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Opera suspicionată (OS)	Opera autentică (OA)
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OS	Filimon, M. V., „Securizarea accesului, interogarea şi sincronizarea bazelor de date distribuite utilizând tehnici de inteligență artificială." Teză de doctorat, Universitatea Tehnică din Cluj-Napoca, 2011.
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p.58:01 – p.58:09	p.3:52d - p.4:14s
p.58:11 – p.58:24	p.4:06d – p.4:27d
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MINISTERUL EDUCAŢIEI, CERCETĂRII, TINERETULUI ŞI SPORTULUI

UNIVERSITATEA TEHNICĂ
DIN CLUJ-NAPOCA

PROCES – VERBAL AL ŞEDINŢEI PUBLICE DE SUSŢINERE A TEZEI DE DOCTORAT

Astăzi, 09.09.2011, la **Facultatea de Automatică şi Calculatoare**, a avut loc şedinţa publică de susţinere a tezei de doctorat intitulată ***"Securizarea accesului, interogarea şi sincronizarea bazelor de date distribuite utilizând tehnici de inteligenţă artificială"***, elaborată de doctorand(a) ***ing. Filimon Maria Viorela.***

Susţinerea publică a tezei de doctorat s-a desfăşurat în prezenţa Comisiei pentru evaluarea şi susţinerea publică a tezei de doctorat *Comisie*, aprobată prin Ordinul **nr. 370/19.07.2011**, al Rectorului ***Universităţii Tehnice din Cluj-Napoca***, fiind respectate toate condiţiile prevăzute de reglementările oficiale în vigoare.

Pe baza celor constatate la evaluarea şi în timpul susţinerii publice a tezei de doctorat, *Comisia* a deliberat şi a acordat tezei de doctorat calificativul(1) "FOARTE BINE".

Pe baza calificativelor primite de doctorand(ă) la examenele şi rapoartele de cercetare, din Contractul disciplinelor şi Programul de Cercetare Ştiinţifică, precum şi la teza de doctorat şi având în vedere gradul de îndeplinire a cerinţelor preliminare privind conferirea titlului ştiinţific de doctor, *Comisia* a deliberat şi a hotărît să (2) CONFERE doctorandului(ei) titlul ştiinţific de ***doctor*** în domeniul: ***Ingineria sistemelor.***

Comisia pentru evaluarea şi susţinerea publică de a tezei de doctorat

Titlul, Prenumele şi Numele	Calitatea	Calificativul acordat	Semnătura
Prof.dr.ing. ***Sergiu Nedevschi***	- Preşedinte	foarte bi	
Prof.dr.ing. ***Honoriu Vălean***	- Cond. de doctorat		foarte bine
Prof.dr.ing. ***Octavian Proştean***	- Referent	foarte bine	
Prof.dr.ing. ***Ioan Ileană***	- Referent	foarte bine	
Prof.dr.ing. ***Mihail Abrudean***	- Referent	foarte bine VOT ÎN SCRIS	

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(1) **foarte bine**; **bine**; **satisfăcător** (caz în care se prezintă, scris, elementele ce urmează a fi refăcute sau completate în teza de doctorat).

(2) **a conferi**; **a nu conferi** (caz în care se prezintă, scris, motivaţia).

Secretar şcoală doctorală,
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Endocrine Control Evolutionary Algorithm

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***Abstract*—The paper presents a new technique for the control of the population's dynamic in evolutionary optimization. The technique is inspired by the endocrine system, respectively, by the control mechanism of the hormones concentration. The approach is suitable for multimodal optimization in static or dynamic environment. The major advantage of the proposal is given by the fact that there is no need of a supplementary mechanism for detecting the changes or an extra parameter for estimate the multiple optima vicinities.**

***Index Terms*—endocrine, optimization, dynamic environment**

I. INTRODUCTION

In multimodal context, diversity of the population represents an important issue of the development of an efficient evolutionary algorithm. Standard evolutionary algorithm has an important drawback: the lack of population diversity and the convergence towards one optimum causes an impossibility of maintaining multiple optima of the problem.

The research is focused on this direction of finding skillful evolutionary techniques for solving multimodal problems. Several significant improvements were made by adding extra mechanisms to evolutionary algorithms to deal with multimodality: the niching techniques inspired by the niche concept [1], [2] are suitable for maintaining several subpopulations (niches) corresponding to each optimum and these techniques are responsible for preventing the genetic drift.

A. Crowding Techniques

De Jong [3] proposed crowding techniques, which are responsible for diversity preservation and, consequently, for maintaining multiple optima into the population. The main idea of these techniques is to provoke the individuals to establish around each optimum by using a replacement procedure based on the similarity degree. Standard crowding described by de Jong [3] and Deterministic Crowding [4] are two variants of the same approach.

A crowding technique is also used in CrowdingDE algorithm[5]. Basically, CrowdingDE is a Differential Evolution algorithm [6], supplied with a crowding mechanism for maintaining multiple solutions in the population. This algorithm is comprehensible and provides good results in multimodal optimization. A major advantage of the CrowdingDE is that it does not use additional user specified parameters (e.g. niche radius) to define the niches corresponding to multiple optima.

B. Sharing Techniques

Fitness sharing described in [1] represents a point of reference for multimodal optimization. In order to make the population converge towards multiple optima, the standard evolutionary algorithm is enriched by an extra mechanism in which case the population consists in several subpopulations corresponding to all promising regions of the search space. This partitioning of the population is suggested by the biological concept of ecological niches. Each subpopulation tends to occupy a specific zone, and therefore to converge to one optimum.

The principle of sharing technique is to reduce the fitness of each individual of the current population by an amount proportional to the number of similar individuals of the population.For establishing the sharing degree among the individuals of the population a distance function d is chosen. This function could be Euclidian distance, Hamming distance, Levenstein distance. The larger the distance is, the less the sharing degree is.In order to compute the modified fitness function, also called shared fitness, an extra parameter is taken into account: niche radius. Parameter niche radius has the meaning of the maximum allowed distance between two individual which they are considered from the same niche. Setting proper value for the niche radius is crucial and requires a previous knowledge of distances among the optima. Generally these information are not available at the time of algorithm design, therefore, choosing the value for the niche radius is problematical.

C. Speciation Techniques

Speciation techniques ([7],[9]) , inspired by a natural process of evolution, are also niching methods which exploit the concept of species. One of these techniques, SCGA [7] represents an evolutionary algorithm which makes use of species concept. The algorithm is based on the concept of partitioning the population into several subpopulations according to similarity degree of the individuals. Each of these subpopulations is called species and is built around a dominating individual called the species seed. All species seeds of the current population are conserved by moving them into the next generation. A species is defined as a ”class of individuals with the same characteristics” [7]. A supplementary parameter species distance indicates the maximum value of the distance between two individuals for which they are considered similar. Therefore, a species is a subpopulation for which the distance between any two individuals is less than the species distance. The species distance is also used to decide which individuals should be preserved from one generation to the next one. Setting the proper value for the species distance represents an important disadvantage of the technique.

D. Clearing Techniques

The clearing technique [8] is based on the niching principle according to which the subpopulations share the limited resources of the same area. There are similarities with the sharing techniques, but in clearing procedure's case, each subpopulation has a winner (the individual with the best fitness) which will fully gain the whole resources, while the others' fitness will be set to zero. The procedure can be generalized by accepting more than one winner on each niche. In order to establish the niches, a supplementary parameter is used: clearing radius. The significance of this parameter is equivalent to the niche radius defined in sharing procedures.

E. Optimization in dynamic environment

Optimization in dynamic environment also represents an important field in evolutionary computation. The main drawback of the evolutionary algorithms in a dynamic environment is given by the lack of population diversity by converging to the optima and further incapacity to adapt to the new changes. Branke [10] states that: "For static optimization problems, convergence is desired. If the problem is dynamic, convergence is dangerous." Avoiding the shortcoming of traditional EA's in dynamic optimization problem is mainly accomplished by using one of the following mechanisms [11], [12]:

1) The evolutionary algorithm is let to evolve in a classical manner, but as soon as a change is detected, some explicit actions are carried out in order to amplify the population diversity, e.g., restart the population or generate hypermutation.
2) The algorithm is supplemented by some mechanisms for maintaining diversity throughout the run by avoiding convergence. This approach disturbs the optimization process.
3) The evolutionary algorithm is supplemented by a memory where useful information from the last generations is stored. This technique is efficient when the optimum returns to the previous positions [13].
4) Multipopulation approaches maintain different subpopulation on different optimum: Multi-National EA [14].

Tracking multiple optima in dynamic environment represents a real challenge for evolutionary algorithms. The population should be able to find and maintain the multiple optima and to quickly adapt to the changes which could occur into the environment. In static multimodal optimization problem a good equilibrium between exploration and exploitation of the search space is desired. Designing an EA for tracking multiple dynamic optima should follow the next three criteria:

- Population's diversity preservation - to maintain multiple optima;
- A fast convergence in the neighborhood - to find a good approximation of the local optima;
- Quick adaptation of the population to the changes - to track dynamic optima.

Emphasizing one of the three mentioned issues could compromise the EA's abilities to assure the other important requirements.

The following sections present a new evolutionary approach for multimodal optimization which proves to be efficient in dynamic environment.

II. ENDOCRINE PARADIGM

The endocrine system is composed by the totality of the endocrine glands (pituitary gland, thyroid gland, so on) which are responsible by the hormonal secretion. The functionality of the endocrine system is multiple. This complex system regulates many functions of a living organism including growth, metabolism, tissue function, and reproduction. A gland is formed by a group of cells and it produces and secretes the specific hormones. Endocrine glands release hormones directly into the bloodstream where they can be transported to target cells in other parts of the body.

A. Biological Aspects

Each gland of the body has a vital importance but especially one gland is remarkable by its control role of the entire system. The pituitary gland, anatomically disposed inside the skull, close to the brain, has the major responsibility of controlling many vital aspects of the endocrine system. It is considered as the major gland of the organism. In fact, the control role of this master gland is given by the close connection with the hypothalamus and subsequently with the nervous system. The hypothalamus releases neurohormones, which stimulate or inhibit the secretion of pituitary hormones. Because of the very close link between the nervous and the endocrine system, we can deduce that the endocrine system cannot be considered as an autonomous system, as it is controlled by the brain. However, since the endocrine system possesses a different and specific communication system, not by electrical impulses as the nervous system, but by chemical messengers, we can admit that the endocrine system has a partial autonomy.

Hormones are chemical messengers that transmit information through the body. Each type of major hormones is produced and secreted by a certain gland and using the bloodstream, they will transport the information to the target cells in the body. Even there are many different hormones throughout the bloodstream, only the target cells will accept the message and further react accordingly. The identification of the target cells is possible by the receptors. Each target cell has particular receptors which permit its recognition by the specific hormones and further, the information transmission into the cell.

In a healthy organism, the hormone levels increase and decrease in a range. The variation of the hormone levels in the particular limits is controlled by an intrinsic process of releasing and inhibiting hormone regulation. Thus, when hormone levels reach a normal amount, the endocrine system is responsible for maintaining that level of hormone in the blood. Also, when hormone levels are lower than the limit, the secretion of hormones is stimulated in order to attain the normal concentration. For example, if the thyroid gland has secreted the proper amount of thyroid hormones into the blood, the pituitary gland recognizes this event and helps to keep the normal levels of thyroid hormone in the bloodstream. Then, the pituitary gland adjusts its release of thyrotropin - the hormone that stimulates the thyroid gland - in order to produce and release thyroid hormones. This process is called a negative feedback.

B. *Hormones, Tropes and Endocrine Control*

Tropic hormones are hormones produced and secreted by the pituitary gland that target endocrine glands. The importance of these chemical items is given by their function of controlling the hormonal concentration in the blood. When hormone concentrations are either too high or too low, the organism suffers. Therefore, the control mechanism over circulating concentrations of hormones is essential.

The negative feedback process is the basis of hormone regulation. The pituitary gland produces hormones that influence and control the body cells and processes. Its role of supervisor is actually offered by the function of the hypothalamus, which represents the bound between the nervous and endocrine systems. The hypothalamic neurons secrete hormones that regulate the release of hormones from the pituitary gland. The hypothalamic hormones are of two types: releasing and inhibiting hormones, reflecting the influence they have over the production of pituitary hormones, called tropes.

The optimal balance of hormonal concentration is controlled at the level of the pituitary gland. Through a feedback mechanism, the supervisor gland is announced of possible overloads. In these situations, the tropes (a special type of hormones generated at control level) adjust the concentration of a particular hormone by stimulating or inhibiting the release of that type of hormone.

An example of the negative feedback cycle can be seen in control of the thyroid hormones secretion. The releasing thyroidian hormone (TRH) produced by the hypothalamus actions on the hypophysis determines the secretion of the thyroidian stimulation hormone (TSH). This will act on the target organ i.e. the thyroid gland. The action of the TSH hormone on the thyroid results in the secretion of the specific thyroidian hormones. Thus, when the concentration of the specific thyroidian hormones becomes too high or too low, through a negative feedback process, the hypothalamus is announced about this aspect. Therefore, by using inhibiting or releasing hormones, the hypothalamus acts on the hypophysis producing an inhibition/releasing in the production of the thyroidian stimulation hormones (TSH) with a direct effect on the thyroid gland activity and thus, a return to normal of the thyroidian hormones concentration.

To conclude, the concentration of specific hormones is controlled through a feedback mechanism. So, a special type of hormones generated by the hypophysis, called tropes, have the role to supervise and to imprint the releasing or inhibiting of specific hormones.

III. ALGORITHM DESCRIPTION

The biological aspects of the endocrine system reveal several inspiring issues for developing a technique for preserving the population diversity in evolutionary optimization algorithms. For that reason, our approach aims to design an innovative procedure inspired by endocrine system in order to increase the performance of the optimization algorithm.

The following paragraphs describe the particularities of the proposed algorithm and the endocrine control mechanism. The specialized terminology is taken from the natural endocrine paradigm and therefore in the following description of the proposed approach, we will further use the terms as hormones, tropes and so on.

A. *Outline of the technique*

The algorithm is mainly an evolutionary algorithm endowed with an extra procedure for controlling the diversity and convergence toward the solutions. The algorithm works with two populations of individuals. The basic population is made of the possible solution in the search space and each element of the population is called a hormone due to the specificity of the codification. The second population is made of tropes, which essentially represents solutions from the search space but they also have a supplementary role of controlling the diversity and convergence of the basic population.

In an optimization process, which involves multiple solutions or a dynamic environment, the very important feature of the algorithm is given by its ability to preserve a balance between exploration and exploitation of the search space. From this point of view, in our approach, we focus on attaining a good balance between these aspects.

The basic population evolves in the usual manner by using genetic operators like selection and crossover. The second population is updated accordingly by using a simple classification and replacement procedure. Each trope of the second population controls a promising zone of the search space and also leads the neighbouring hormones to the optimum solution. By using the negative feedback mechanism, the selection probabilities of the hormones of the basic population are fixed and further the balance is obtained.

The advantage of the proposed technique consists in finding the multiple optima without a preset parameter, which represents the number of the needed solutions. In a dynamic environment, the algorithm does not need an extra procedure for diversity preservation or an extra mechanism for detecting possible changes.

1) Description of the hormones: Each individual (hormone) of the base population represents a possible solution in the search space. The codification of the possible solution is made in the same manner as chromosomal representation in genetic algorithm paradigm. From this point of view, there are similarities with a chromosome, except for the extra information that a hormone holds. This supplementary information contains the receptor and a binary code that notifies if the hormone is active or not:

$$h = \{(x_1, x_2, ..., x_n), receptor, active\} \tag{1}$$

The receptor field informs about the association class controlled by one trope and it is connected to a specific promising region of the search space. Therefore, according to the receptor value, the hormones with the same receptor build a subpopulation which corresponds to one optimum solution and it is directed by one trope. During evolution, the number of classes among the population, respectively, the number of tropes is variable. Also, the number of receptor values is changeable according to the size of the population of tropes.

The active item has the possible values 0,1 and its meaning is related with the integration or not of the specific hormone into the class of the corresponding trop. Each time the tropes' population is updated, the active fields of the hormone are re-set to the null value. In addition, the active field becomes useful when a decision is needed about replacing a parent hormone by its descendent or not.

Each trope represents a niche in the search space and guides the corresponding subpopulation to the optimum from each promising zone. The trope has a twofold role: first, it represents a zone leader of the hormones and secondly, it will further correspond to one optimum.

B. Population

Actually, the proposed algorithm works with two parallel populations: a base population of hormones and a population of tropes. The sizes of both populations are not constant. There is only a pre-set maximum size of the base population and the trope population will not exceed a specific fraction of the base population's size. The algorithm starts with a null population of tropes and a base population with a single hormone. Throughout the evolution of the base population, the hormone population's size increases and the size of trope population adjusts itself. Finally, it is expected that the size of the trope population should match or be close to the number of the optima.

The principle of the proposed technique relies on keeping two populations: an active population of hormones and a passive population of tropes. The members of the passive population behave as a population of elite and they also have a supplementary function: to lead the hormones toward the optima, keeping a good diversity among the search space as much as possible. These two populations correspond to the two classes of hormones in the endocrine paradigm:

1) Specific hormones, which are released by different glands of the body - the active population.
2) The hormones of control (tropes), which are produced by control level of the endocrine system (hypothalamus and hypophysis) in order to supervise the concentration of each type of hormone - the passive population.

The population of tropes is modified at each generation or it can be adjusted at each k generations. In our approach, we consider that by providing a smaller k value, the probability of capturing the eventual change in environment increases. The new population of tropes gathers the best found solutions so far from the active population. The passive population does not suffer modification at individual level under the variation operators as crossover and mutation. It behaves as an elite population of best solutions from the current generation, which is only updated at each kth generation. In the end, the population of tropes contains multiple solutions and its size is close to the number of optima. The manner of updating the tropes is described next.

C. Trope's update

First of all, the size of the trope population is smaller than the hormone population. Therefore, each trope controls a subpopulation of hormones. The size of one specific cluster depends on the degree of crowding in the promising zone associated with one optimum. In the process of dividing the hormones population into classes, each hormone will obtain its receptor and gets the active status. The receptor represents a value by which the tropes are linked by their controlled hormones. One trope has the same receptor value as the controlled cluster of hormones. The crowding degree in the trope's zone from the search space can be estimated according to the size of the cluster. The clustering procedure takes into account a parameter that represents the expected radius of the possible clusters. This parameter, called ρ, is computed by using the following formula:

$$\rho = \left(1 - \frac{1}{n}\right) \cdot \frac{\sum_{i=1}^{SizeH} \sum_{j=i+1}^{SizeH} Dist\left(H\left(i\right), H\left(j\right)\right)}{SizeH^2 + SizeH + 1} \tag{2}$$

Where:

- *n* - represents the dimension of the search space
- *SizeH* - the size of the population of hormones
- *Dist(H(i),H(j))* - represents the Euclidian distance in the search space between the i^{th} and j^{th} hormones from the population H.

According to the computed value ρ the classes of the hormones can be identified and the population of tropes is updated. Therefore, a hormone replaces a trope in the elite population T, and also, it remains as an inactive hormone in the population H. The activity status of one hormone represents its quality of participating or not to the next step in the classification procedure. For example, if one hormone is already classified and its receptor is set up, further, that hormone will no longer be taken into consideration for another class even if the Euclidian distance from it to the other trope would be smaller than the radius ρ. Finally, each hormone will take part only into one cluster corresponding to the control trope and the tropes are the best possible solutions from each cluster of the population of hormones H.

The procedure works as follow: firstly, the hormones are sorted according to the fitness function. Then, starting with the best hormone, the population of tropes is constructed by including the current hormone and setting its receptor in order to let the trope recognizes the controlled hormones. Moreover, at this step, the other hormones from H which are not already included in other classes and are in the neighbourhood of the new trope will receive the same receptor value and their status becomes inactive. If remaining unclassified, isolated hormones will form one residual class which will not provide the best hormone as a member of the trope's population.

The update procedure is uncomplicated and it is helpful due to the fact that it does not require the number of classes in which the population of hormones is divided. In fact, the number of classes in which the hormones are divided should be chosen equally to the number of optima in the search domain. Since that number of solutions is generally unknown and it also represents one of the output data of the algorithm, it is more useful not to take into account an expected number of optimum solutions in any procedure of the described technique. The formula (2) estimates the maximum distance for which two hormones are considered as similar and corresponding to the same zone of the search space. This radius ρ is computed freely of any other additional parameter whose value is difficult to establish.

```
procedure $TropesUpdate$
T={} $//erase\ old\ tropes$
SizeT=0
Compute $\rho$ - the radius of the possible clusters
Sort hormones according to the fitness values
for $each\ hormone\ h\ from\ H$ do
    $h.receptor = 0$
end for
for $each\ h\ fromH$ do
    if $h.receptor = 0 \wedge h.inactive = 0$ then
        $T = T \cup \{h\}$ : SizeT=SizeT+1
        h.receptor=sizeT : h.inactive=1
        for $each\ k\ from\ H$ do
            if $k.receptor = 0 \wedge Dist\,(k,h) \leq \rho$ then
                k.receptor=sizeT : k.inactive=1
            end if
        end for
    end if
end for
```

D. Feedback Control

The Feedback Control procedure is responsible for keeping the balance between the exploration and exploitation of the search space. Each new generated hormone has its own probability of replacing its parent. First, the new hormone is compared with its parent and the corresponding control trope. Therefore, each new created hormone replaces the parent in the population if the new hormone is better than the corresponding control trope or if its performance value is in between parent's performance and the corresponding trope's performance; otherwise, if the new hormone is weaker than its control trope or its parent, it will survive in the next generation with the a small probability value computed by the following formula: Consider: ratio λ_i computed as follows:

$$\lambda_i = \frac{1}{|C(H(i))|} \cdot \sum_{i=1}^{|C(H(i))|} \{1 \mid w_i = true\} \tag{3}$$

Then,

$$p_H\,(H(i)) = \lambda\ if\ \lambda \leq c \tag{4}$$

$$p_H\,(H(i)) = 0\ ,otherwise \tag{5}$$

where

- λ_i represents the ratio of hormones from the i^th cluster which increases the performance in the last step
- *c* is a predetermined parameter from the interval [0,1] (e.g. 0.2).
- *C(H(i))* - represents the cluster of the hormone *H(i)*

Each trope is accompanied by a sequence composed by Boolean values. Each component of the sequence corresponds to a hormone from the trope's controlled cluster and the true value is established if the hormone resulted in the last action overcome the parent's performance or its performance is closer to the corresponding trope's performance. The size of the sequence is equal to the size of the cluster. Therefore, the ratio between the true values against the size of the sequence is a proper measure of the occurrence of a change in the environment. For example, if the entire cluster of hormones comes closer to the specific trope in the last generation, it means that the position of the optimum in the zone remains unaffected; otherwise, if the cluster's overall performance decreases, it means that the optimum has changed and the cluster is no longer appropriate to the current position of the optimum. If a change occurs in the environment, the hormone population senses the change through the probability values pH that become bigger and finally regroups into new classes according to the new configuration of the optima in the search space.

This process takes place without any extra mechanism which reports if a change happens or not. The balance is obtained in an uncomplicated manner by allowing the worse descendents to survive if a change occurs in the environment. In this way, the diversity increases and the exploration process restarts. In the stationary phases, the technique encourages the better hormones to survive and the replacement procedure is an elitist one.

The relaxation into the replacement procedure improves the overall performance of the algorithm in dynamic environment and contributes to the good balance between the convergence and diversity of the population in the search space.

```
procedure $Feedback$
for $each\ t\ fromT$ do
    Compute the values $\lambda(t)$
    for $each\ h\ fromC(t)$ do
        if $\lambda(t) \leq c$ then
            $p_H\,(h) = \lambda(t)$
        else
            $p_H\,(h) = 0$
        end if
    end for
end for
```

where

- $\lambda(t)$ represents the ratio of hormones which increases the performance in the last step, from the cluster controlled

by the trope *t*
- *C(t)* is cluster controlled by the trope *t*

E. Searching

The population of hormones evolves by using evolutionary operators as mutation and selection. Therefore, the base population explores the search space, while the trope population behaves as elite population and also as a leader among the multiple optima. According to the computed values of the probabilities pH, the hormones are selected by using a tournament selection mechanism. A hormone is preferred if its probability value pH is higher. The idea of this procedure is to encourage exploring those zones of the search space, which are more critical regarding the presence of identified optimum. If for a specific cluster, the pH is higher, it means that the hormones were not able to attain an increasing performance during the last steps and the related trope is not close to one potential optimum. The hormones from the uncertain cluster will further suffer the effects of mutation. Otherwise, if the pH value is smaller or null, it means that during the last steps, the related cluster established in the region of a possible optima and further, those hormones will have a higher chance to be preserved.

The selection mechanism promotes the uncertain hormones to be subject of the mutation operator. The mutation procedure alters one real-value gene from the hormone representation by adding or subtracting a randomly generated value. The altered gene is randomly selected.

The offspring of the mutated hormones replace their parents in special circumstances, otherwise, the parents survive. After a hormone is obtained, it is compared with the corresponding trope according to the fitness value:

1) if the hormone's performance overcomes the trope's fitness and its location is in the vicinity of the controlling trope of the parent's cluster, the new hormone replaces the parent, and the parent becomes inactive, otherwise:
2) if the descendant's performance is better than the parent's performance and the parent is not among the tropes, the descendant survives by replacing the parent and the parent becomes inactive otherwise:
3) if the pH value of the parent is not equal to zero and the parent is still active, the new hormone replaces the parent and the parent becomes inactive.

The three cases of replacing the parents exclude themselves. The parent survives only if its descendent is worse and also the parent is uncertain regarding the identification of one possible optimum. Each time a parent is replaced, its status becomes inactive in order to not permit its later replacement in the situation 3). The searching procedure represents a repetitive process, which involves the following steps: selection of the parent, creating the descendent by using the mutation operator and replacement mechanism. The three steps are repeated until the next population of hormones is created.

procedure *Search*

```
for $k = 1\ to\ Size(H)$ do
    $Select\ h_i\ from\ H$
    $h_{new} = MUTATE(h)$
    $Let\ be\ t(h_i)\ the\ controlling\ trope$
    if $(fit(h_{new}) > fit(t(h_i))) \wedge (h_{new} \in C(t(h_i)))$ then
        $Replace\ h_i\ with\ h_{new}$
        $h_i.inactive = true$
    else
        if $(fit(h_{new}) > fit(h_i))$ then
            $Replace\ h_i\ with\ h_{new}$
            $h_i.inactive = true$
        else
            if $p_H(h_i) > 0 \wedge h_i.inactive = false$ then
                $Replace\ h_i\ with\ h_{new}$
                $h_i.inactive = true$
            end if

        end if
    end if
end for
for $each\ t\ from\ T$ do
    Compute $t.sequence$
end for
```

As presented before, each trope encloses the sequence of Boolean value corresponding to the progress of each hormone from the corresponding cluster. Therefore, if one controlled hormone increases its performance during the last search procedure, the corresponding Boolean value from the trope's sequence is set to true, otherwise, it is set to false. Moreover, the number of true values from a sequence provides an image of the local search progress and it can be considered as a warning of the possible changes in the environment.

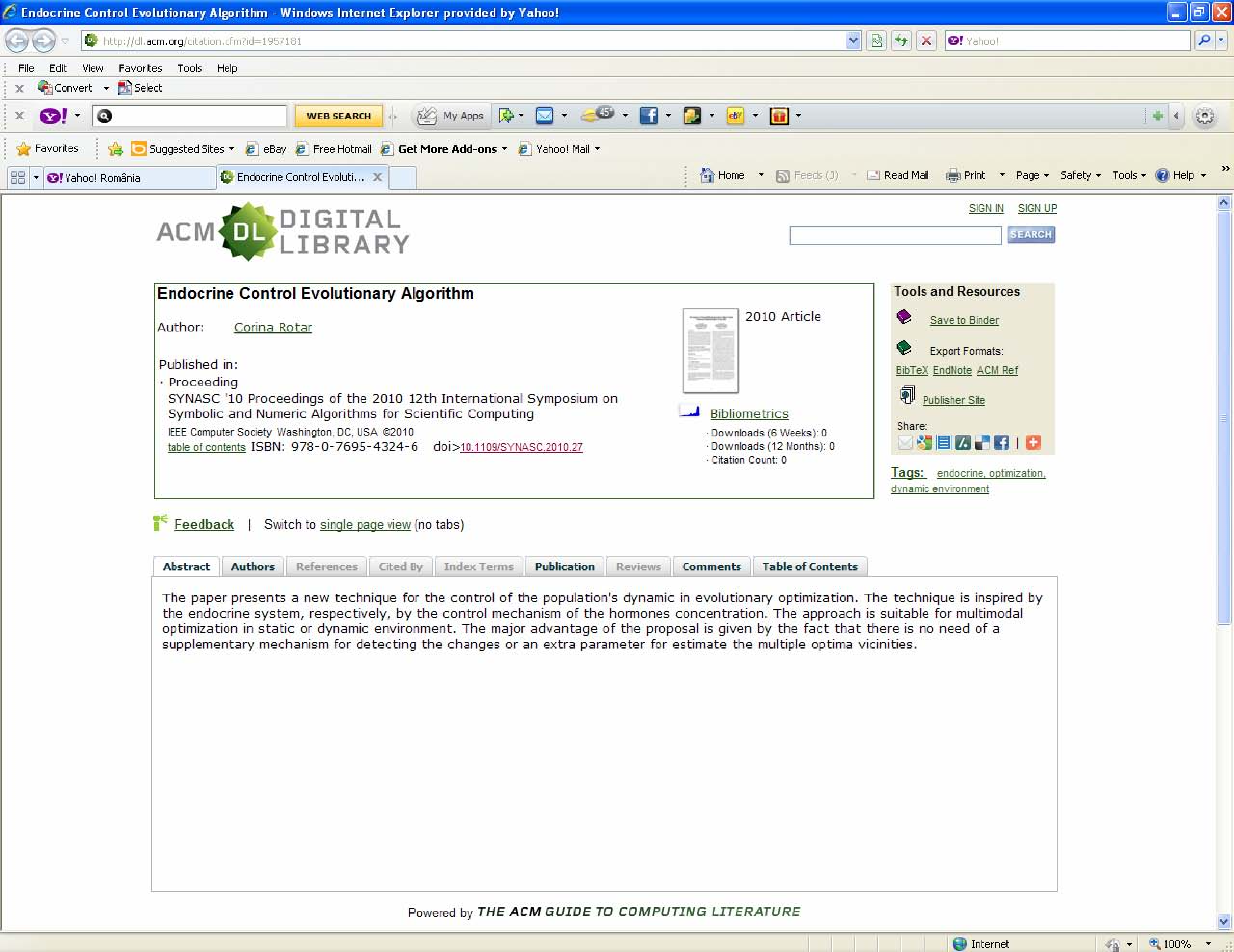
Endocrine Control Evolutionary Algorithm is described next:

Algorithm *ECEA*

```
Initialization
while (stopping condition is false) do
    Call TropesUpdate
    Call Search
    Call Feedback
end while
```

IV. EXPERIMENTS

In the following experiments, the Moving Peak Benchmark is considered [11]. A change occurs when the peaks' positions, heights, and widths are randomly modified. The first experiments were conducted for 8 considered scenarios, with restarting the hormone population before each change in the environment occurs. The size of the base population does not overcome the maximum value of 100 hormones for each scenario involved. The trope population size represents a fraction of the current size of the base population. In our tests, we consider that maximum number of tropes is less than half from the number of hormones. In case that the tropes population size becomes higher than the pre-set fraction of hormones population's size, it is truncated as the



Endocrine Control Evolutionary Algorithm

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The paper presents a new technique for the control of the population's dynamic in evolutionary optimization. The technique is inspired by the endocrine system, respectively, by the control mechanism of the hormones concentration. The approach is suitable for multimodal optimization in static or dynamic environment. The major advantage of the proposal is given by the fact that there is no need of a supplementary mechanism for detecting the changes or an extra parameter for estimate the multiple optima vicinities.

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