# OBJECT-BASED CLASSIFICATION USING HIGH RESOLUTION SATELLITE DATA AS A TOOL FOR MANAGING TRADITIONAL JAPANESE RURAL LANDSCAPES

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**WG IV/9 – Mapping from High Resolution Data**

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**ABSTRACT:**

A system for object-based classification of landscape types incorporating topographic data was designed and tested in a Japanese countryside target area. IKONOS data (Japan Space Imaging - multi-spectral resolution 4 meter, panchromatic resolution 1 meter) acquired on 23 April 2001 was utilized, and the classification used Definiens Ver.5 software (Definiens). Initial segmentation was a muli-resolution, bottom-up system, and each segment identified was considered to be one object. Topographic data was derived from field surveys and topographic maps. Using a master landscape map for assessment of accuracy, two classifications, employing the same landscape types and ground truth, were implemented. One classification employed only the extant classification system based on spectral characteristics; while the other featured integration of the topographic data. The results showed that in terms of overall classification accuracy, the object-based using topographic data (56%) scored higher than the object-based alone (52%). In terms of overall Kappa index as well, object-based with topographic (0.51) outscored the object-based only (0.47). Several misclassifications seen in the extant system were eliminated by addition of the topographic data. These results indicate that object-based classification of very high resolution data combined with topographic data produces a system that promises to be an effective tool for landscape classification. The results also indicate that additional gains in accuracy may be achieved by developing a system for adjusting scale parameter according to the characteristics of individual landscape types.

## 1. INTRODUCTION

Accurate identification and continuous monitoring of landscape elements is essential for conservation of regional environments. This is especially so in many areas of Japan, where traditional countryside ecosystems can be found on the outskirts of major cities. These ecosystems are highly susceptible to disruption by various factors, including urbanization, illegal dumping of industrial refuse, and changes in lifestyle patterns.

Remote sensing technology has been identified as an effective means for fast and continuous landscape monitoring. In particular, very high resolution satellite data such as IKONOS, which became available after 2000, provides image quality high enough to allowed accurate extraction of even small landscape elements. This is of especial importance in the Japanese countryside, which often consists of various small landscape elements mixed together in a complicated mosaic pattern.

In addition, recent research (Kamagata et al., 2006) has shown that the object-based classification method, when applied to very high resolution data, can be an effective tool for classification of vegetation and land cover. In addition, Hara et al (2007) have used this approach to extract landscape elements. Extant object-based image analyses, however, rely on classification using spectral characteristics of the image. When dealing with landscapes, classifications should include not only land-use data but topographic elements as well. The goal of this research is to add topographic data to object-based classification of IKONOS very high resolution data, and to test the ability of this system to extract and classify landscape types.

## 2. STUDY AREA AND METHODS

### 2.1 Study Area

This research was implemented on a 1500 meter by 2000 meter test plot, located in an agricultural area of Sakura City in northern Chiba Prefecture, about 40 kilometers northeast of Tokyo. Sakura City is situated in the center of the Shimousa Uplands (Figure 1). The topography in the study area consists of relatively flat, terrace-like uplands, around 30 meters above sea level in elevation, into which narrow, branching valleys have been cut. The traditional land use pattern is irrigated rice paddy on the marshy soils that form the valley bottoms, and dry vegetable fields and orchards on the uplands. The short but steep slopes between the valley bottoms and the uplands were used for bamboo groves and oak coppices (Fujiwara et al., 2005).

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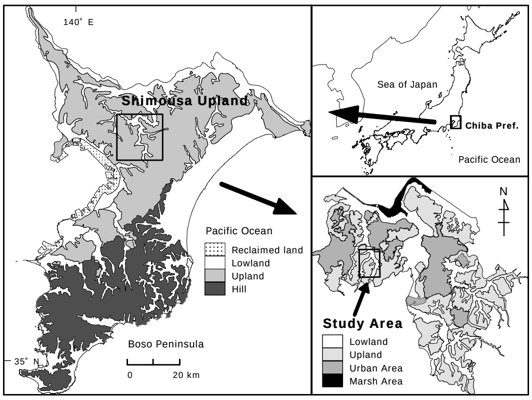



Figure 1. Location of study area

## 2.2 Methods

IKONOS data (Japan Space Imaging – multi-spectral resoulution 4 meter, panchromatic resolution 1 meter) acquired on 23 April 2001 was utilized (Figure 2). In addition, anticipating the role that topographic elements would play in the analyses, the local topography was surveyed in the field, and a topographic map was traced to form a GIS data base showing the boundary between the valley bottom lowlands and the slope (Figure 3). This division between the lowlands and the uplands (including the valley slopes), was incorporated in the initial process of segmentation and object-based classification.


Figure 2. IKONOS true color image of study area

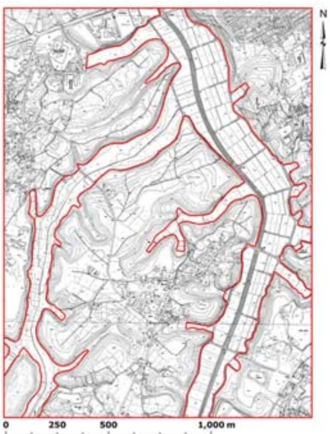



Figure 3. Lowland boundary based on topographic data
Red line: the boundary between valley bottom and slope

To verify accuracy of the results, a master landscape map was created based on field surveys and aerial photographs (Figure 4). Taking into consideration the local topography and land-use patterns, the following 11 landscape types were identified.

1. Conifer Plantation
2. Evergreen Broad-leaved Forest
3. Deciduous Broad-leaved Forest
4. Bamboo Grove
5. Grassland
6. Wetland Vegetation
7. Paddy Field
8. Bare Ground
9. Rural Residential
10. Urban Residential
11. Open Water

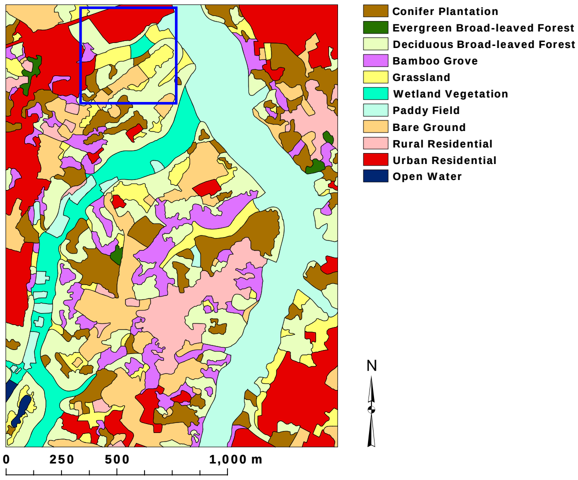



Figure 4. Landscape map (Master map)
Blue area shown in expanded view in Fig 8

This classification employed the system developed by Kamagata et al (2006), using Definiens Ver.5 software (Definiens). Initial segmentation was a muli-resolution, bottom-up system based on the method of Baatz and Schape (2000). The panchromatic data was used only in the segmentation processing. In object-based classification, object size, shape and other parameters can be adjusted to fit the needs of the research. Texture and color of the image data were used to classify each unit, and integration of areas was accomplished by increasing the scale parameters. A scale parameter of SP=66 was decided on. The study area was divided by segmentation processing, and each segment identified was considered to be one object.
This research also integrated topographic data into the classification. The results of the above segmentation process were first classified into lowland and other terrain types based on the topographic data, using a higher scale parameter. Based on these classification results, landscape types were divided into three categories; those found only in the lowlands; those found only on the uplands, and those found on both. Classification criteria were established using the decision tree shown in Figure 5. Each landscape type was allocated into the hierarchy correlated with the proper terrain element. Landscape maps, field surveys and aerial photographs were used to establish the ground truth and set training data; and the classifications were implemented using the nearest neighbour method based on the mean value of each object.

To test the effectiveness of the addition of topographic data, an additional classification, using the same methods, landscape types and training data, was implemented using only the IKONOS data. The results of these two classifications were then compared.

For evaluating the accuracy, the master landscape map was converted from vector data to 4 meter square raster data, and stratified random sampling was employed to choose a total of 5000 points from each category. Using the master landscape map as a base, producer's accuracy, user's accuracy and Kappa index were calculated for each landscape category in each of the two classification methods.

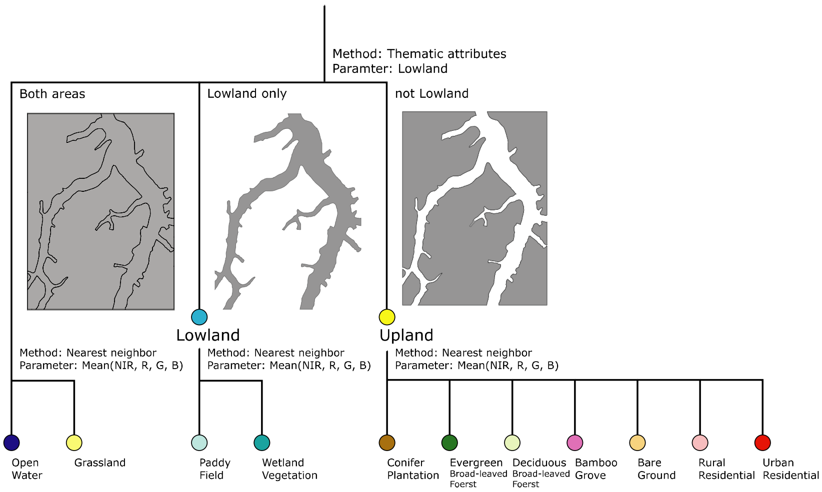



Figure 5. Decision tree for object-based classification using topographic GIS data

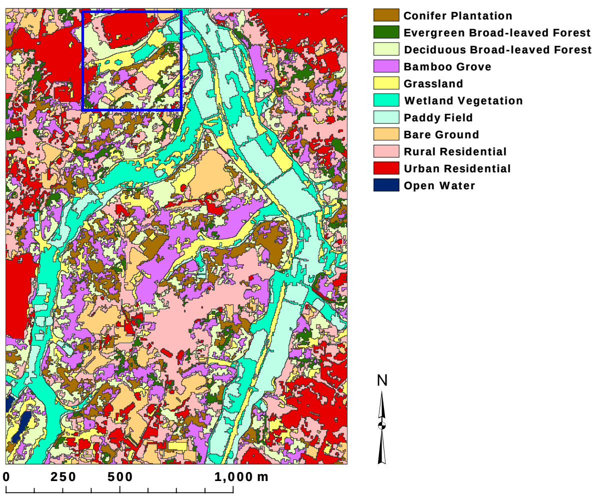



Figure 6. Result of object-based classification with topographic data

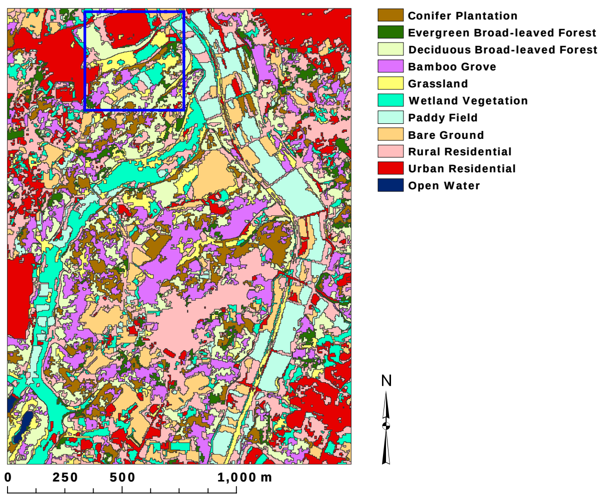
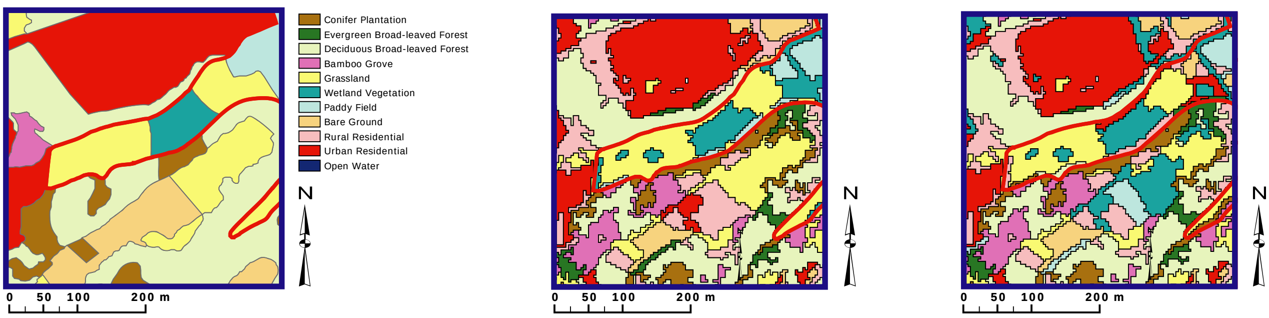



Figure 7. Result of object-based classification only (Kamagata et al., 2006)




(a) Landscape Map (b) Object-based + Topographic data (c) Object-based only

Figure8. Expanded comparison of master map with results of two classification methods

Table1. Accuracy results for object-based classification with topographic data

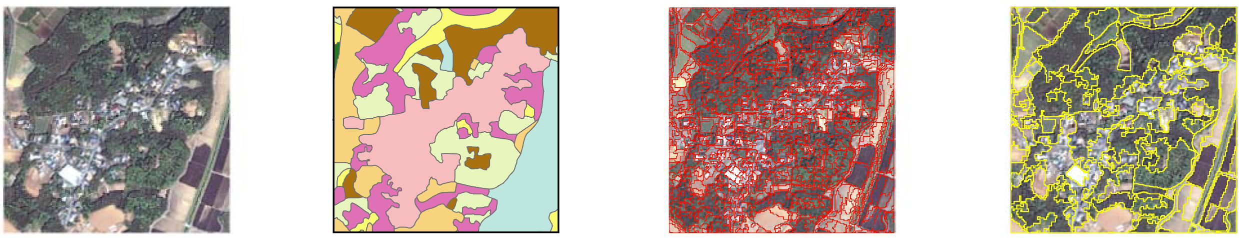
| No | Classification Category | Master Landscape Type: Conifer Plantation | Evergreen Broad-leaved Forest | Deciduous Broad-leaved Forest | Bamboo Grove | Grassland | Wetland Vegetation | Paddy Field | Bare Ground | Rural Residential | Urban Residential | Open Water | Total Point | Match Point | User's Accuracy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Conifer Plantation | 219 | 2 | 66 | 40 | 20 | 1 | 0 | 16 | 4 | 2 | 1 | 371 | 219 | 59% |
| 2 | Evergreen Broad-leaved Forest | 35 | 32 | 56 | 23 | 6 | 0 | 0 | 6 | 6 | 8 | 0 | 172 | 32 | 19% |
| 3 | Deciduous Broad-leaved Forest | 64 | 7 | 445 | 35 | 7 | 1 | 0 | 11 | 2 | 2 | 0 | 574 | 445 | 78% |
| 4 | Bamboo Grove | 130 | 0 | 132 | 229 | 8 | 0 | 0 | 4 | 15 | 5 | 0 | 523 | 229 | 44% |
| 5 | Grassland | 11 | 1 | 54 | 10 | 144 | 62 | 125 | 12 | 6 | 35 | 6 | 466 | 144 | 31% |
| 6 | Wetland Vegetation | 5 | 0 | 4 | 2 | 20 | 200 | 240 | 3 | 3 | 0 | 0 | 477 | 200 | 42% |
| 7 | Paddy Field | 1 | 0 | 2 | 0 | 7 | 20 | 429 | 0 | 1 | 0 | 1 | 461 | 429 | 93% |
| 8 | Bare Ground | 2 | 2 | 2 | 1 | 11 | 0 | 0 | 281 | 9 | 23 | 0 | 331 | 281 | 85% |
| 9 | Rural Residential | 79 | 16 | 125 | 54 | 77 | 0 | 0 | 167 | 242 | 174 | 0 | 934 | 242 | 26% |
| 10 | Urban Residential | 7 | 1 | 6 | 3 | 23 | 0 | 0 | 68 | 24 | 518 | 0 | 650 | 518 | 80% |
| 11 | Open Water | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | 40 | 40 | 100% |
| | Total | 553 | 61 | 892 | 397 | 323 | 284 | 794 | 568 | 312 | 767 | 48 | 4999 | 2779 | |
| | Produser's Accuracy | 40% | 52% | 50% | 58% | 45% | 70% | 54% | 49% | 78% | 68% | 83% | | | |

*$K$ = Class Kappa Index
Overall Accuracy = 56%
Overall Kappa Index = 0.51

Table2. Accuracy results for object-based classification only (Kamagata et al., 2006)

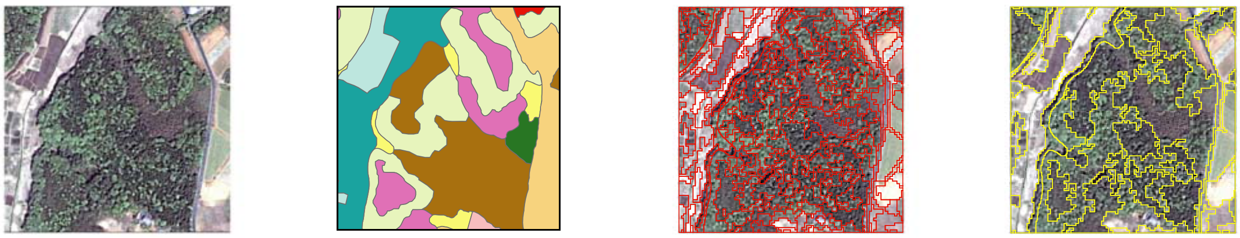
| No | Classification Category | Master Landscape Type: Conifer Plantation | Evergreen Broad-leaved Forest | Deciduous Broad-leaved Forest | Bamboo Grove | Grassland | Wetland Vegetation | Paddy Field | Bare Ground | Rural Residential | Urban Residential | Open Water | Total Point | Match Point | User's Accuracy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Conifer Plantation | 217 | 2 | 67 | 39 | 24 | 8 | 12 | 13 | 4 | 2 | 4 | 392 | 217 | 55% |
| 2 | Evergreen Broad-leaved Forest | 31 | 32 | 55 | 22 | 7 | 7 | 7 | 2 | 5 | 5 | 1 | 174 | 32 | 18% |
| 3 | Deciduous Broad-leaved Forest | 67 | 7 | 448 | 36 | 9 | 7 | 36 | 11 | 2 | 2 | 0 | 625 | 448 | 72% |
| 4 | Bamboo Grove | 130 | 0 | 133 | 232 | 12 | 1 | 22 | 4 | 15 | 5 | 0 | 554 | 232 | 42% |
| 5 | Grassland | 8 | 1 | 50 | 5 | 104 | 34 | 48 | 6 | 4 | 23 | 2 | 285 | 104 | 36% |
| 6 | Wetland Vegetation | 4 | 3 | 8 | 4 | 65 | 173 | 34 | 38 | 16 | 48 | 1 | 394 | 173 | 44% |
| 7 | Paddy Field | 8 | 0 | 5 | 2 | 5 | 1 | 357 | 31 | 6 | 7 | 0 | 422 | 357 | 85% |
| 8 | Bare Ground | 2 | 2 | 2 | 1 | 11 | 6 | 93 | 273 | 6 | 17 | 0 | 413 | 273 | 66% |
| 9 | Rural Residential | 79 | 13 | 123 | 52 | 63 | 42 | 155 | 138 | 234 | 154 | 0 | 1053 | 234 | 22% |
| 10 | Urban Residential | 7 | 1 | 2 | 4 | 23 | 5 | 30 | 52 | 20 | 504 | 0 | 648 | 504 | 78% |
| 11 | Open Water | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | 40 | 40 | 100% |
| | Total | 553 | 61 | 893 | 397 | 323 | 284 | 794 | 568 | 312 | 767 | 48 | 5000 | 2614 | |
| | Produser's Accuracy | 39% | 52% | 50% | 58% | 32% | 61% | 45% | 48% | 75% | 66% | 83% | | | |

*$K$ = Class Kappa Index
Overall Accuracy = 52%
Overall Kappa Index = 0.47



(a) IKONOS (b) Landscape Map (c) SP = 66 (d) SP = 235

Figure 9. Comparison of landscape map with results of two segmentation levels for Rural Residential



(a) IKONOS (b) Landscape Map (c) SP = 66 (d) SP = 235

Figure10. Comparison of landscape map with results of two segmentation levels for other landscape types

### 3. RESULTS AND DISCUSSIONS

The image results generated by the two classification methods are shown in Figure 6 (object-based using topographic data), and 7 (object-based only); and the classification accuracy for these two methods are shown respectively in Table 1 and 2.

In terms of overall classification accuracy, the object-based using topographic data results (56%) scored higher than object-based alone (52%). In terms of overall Kappa index as well, object-based with topographic (0.51) outscored the object-based only (0.47).

The results using only spectral characteristics generated a producer's accuracy for Rural Residential of 75%. In contrast, the user's accuracy for this same landscape type was only 22%. This large gap may be attributed to the fact that the Rural Residential area also included small patches of forest, barren land and agriculture area, which in terms of spectral characteristics overlap substantially with other landscape types such as forest and Bare Ground. Misclassification of Paddy

Field and Wetland Vegetation were also significant. In addition, Paddy Field and Wetland Vegetation area, which in reality exist only in the lowlands, and shown in the uplands as well. This is most likely due to the fact that Paddy Field and Wetland Vegetation patches may not have held water at the time the data was acquired, and thus showed spectral characteristics that can easily be misinterpreted as Bare Ground or other upland landscape types. Using only spectral characteristics, producer's accuracy for Paddy Field was as low as 45%.

In contrast, classification results incorporating the GIS data showed overall accuracy and overall Kappa index above those for the spectral only classification. This difference was especially evident in terms of producer's accuracy for Grassland, Wetland Vegetation and Paddy Field. These results show that misclassifications among the upland and lowland landscape types can be eliminated by using the topographic data.

Figure 8 shows an expanded view of one section of the master landscape map (a) compared to the object-based classification using topographic data results (b), and the object-based only classification results (c). As can be clearly seen, the misclassifications of lowland landscape types Paddy Field and Wetland Vegetation as upland landscape types Bare Ground and Grassland, have been eliminated by incorporating the topographic data. Although the user's accuracy for Paddy Field was improved, that for Grassland and Wetland Vegetation remained low. This is most likely due to the fact that at the time the data was acquired some of the paddies had been planted in a winter crop of wheat, which was easily confused with Wetland Vegetation or Grassland.

In addition, although the producer's (78%) and user's (26%) accuracies for Rural Residential improved slightly, the gap between these two remained large. In both classifications, the mean value for each object was used to derive the minimum distance. In the Rural Residential landscape, very tiny patches of forest, Bare Ground and Grassland are mixed together. For this type of landscape some improvement in accuracy may be obtained by using the standard deviation rather than the mean value.

IKONOS image, master landscape map, and segmentation results for a section of the target area are shown in Figures 9 and 10. In Figure 9, segmentation results for Rural Residential are shown at two different scale parameters, SP=66 (Fig.9c) and SP=235 (Fig.9d). As can be seen, at the lower scale parameter each individual object is too small, resulting in over-segmentation. The higher parameter, on the other hand, produces a much more accurate segmentation.

In Figure 10 the same comparison is made for the other landscape types. In this case, the higher parameter fails to distinguish among the different types of vegetation. These results indicate that the best scale parameter may vary according to the type of landscape being segmented. Further research in this direction may lead to future improvements in accuracy.

## 4. CONCLUSION

This research was designed to test and improve systems for applying object-based classification of very high resolution IKONOS data to mapping of landscape types. In addition to the extant multi-spectral object-based classification system as developed by Kamagata et al (2006), topographic data derived from field surveys and topographic maps was used to perform an initial segmentation that divided this research area into two topographic zones. The results showed that some of the misclassification problems that plagued the extant system could be eliminated by this method. Incorporation of topographic data should prove especially useful in the Japanese countryside, where various small patches are scattered in a complicated mosaic pattern. The research also indicated that further gains in accuracy can be achieved by adjusting the scale parameter to the characteristics of each landscape type.

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