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Feature selection for steganalysis using glow worm algorithm

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Abstract

Steganography is the process of communicating the way in which a secret message is hidden in some other information. Steganalysis is the art of finding the hidden messages inside digital data, if exists. Feature based steganalysis is a branch in information forensics. Its fundamental point is to identify the nearness of an incognito correspondence by utilizing the factual features of the cover and stego image as pieces of information. Because of the substantial volumes of security review information and additionally mind boggling and dynamic properties of steganogram practices, enhancing the execution of steganalysers turns into an imperative open issue. To enhance the execution of steganalyser, the order procedure is streamlined by utilizing less number of features required for the arrangement. This is finished utilizing feature determination. In the proposed paper, steganalysis of pictures is done and four distinctive feature sets were utilized for the examination. ELM is utilized as the classifier for steganalysis and Glow-worm Swarm Optimization Algorithm was effectively actualized for includes determination. The test comes about demonstrate that there has been an extraordinary lessens the quantity of features being chosen and the classification rate has moved forward.

Keywords: steganalysis, feature selection, glow-worm swarm optimization

1. Introduction

As the Internet and different types of electronic correspondence are getting to be plainly pervasive it is not quite recently enough to keep the substance of a message secret, yet additionally important to keep the presence of the message secret [19]. The procedure used to execute this is called Steganography. In Steganography the fact that some secret message is being transmitted, is itself hidden. The art of breaking stegonographic system that is finding the hidden message is known as Steganalysis. The stegnanalyser focuses on finding the message by searching for deviation of the test image from the cover image that is attempts to find the differences between the cover image and the test image. When a message is hidden in an image some features of it changes. We have worked on data set of features of various images and have tried to find minimum possible features that identifies whether the given test image belongs to stego class or non-stego class with as high accuracy as possible. In our report we have implemented several different methods to find such subsets of feature and have compared them.

Next chapter briefly describes how features are selected in steganalysis. In the third chapter glow worm swarm intelligence technique is introduced. In the fourth chapter, we present glow-worm swarm optimization based feature selection algorithm using ELM followed by experimental setup in the next chapter. And in the last sections result and conclusion is presented. The following subsection explains Steganography and steganalysis.

1.1 Steganography

Steganography implies concealing data in some other data, in this manner concealing the presence of the conveyed data. Steganography shrouds information in plain content as opposed to scrambling the message, it is installed in the information being sent, (known as cover) and doesn't require any secret transmission.

Steganography is derived from two Greek words;

> "*stegos*" meaning "*cover*" and
> "*grafia"* meaning "*writing*",

defining it is as "covered writing" [2]. On the off chance that a sender is sharing a secret message m, at that point he haphazardly picks an innocuous message c, called cover-object, it can be transmitted to receiver without doubt, and embeds the secret message into c, likely utilizing a key k, called stego-key. Sender accordingly changes the cover c to a stego-object s [1]. This is done rigorously, with the goal that an outsider, knowing just the evidently safe stego s, can't distinguish the presence of the secret message. The recipient can recreate m since he knows the embedding strategy and approaches the key utilized as a part of the embedding procedure. In short,

Embedding Process – E: C x K x M -> C
Extraction Process - D: C x K -> M

where,
C: the set of possible cover
K: the set of keys
M: the set of messages

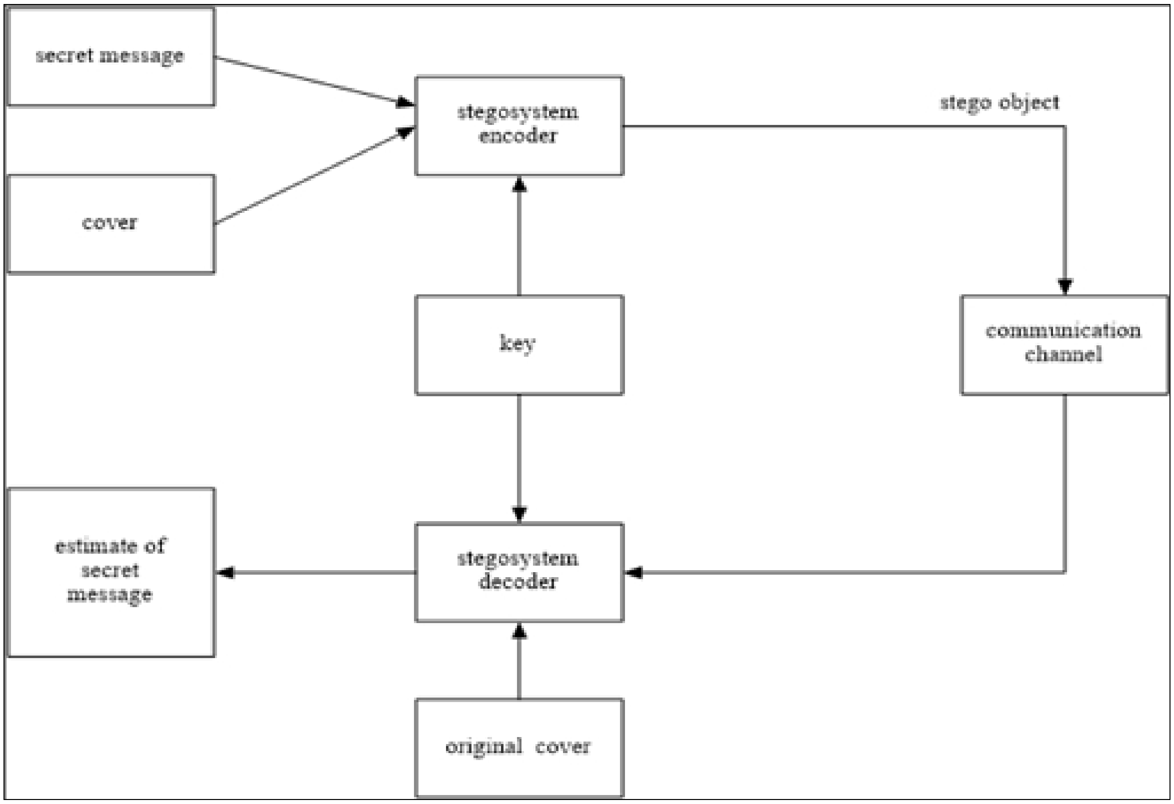

Fig 1: Steganography

1.2 Steganalysis

Steganalysis is the investigation of recognizing messages concealed utilizing Steganography. In light of whether a image incorporates shrouded message or not, images can be ordered into the image with no concealed message called cover-image, and the image with a message concealed called stego-image. Steganalysis incorporates two phases: training phase and testing phase [20]. In the training phase, the features of stego-images and cover images are extricated which get influenced after Steganography (features of the training informational index are separated). These features are utilized to prepare the classifier. In the testing phase, the test informational collection is given to classifier to recognize stego and non-stego images.

The steganalysis strategies chip away at the key that Steganography techniques on images modify the factual properties of the image, which can be utilized to distinguish nearness of messages [21]. The features extracted by altering statistical property of an image are then given to a classifier. The classifier is then trained on these features. After this the features of the test images are extracted and then these features are given to the trained classifier and the classifier tells to which class the test image belongs to.

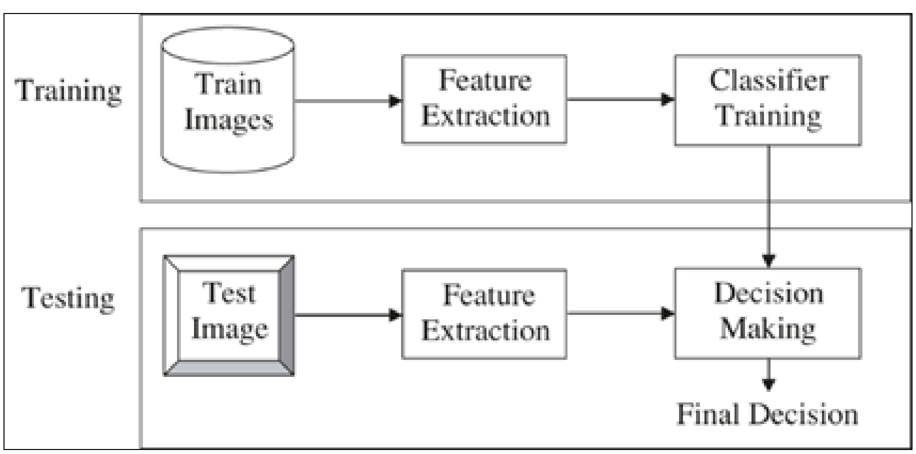

Fig 2: Implementation of Steganalysis

2. Feature selection for steganalysis

Feature selection also known as variable elimination strategy help in understanding information, decreasing calculation prerequisite and enhancing classifier's execution. A feature is an individual quantifiable property of the procedure being watched. This strategy chooses a subset of features from the information set of features which can effectively portray the information while lessening impacts of commotion (the reliant factors give no additional data about classes) or immaterial factors yet at the same time give great expectation comes about. Feature selection algorithm has following four components [18]:

1. *Starting point in the feature space*: The search for feature subsets starts with
   1. no features,
   2. all features,
   3. random subset of features.
2. Search procedure: The best subsets of features are evaluated from all the possible subsets.
3. Evaluation function: Parameter that measures how good a specific subset is in distinguishing between classes. These are divided as filters and wrappers.
4. Criterion for stopping the search: Feature selection methods should and must decide when to halt searching.

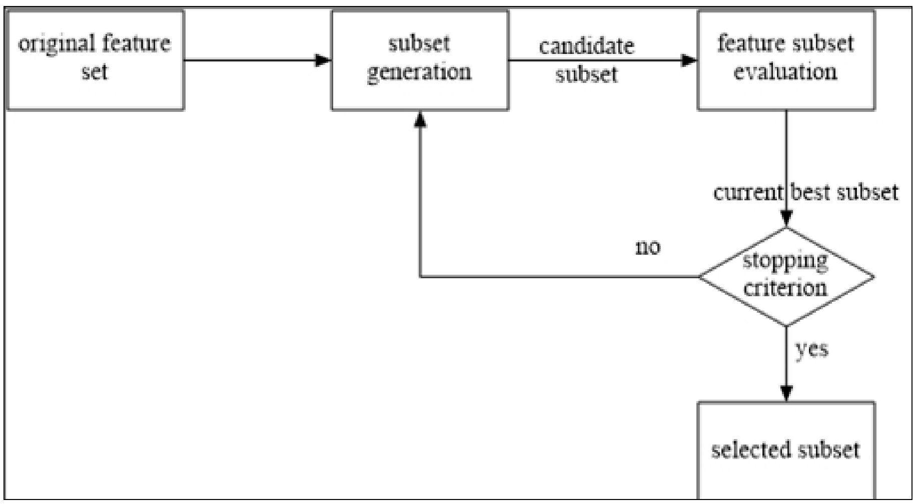

Fig 3: Feature Selection Process

The feature selection methods are broadly classified as [5]:

1. Filter method:

a) Pre-procedures to rank the features wherein the profoundly positioned features are chosen and connected to an indicator.
b) An appropriate positioning criteria is utilized to score the factors and a threshold is utilized to evacuate the factors underneath the edge.
c) Advantage: Computationally light, don't depend on learning algorithms.

2. Wrapper method:

a) A search algorithm wraps the predictor which is used to find a subset that gives the highest predictor performance.

Feature selection for steganalysis

Feature based steganalysis is a branch that helps in identifying the nearness of a secret communication by utilizing the measurable features of the stego and cover image as insights. Feature based steganalysis plans works in two phases: extraction of feature vectors and training a classifier with these features keeping in mind the end goal to isolate stego images from unique images. Characterization by hand is unthinkable on the grounds that the measure of information and features is substantial. The relationship among the features is perplexing which is for all intents and purposes incomprehensible for people to find. Features contain false relationships, which can impede the way toward identifying stego anomalies. Additionally, a few features might be repetitive since the data they include is contained in different features. Since additional features can expand calculation time, and can affect the precision of the steganalyser, a steganalyser must diminish the measure of information to be handled. This is extremely important if real-time detection is desired.

3. Glow-worm swarm optimization technique

Glow-worm swarm optimization exploits the collective nature of glow-worms. Glow-worms are a lightening bug whose brightness depends on a substance known as luciferin [13]. The value of luciferin decides with which intensity a glow-worm will glow. Higher the value of luciferin, brighter the bug and lesser value leads to less light intensity with which the glow-worm glows. Each glow-worm has its own sensor range and decision range. Sensor range determines the neighbor of glow-worm and decision range determines which glow-worms can move towards it.

There are two phases: movement phase and luciferin updation phase. The movement of glow-worm in the search space is such that they move towards the glow-worm that glows brighter than it and that resides in its circular sensor range. After that the decision range of each neighbor is checked to see whether the glow-worm that wants to move towards them resides in it or not. If multiple such neighbors exist, in whose decision range the glow-worm in question resides then probability is being calculated to find the neighbor for final movement. Luciferin updation phase updates the luciferin value of each glow-worm according to its current luciferin value and according to the goodness of the new position attained. The decision range of each glow-worm is also updated which is governed by current decision range and the number of neighbors found. Hence moving towards glow-worm that has better luciferin value leads to an ultimate arrangement, that is optimized.

In this paper, we propose a novel feature selection algorithm for image steganalysis-Glow Worm Swarm Optimisation. To the best of our insight, this is the first endeavor to utilize Glow-worm Swarm optimization with ELM for choosing the diminished list of feature set for image steganalysis.

4. Feature Selection using Glow-worm Swarm Optimization Algorithm

Glow-worm swarm optimization algorithm exploits the swarm intelligence nature of an insect known as "glow-worm" (fireflies). As the name says glow-worm are the lighting bug that are capable of emitting light at different intensities. The intensity of light with which a glow-worm glows depends on the amount of luciferin (a substance) emitted by the glow-worm. Lesser the amount of luciferin lesser is the intensity of light with which glow-worm glows and vice-versa. Glow-worm flies in their search space and move closer to glow-worm that glows brighter than them. Each glow-worm has a circular sensor range (r_s) [13] that describes its neighbourhood. We have used Euclidian Distance to measure the distance between two glow-worms. When a glow-worm moves in the search space they consider only those glow-worms that tend to fall in its sensor range (we have initialized it to be $^1/_{12}$ percentage of total features). Glow-worms moving outside its sensor range are not being considered. All those glow-worm in its sensor range that have higher luciferin value as compared to their own luciferin value are shortlisted as few of the final glow-worms for movement. Then each glow-worm is considered one by one and their decision range (r_d) is being checked to verify whether the glow-worm that is trying to come closer to them resides in their decision range or not. The decision range of a glow-worm resides within its circular sensor range ($0 < r_d \leq r_s$). Now if the glow-worm that is trying to move has several neighbour in whose decision range it resides, then it probabilistically move towards one of them. For each glow-worm i, the probability of moving towards a neighbour j is given by:

$$p_j\,(t) = \frac{lj\;(t)-li(t)}{\sum_{k\in Ni(t)} lk(t)-lit)} \qquad \text{(eq 4.1.1)}$$

where, $j \in N_i(t)$, $N_i(t) = \{\, j : d_{i,j}(t) < r_i\ d(t);\ l_i(t) < l_j(t)\}$, t is the time index, $d_{i,j}$ (t) represents the Euclidian Distance between glow-worms i and j at time t and l_i represents the luciferin value of the i^{th} glow-worm [22].

The neighbour with the highest probability is the best candidate for the movement and the glow-worm moves towards it. The luciferin value and hence the intensity with which a glow-worm glows is also updated.

In the proposed feature selection algorithm using glow-worm swarm optimization, each glow-worm is considered to be an agent whose position is represented as bit string. Bit string of 1 and 0 represents the presence and absence of features. '1' signifies that the corresponding feature is present and '0' means the corresponding feature is absent.

Steps for the Algorithm

The main steps of the proposed algorithm are:

1. **Initialization:** The agents (glow-worm) are initialized in this phase i.e. each agent's position is randomly assigned with bit string that have random number of features on. Other parameters used are:
   - circular sensor range, of some percentage of number of features, N
   - Randomly initialised decision range, r_d which varies between 0 to r_s
   - Luciferin decay constant, ρ and enhancement constant, ϒ whose value varies between 0 to 1 are also set in this phase [13].
2. **Luciferin updation phase:** In this phase, the luciferin value is updated for each glow-worm. The luciferin is updated by the formula:

$$l_j\,(t+1) = (\,1 - \rho\,)\; l_j\,(t) + \gamma\; J_j\,(t+1) \qquad \text{(eq 4.1.2)}$$

This equation is governed by two parameters "Luciferin Enhancement Constant" (ϒ) and "Luciferin Decay Constant" (ρ) [13]. The decay constant specifies by what fraction the new luciferin value should be dependent on the old value and the enhancement constant specifies by what percentage the new luciferin value should depend on the classifier's accuracy obtained after the glow-worm reaches its new position. The value of both decay and enhancement lies between 0 and 1. $J_j(t)$ represents the value of the objective function at agent j's location at time t and l_i represents the luciferin value of the i^{th} glow-worm.

3. **Movement phase:** This phase includes several steps and all steps are followed for each glow-worm.
   a. All the neighbours of the glow-worm are determined that have luciferin value greater than their own luciferin value. The neighbours are found using Euclidian Distance.
   b. For each neighbour their decision range is checked to see whether the glow-worm who wants to move towards them lie in their decision range not.
   c. If multiple such neighbours exist then probability is calculated for each neighbour as specified in equation (eq 4.1.1) above and the glow-worm moves towards the glow-worm with highest probability.
   d. Since we are dealing with bit strings hence the movement of a glow-worm towards other glow-worm is in form of bit flips. The number of bits to be flipped is calculated by multiplying the *step size s* (a random variable between 0 and 1) with the Euclidian distance between the two glow-worms. Then bit-wise matching of feature bit string of both glow-worm is done. If corresponding bits are not same, the bit in the string corresponding to the glow-worm that is moving is flipped to match it to the bit of the string corresponding to glow-worm towards which it is moving. This is done until required number of bits are

flipped. This marks the end of glow-worm movement and the glow-worm reaches its new position.

4. After that the decision range (r_d) for each glow-worm is updated according to equation:
$r_d(t+1) = \min\{ r_s, \max\{ 0, r_d(t) + \beta (n_t - |Ni(t)|) \} \}$ (eq 4.1.3) here n_t is a parameter that controls the number of neighbour a glow-worm has in each iteration and β is a constant.
5. Both the luciferin updation and the movement phase are repeated a predefined number of times.
6. Now to get the solution, the best glow-worm (the bit string with the maximum classifier's accuracy) is chosen among all the glow-worms.

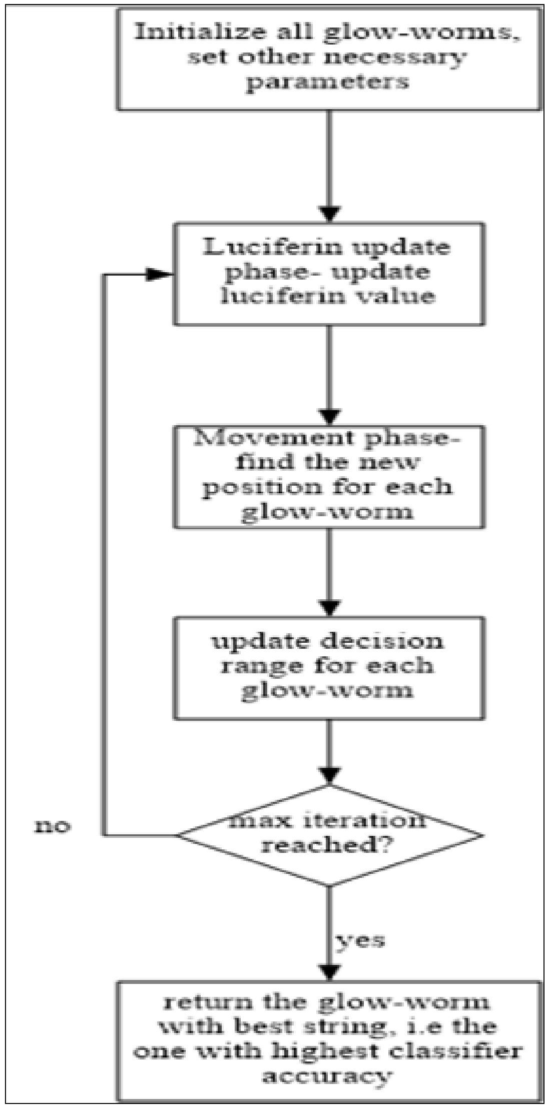

Fig 4: Glow-worm Algorithm

5. Experimental Setup and Result

Image Set: The examinations are led on two unique informational data set comprising of both stego and non-stego shaded JPEG pictures of size 256 × 256.One data set consists of 1098 images and other consists of 1892 images. The cover images include images freely available over internet and images captured by the authors' camera. The images are of different substance and surfaces running from indoor to open air scenes. The stego-images are created using publicly available JPEG image Steganographic tools: OutGuess, F5 and Model-based Steganography [14]. The image dataset is separated arbitrarily into a non-covering training set and testing set.

Steganalytic Feature Sets: The key piece of Steganalysis is feature extraction. Different steganalysis strategies vary chiefly in the feature sets that are removed from images. In this paper, the investigations are directed on four sorts of feature sets to be namely: Co-occurrence in DCT coefficient (Co-DCT Features), Neighbourhood Joint Density based features (absolute) (NJD-A Features), Neighbourhood Joint Density based features (normal) (NJD-N Features) and Markov based features (MB Features) and Neighboring Joint Density based features (NJD-Features) [1] with 120, 72, 338 and 486 as dimensions, respectively. DCT feature extraction consists of two stages. DCT is applied to the entire image to obtain DCT coefficients and then some of the coeffients are selected to construct feature vectors in second stage. The feature set of NJD-Features, proposed by Q. Liu *et al.* [11, 16], include features based on Intra-block Neighboring Joint Density and Inter-block Neighboring Joint Density. Features are extracted to detect the modification caused by information hiding. The feature set of MB Features, proposed by Chen *et al.* [15], used both the intra-block and inter-block correlations among JPEG coefficients for feature extraction using Markov Process. The elements of transition probability matrix (TPM), obtained by applying Markov process, form the features set. TPM is a matrix constructed using the conditional probabilities on the matrix obtained after thresholding technique. This process is connected to the first image, to acquire 324 intra-blocks and 162 inter-blocks features, together shaping the list of the feature set of size 486.

Extreme Learning Machine (ELM): For the experiment, ELM is used as the classifier. It is utilized to register classification precision (how great a subset of features is in recognizing distinctive classes) amid feature selection for steganalysis. ELM was proposed by Guang-Bin Huang. ELM is feed forward neural network for classification or regression with a single layer of hidden nodes, where the weights connecting inputs to hidden nodes are randomly assigned and never updated. The weights between hidden nodes and outputs are learned in a single step [17]. Therefore, ELM is considerably less difficult and saves huge time. ELM with sigmoid actuation work and 160 concealed neurons is utilized for tests.

For feature selection by Glow Worm Swarm Optimization, the feature set computed from training set are used. The ELM is trained using the reduced feature set so obtained. Then, the testing images set are classified into stego and non-stego images by this trained ELM utilizing the chose features from testing images. The algorithm is implemented in MATLAB.

For the proposed algorithm for image steganalysis, the performance is determined by employing classification accuracy percentage and the features selected. The test has been conducted 10 times employing ten-fold cross validation for all the four feature sets (Co-DCT Features, NJD-A Features, NJD-N features and MB-Features). Every one of the outcomes are then averaged.

Table 1 shows the experimental results for different feature sets. The result indicates that the algorithm proposed in this paper, the dimension has been reduced to a great extent and also, the steganalytic efficiency has been improved. Following results verify the goodness of the proposed algorithm, when it is used in steganalysis process.

Table 1: Performance of FS-GWSO

Steganalytic Feature Set	No. of features	Accuracy % using original features	No. of features selected by algorithm	Accuracy % using features selected
Co-DCT Features	120	81.42	58	94.50
NJD-A Features	72	75.97	30	77.25
NJD-N Features	338	78.82	168	84.66
MB Features	486	81.26	238	81.48

6. Conclusion

This paper introduced a feature selection technique Glow-worm Swarm Optimization for steganalysis. JPEG images of size 256 x 256 were utilized for the analysis. The JPEG image Steganographic apparatuses: Out Guess, F5 and Model-based Steganography were utilized to make stego images. The ELM was used as classifier. To show the effectiveness and usefulness of the proposed algorithm, four different types of steganalytic feature sets were used for the experiment. The experimental test comes about demonstrate that there has been an awesome diminishes in the quantity of features being chosen and the classification rate has enhanced, when the proposed feature selection strategy is utilized as a stage in the steganalysis procedure.

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