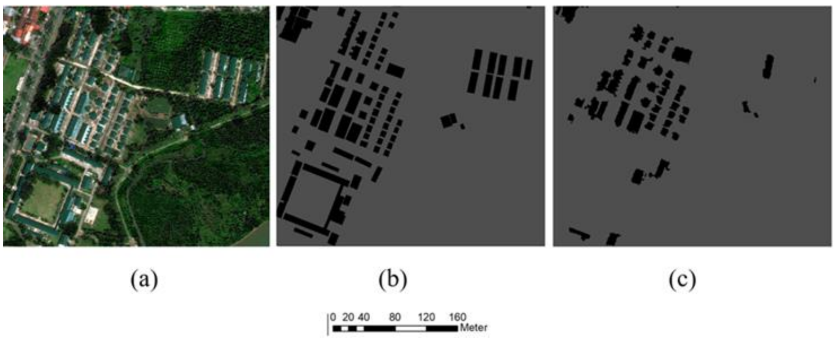

Figure 5. Military building objects at (a) GeoE-1 Image, (b) visual interpetation, and (c) extraction with spectral features. **(**source : Processing, 2019)

The use of spectral features of objects for visual extraction of buildings show good results

(Figure 6) except for military buildings. Extraction errors generally occur between building objects and parking lots, this is because the spectral similarity between buildings, especially the rooftop buildings above and parking lots is difficult to avoid. Residential buildings can be well identified and the type of buildings can also be extracted quite well, while military buildings are difficult to recognize from the spectral aspect only. Spectral features in the form of band ratios play a role in the extraction of residential building objects and spectral features in the form of layer values play a role in the extraction of buildings. The match between reference data and building data extracted by using object spectral features can be seen in Figure 6. The collection of spectral features used for building extraction in this study are described in Table 1.

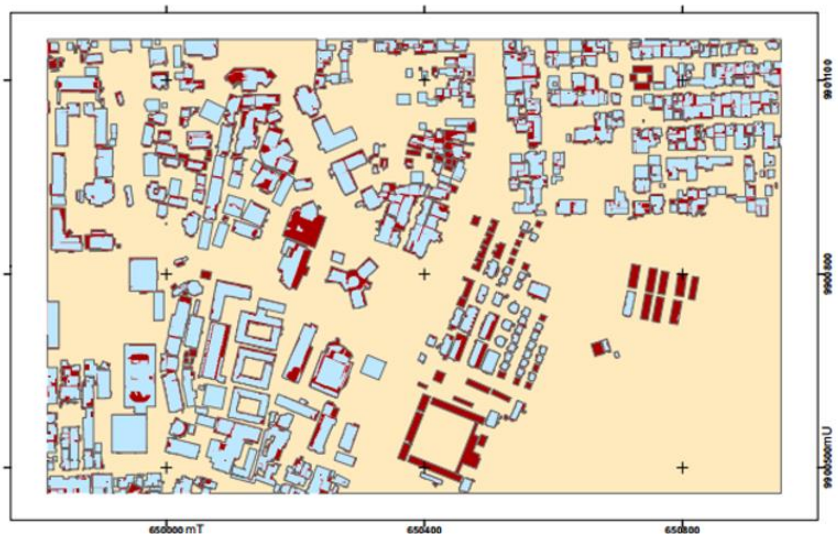

Figure 6. The result of building extraction using spectral features (blue objects area of the classified object and brown object are the area of reference that is not classified as buildings).

Table 1. spectral features used for building extraction (source : Processing, 2019)

BUILDING TYPE	FEATURE	VALUE
Housing	*(Blue-red)/(Nir-Red)*	3 - 18
	(Red-blue)/(nir-red)	-10 - 0
	(Red/green)	>1,2
	(Blue-red)	0 - 160
	Iron Oxide Index	>1,9
Big buildings	*Brightness*	>100
	Border contrast NIR	13 - 40
	Border contrast RED	50 - 60
	HSI	0,54 – 0,64
	Q2 *red*	194 - 254
Military Buildings	*Mean* NIR	7 - 40
	NDVI	0,24 – 0,44

3.2 Results of accuracy assessment

Spectral feature accuracy assessment was performed by overlaying the extracted data and reference data with spectral features. Reference Data was a Visual interpretation that conducted to manually identify and delineate building objects found in the selected image, the result shown in Figure 7. The overlay process aimed to carry out a mathematical analysis of the area between the extracted data and reference data. In area-based accuracy assessment, the accuracy of the results of object-based classification was assessed from user's accuracy (quality from the user's viewpoint), producer's accuracy, (quality from the mapmaker's point of view) and overall accuracy (overall map quality). The overall accuracy testing process of extraction by using spectral features can be seen in Table 2, involving the extent of reference data (visual interpretation data) and extracted data, obtained an overall accuracy of 0.6869or 68.69%. Further accuracy assessment for each building type was also carried out to determine the effectiveness of the use of spectral features for building extraction.

Table 2. Spectral feature accuracy assessment results.
(source : Processing, 2019)

DATA		(m^2)
R	area of the reference object	218432,7
C	area of the classified object	197873,18
C ∩ R	the intersection between C and R	169490,84
C ∪ R	the area covered by both classified and reference objects	246731,48
¬C ∩ R	the area of R that is not covered by C	48924,62
C ∩ ¬R	the area of C that is not covered by R	28316,00
ACCURACY		
OQ (O*verall Quality*)		0,68
UA (U*ser's Accuracy*)		0,85
PA (P*roducer's Accuracy*)		0,77
OA (O*verall Accuracy*)		0,68

The data in Table 1 shows that the total area of the building from extraction by using spectral features was smaller than the reference data with a difference of about 2056 m^2, this was due to the absence or very few military buildings that have been successfully extracted. Comparison between reference data and the results of object-based classification reached 169490 m^2 so that the overall accuracy value was 0.6869 or 68.7%. Testing the extraction accuracy by utilizing spectral features was also carried out on each type of building which includes buildings, residential buildings, and military buildings. Each type of building was calculated by the extent of reference data, extraction data, and user's accuracy, producer's accuracy, and overall accuracy. Calculations and data obtained can be seen in Table 3.

Figure 7. Reference data for Accuracy Assessment. **(**source : Processing, 2019)

The overall accuracy value of each building type shows that residential building type was the most effective type of building to be extracted by utilizing spectral features because it had the highest value of 0.730085773, while the lowest value was found in military building types of 0.327569442. This is because military buildings tend to have spectral characteristics that are very similar to vegetation where visually the roofs of military buildings also green colored. The results of extraction using these two methods also experience differences in terms of area, and the difference in area was found in military building objects or can be seen more clearly in Figure . Besides due to the reasons mentioned, there are other factors that can also reduce the accuracy of building extraction, namely the border of the formed object segment, there was a difference with the border on the reference data, although it was not a significant difference.

Table 3. Calculations and data of each type of buildings.
(source : Processing, 2019)

BUILDINGS TYPE	DATA (m^2)						ACCURACY	
	R	C	C ∩ R	C ∪ R	¬C ∩ R	C ∩ ¬R		
BIG BUILDINGS	147604,64	135324,44	119052,31	163825,77	16231,25	28542,20	OQ	0,73
							UA	0,88
							PA	0,81
							OA	0,73
MILITARY BUILDINGS	22496,63	11007,05	8211,038	25066,55	2570,00	14285,51	OQ	0,33
							UA	0,74
							PA	0,36
							OA	0,33
HOUSING	48324,66	51776,598	42227,52	57839,13	9514,74	6096,86	OQ	0,73
							UA	0,81
							PA	0,87
							OA	**0,73**

4. CONCLUSION

Buildings object extraction could be done by using GEOBIA especially by ultilizing the spectral feature from the imagery. Various calculations obtained several ratios are able to extract buildings properly. The ratios involving several relevant bands at GeoEye-1 Image. the use of object spectral features for the extraction of building objects also utilizes other spectral values that are owned by segments that have been formed, so that the selection of the right image segmentation parameters plays an important role in providing precise delineation of object.

An area-based accuracy assessment shows that the use of spectral features provides an overall accuracy of 68.7%. Each calculation of buldings type in the study site shows that residential building type was the most effective type of building to be extracted by utilizing spectral features. Military building was the hardest building tib e extracted by using spectral features because its characteristics that are very similar to vegetation where visually the roofs of military buildings also green colored. GEOBIA provide many aspects and features that can be use tho extract object from imagery, and the advantages of using GEOBIA to clasifiy object could be obtained by inegrating them based on each effectiveness.

5. ACKNOWLEDGEMENT

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