Placing on a basis SWARM intelligence and genetic evolution

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Abstract

New technologies of the placing problem decision using mathematical methods in which principles of natural mechanisms of decision-making are put in pawn are offered. The placing problem is represented in the form of adaptive system, on the basis of integration of evolutionary and swarm approaches to decision search. The search process which is based on modeling of adaptive behaviour of a particle swarm is organized in space of decisions with disorder linguistic scales. For strengthening of convergence of algorithm and ability of an exit from local optimum the organization of search procedure is made on the basis of hybridization swarm intelligence with genetic search. In comparison with existing algorithms improvement of results is reached. Experimental researches were spent on IBM PC. Comparison with known algorithms has shown, that at the decisions of value of criterion function received by means of hybrid algorithm it is better on the average on 3-4 %.

Keywords: a particle swarm; genetic search; collective adaptation, self-organizing, placing, optimization.

Introduction

Feature of designing VLSI is very big area of search of decisions [1]. For this reason there is a problem connected to huge number of possible design decisions, which are necessary for investigating to choose the decision which would meet entrance requirements and which would be close to optimum from the point of view of objects in view. The purpose of designing can be, for example, achievement of the maximal speed or the minimal cost. Restrictions are time delays, the area of a crystal or the limiting sizes of the case and the maximal number of conclusions. Many subtasks of synthesis and formation of topology are NP-hard, i.e. the number of steps during search of the decision of these subtasks grows after an exhibitor.

The review and the analysis of existing approaches has revealed the following: many authors undertake attempts of data above the specified tasks to tasks of integer programming. Mathematical models of tasks to which standard methods of optimization were applied, such as methods of linear programming, dynamic programming have been received, etc. In the given statement it is theoretically possible receptions of global result. However, as not one of standard methods does not exclude an opportunity full sort out, the given methods appear unacceptable for tasks of real dimension. In this connection developers of algorithms have been compelled to develop algorithms based on heuristics.

One of powerful methods of integer programming is the method of branches and borders. In search algorithms constructed under the circuit of a method of branches and borders the basic scientific problems are methods of calculation of the bottom estimation and methods of branching which define efficiency of a method as a whole. Development of these methods is carried out in view of specificity of a problem. It makes search by more purposeful. Distinctive features of a method of branches and borders is: an opportunity of reception of a strict local optimum; whether presence of the information on that is the received decision a global optimum; presence of the information on the greatest possible deviation of the received decision from global.

It allows to make more effective a technique during search of the decision. However the given algorithms differ enough the big labour input and do not guarantee reception of optimum result for polynom time. Except for that by development of a design procedure of the bottom estimation there are difficulties for the account of all complex of specific features of a problem. Therefore very big class of algorithms is based on various sorts heuristics, providing receptions of comprehensible result in polynom time. Usually such algorithms divide on consecutive and iterative. In a basis of work of these algorithms is a search in space of decisions.

Essence of consecutive algorithms in consecutive narrowing initial space of decisions while in it there will be no one decision. On each step, chosen on the previous step space, it is broken by partial decisions on subspaces. For example, at placement space it is broken on subspaces according to a choice of the element placed in a position considered on the given step. Then according to heuristics the choice subspaces for splitting into the following step is carried out. Consecutive algorithms differ the least labour input, but on the other hand, give the least quality. The basic problem of consecutive algorithms is a choice of alternative on each step. And the second - a problem of sequence of the decision of the same tasks. So, for a problem of trace it is a problem of sequence routing connection. For a problem of placement it is a problem of sequence of consideration of positions or a problem of sequence of consideration of elements.

For consecutive algorithms the full decision of a task turns out after performance of last step.

On the contrary, iterative algorithms provide presence of any initial decision. The essence of iterative algorithms consists in consecutive improvement of the decision on each iteration.

Search in space of decisions. is convenient for presenting as focused graph $G = (X, Y)$, where $X = \{xi|(i=1,2 \dots k)\}$ - set of vertices, each of which is identified with one of decisions. Presence of edge $uk= (xi, xj)$ testifies to existence of some operator $fl \in F$, which transform a decision corresponding to vertex xi, in a decision corresponding to vertex xj.

Standard iterative algorithms do not guarantee reception of global result. Work of such algorithms comes to the end or after hit in a local optimum, or after performance of the next quantity of steps. Recently the further perfection of iterative algorithms was development of the search methods based on modeling of natural processes. Methods of genetic search (evolutionary adaptation), methods of alternative search adaptation, method of swarm intelligence. Being inherently iterative, algorithms on the basis of modelling differ from usual iterative procedures of " blind searc».

All three methods concern to methods of the casual directed search, but have essential differences among themselves.

Simulated Annealing. Not pressing in background and theoretical calculations of simulated annealing can be described essence of modeling as follows [2]. Parameters which names reflect a history of occurrence of a method are set. It Tн,Tк initial and final temperature, Δt - an interval of change of temperature. Temperature T varies from Tн up to Tк with an interval Δt. Initial value Tн - high, Tк - low, is usual Tк=0. At each value T the set of iterations is carried out.

On each iteration the following actions are carried out. With the help of some operator D trial change of decision is carried out. If trial change has led to improvement parameter F this change is fixed. If trial change has led to deterioration F on size ΔF change is kept with probability

$P = \exp(-\frac{\Delta F}{kT})$, k - a constant.

r- the random number gets out of uniform distribution from zero up to unit. If r≤P that change is kept, if r> P that is carried out return to the previous decision.

Actually the algorithm of simulated annealing realizes the iterative approach to the decision problems of optimization, thus in case of failure on some iteration preservation of the last change worsening values of a optimization parameter is possible with some calculated probability.

Lack of a method of simulated annealing is that it does not store the information on the different actions executed on the previous iterations. Feature of a method is that quality of the received decision in many respects depends from initial, the it is better initial, the above chance improved.

Alternative search adaptations on a basis probability training automatic devices. In 1948 U.Eshbi has suggested the analog electromechanical device - homeostat, modeling property of alive organisms to support some characteristics (for example: a body temperature, the maintenance{contents} of oxygen in blood, etc.).

Homeostat of U. Eshbi represents dynamic system dU/dt=F (U, X, E) [3].

The condition of system is described by vector U=(u1,u2,…,un) and defined as a vector of controlled parameters X={x1,x2,…,xm},, and a vector of the unguided parameters describing stochastic properties of environment. Change of condition U of homeostat is carried out with the help of managing influence on parameters X, and the purpose of management is removing homeostat in set condition U *, i.e. minimization of parameter Q = | U-U * |.

Process of homeostat removing in the set condition is made by a trial and error method which is actually reduced to casual sorting out managing influences on X with the subsequent check of their efficiency and reaction. Thus two kinds of reaction are possible. Negative reaction R- arises in reply to the managing influence which is not resulting in reduction parameter Q. This reaction, according to algorithm of homeostat, causes a choice of the next casual influence. Positive reaction R + follows at reduction of parameter Q. It causes recurrence of influence resulted to positive result.

The behaviour of homeostat is expedient and is directed on search and preservation in system of a condition which provides positive reaction R+.

Significant step in development of technical devices, for imitation of adaptation, the suggested by M. L. Tsetlin the approach based on use of probability training automatic devices was [4].

Let's present work of homeostat as functioning of the some the probability automatic device working in the casual environment. Then homeostat breaks up to two components - environment and the managing device.

Environment is understood as object of management (object of optimization), and the managing device works according to algorithm of casual search.

Being based on this idea, M.L.Tsetlin has placed on the environment described by casual reaction, the probability automatic device of adaptation (AA) for realization of function of the managing device. Adaptation of the automatic device is made by self-training during its functioning.

On each step of work of adaptive system according to values A in output of the automatic device of adaptation AA the managing influence U resulting{bringing} in change of a condition of S environment and parameter F (S.) (fig. 1) is formed.

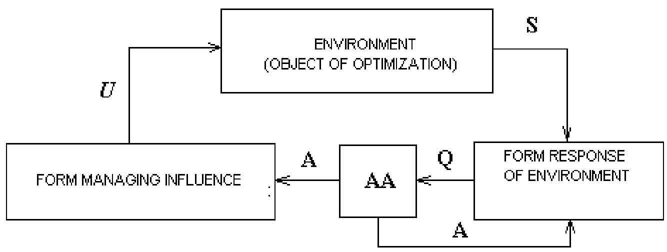

Fig.1.

Q - is the response of environment to realization of managing influence. Under action Q, the automatic device passes in a new condition and develops new target values And.

One of the major problems of designing VLSI is the problem of placing of elements on a chip. In existing algorithms [1], on the one hand, communication between these problems is insufficiently deep, on the other hand, received decisions, from the point of view of their optimality, as a rule, are unsatisfactory [1]. Review resulted in work, comparison and the analysis of the developed algorithms of placing shows, that for creation of the effective algorithm meeting modern requirements, new technologies and approaches are necessary. For reduction of time of the decision, placing problems various heuristic ways of restriction of the search, based on the mathematical laws are used, allowing to reduce time and spatial complexity of algorithm [2]. Recently for the decision of various "difficult" problems which placing problems concern also, the ways based on application of methods of an artificial intellect [2,3] are even more often used. Prompt growth of interest to working out of the algorithms inspired by natural systems [3] is especially observed.

One of new directions of such methods are the multi agent methods of intellectual optimization which are based on modeling of collective intelligence [4, 5]. Optimization with use of a particles swarm (Particle Swarm Optimization, PSO) - it a method of search which is based on concept of population, and models behaviour of birds in flight and jambs of fishes [6,7]. The particles swarm can be considered as multi agent system in which each agent (particle) functions independently by very simple rules. In such cases speak about swarm intelligence.

In work the method of the decision of a problem of placing on a basis swarm intelligence [6] and genetic evolution [8] is stated. The composit architecture of multi agent systems bionic search is offered.

Substantive provisions

Let the set of elements A = {aj | j=1,2, …, n} and set of positions Π = {пi|i=1,2, …, with} on chip is given. As scheme model hypergraph H = (X, E), where X = {xi | i=1,2, …, n} - set of the nodes modeling elements, E = {ej | ej□X, j=1,2, …, m} - set of the hyperedges modeling chains, connecting elements is used. For placing of all elements condition performance c□n is necessary. Any placing of elements in positions represents shift P=p (1), p (2), …, p (i), …, p () where p(i) sets number of an element which is appointed in a position пi. Depending on the chosen criterion for an estimation of results of placing criterion function F (P) is entered. The placing problem consists in search of optimum value of function F on set of shifts of P. For fuller account of communications between placing and trace problems the criterion based on estimations of number of chains, crossing set chip lines is used. These lines can be or direct, crossing all chip, or closed and limiting some area.

Let on chip the basic grid is imposed. The set of edges of grid G = {gi|i=1,2, …, ng} breaks the chip on blocks. We will consider, that positions пi settle down inside blocks. As initial data for chip are set D = {di|i=1,2, …, nd}, where di - throughput of an edge gi, i.e. number of chains (lines) which can cross it is set. Values di are defined by the sizes of an edge and restrictions on a lining of connections.

We name cycle Lk made of edges of grid G and limiting some area, area border. As throughput PSk of border Lk we will understand total throughput of edges of the grid which are a part Lk, i.e.

PSk = ∑ di, where i □ I = {i | gi □ Lk}.

Let's designate as Hк - number of the chains connecting elements, located in the area limited Lk, with the elements located out of this area. We will enter the border characteristic:

□к = (PSk - Hк) / PSk

The greater value has □к, the it is easier to carry out a lining of communications through border Lk.

Let some placing of elements and some set of areas for which sets of borders L = {Lk|k=1,2 are defined, …, kL} is set. We will find among characteristics of borders the least □min, i.e. □k [(PSk-Hk)/PSk) □□□min]. Size F = □□min is used as criterion of optimization. An optimization problem - maximization □min.

The general structure of representation of decisions in algorithm of placing on a basis swarm intelligence and genetic search.

In heuristic algorithms swarm intelligence the multidimensional space of search is occupied by a swarm of particles [6]. Each particle represents some decision. In our case it is the decision of a placing problem. Process of search of decisions consists in consecutive moving of particles to search space. The particle position i in space of decisions at the moment of time t (t has discrete values) is defined by a vector xi (t). On analogies to evolutionary strategy, a swarm it is possible to treat as population, and a particle as the individual (chromosome). It gives the chance constructions of hybrid structure of search of the decision, based on a combination of genetic search to methods роевого intelligence. A link of such approach is the structure of data describing in the form of a chromosome the decision of a problem. If as a particle the chromosome the number of the parameters defining position of a particle in space of decisions should be equal to number of genes in a chromosome is used. Value of each gene is postponed on a corresponding axis of space of decisions. In this case there are some requirements to structure of a chromosome and values of genes. Values of genes should be discrete and independent from each other, that is chromosomes should be homologous. In work the approach to construction of structures and principles of coding of the chromosomes providing them homologous and possibility of simultaneous use in genetic algorithm, and in algorithm on the basis of a particles swarm is offered. As above placing of elements in positions already was specified is set by shift of elements P = <pi|i=1,2, …, n}>. The chromosome corresponding to decision P, consists of the genes which number on unit is less than number n elements in vector P. H = {gj | j=1,2, …, (n-1)}. Possible values of a gene depend on a locus and vary in the range of 1 □ gj □ j+1. Decision P turns out by application to a chromosome of recursive procedure of decoding.

Construction of vector P is made consistently with use of basic vector B = {bi | i=1,2, …, n}. We will designate through Pj partially constructed vector of placing on a step j. On each step j vector Pj+1 by inclusion in Pj an element bj□B is under construction. The inclusion place bj in Pj is defined as a result of gene decoding gj□H. Definitively vector P will be constructed on a step n, i.e. P=Pn. In the beginning is accepted, that P1 = {b1}, i.e. P1 includes the first element b1□B. Let Pj = {pij | i=1,2, …, t}. Then P1 = {p11}, P2 = {p12, p22}, P3 = {p13, p23, p33} etc. On each step j chromosome decoding is under construction Pj+1. The gene gj for this purpose gets out and the place i=gj element inclusions bj+1 in vector P2 is defined. Pj+1 it turns out by an insert in Pj an element bj+1 after pji-1 and shift on one position of elements pji-1+k, k=1,2, …, (j-i). Communication between elements plj and pj+1l is defined by means of following expressions:

plj+1=pj, l=1,2, …, (i-1); pij+1=bt+1; pi+kj+1 = pji-1+k, k=1,2, …, (j-i).

Let's consider a decoding method on an example. Let there is chromosome H = <1,2,2,1> and basic vector B = <2,3,1,5,4>. In the beginning we accept, that P1 = {b1} = {p11} = {2}.

On the first step is under construction P2 by inclusion b2=3 in P1. The gene g1 is for this purpose considered. i=g1=1. From here p2i=p21=b2=3; p22=p11=2. So, P2 = {3,2}.

On the second step is under construction P3 by inclusion b3=1 in P2. The gene g2, i=g2=2 is considered. From here p13=p21=3; pi3=p23=b3=1; p33=p22=2. So P3= {3,1,2}.

On the third step is under construction P4 by inclusion b4=5 in P3. The gene g3 is considered. i=g3=2. Hence, p14=p13=3; pi4=p24=5; p34=p23=1; p44=p33=2. From here P4 = {3,5,1,2}.

On the fourth step is under construction P5 by inclusion b5=4 in P4. The gene g4 is considered. i=g4=1. Hence, pi5 == p51=4, p25=p14=3; p35=p24=5; p45=p34=1; p55=p44=2. Definitively P=P5 = {4,3,5,1,2}.

The phenotype, i.e. the decision of a problem of placing, turns out after decoding of chromosomes and construction of vector P. At placing of one-dimensional elements by value pi□P number of the element placed in i-th of a position is.

Placing on a basis swarm intelligence

The basis of behaviour of a particles swarm is made by the self-organizing providing achievement of overall aims of a plenty on a basis of interaction. Each particle is connected with all swarm, can co-operate with all swarmand it gravitates to the best decision of a swarm. On each iteration each particle moves to a new position. The new position is defined as

$$xi\ (t+1) = xi\ (t) + vi\ (t+1),$$

Where vi (t+1) speed of moving of a particle from a position xi (t) in a position xi (t+1). The initial condition is defined, how xi (0), vi (0 [6].

The resulted formula is presented in the vector form. For separate measurement j the formula will become space of search

$$xij\ (t+1) = xij\ (t) + vij\ (t+1), \qquad (1)$$

where xij (t) - a particle position i in measurement j, vij (t+1) - speed of a particle i measurement j.

Let's enter designations:

fi (t) - current value of criterion function of a particle i in a position xi (t);

x*i (t) - the best position of a particle i which she visited from the beginning of the first iteration, and f*i (t) - value of criterion function in this position (the best value of a particle i);

F (t) - the best value of criterion function among particles of a plenty at the moment of time t, and x (t) - a position with this value.

Then speed of a particle i on a step (t+1) in measurement j is calculated as vij (t+1)=w·vij (t) + k1·rnd (0,1)·(x*ij(t)-xij (t)) + k2·rnd (0,1)·(xj (t)-xij (t)),(2)

where rnd (0,1) - a random number on an interval (0,1), (w, k1, k2) - some factors. The formula for calculation of speed is made of three components.

The last speed vij (t) acts in a role of memory of a particle about its movings to the past and is an inertial component

Value of the second component named cognitive, to in direct ratio current distance of a particle from its best position which has been found from the moment of start of its life cycle. The cognitive component acts in a role of individual memory of the optimal positions of the given particle.

Value of the third component named social, to in direct ratio current distance of a particle from the best position of a plenty at the moment of time t. Thanks to a social component the particle has possibility to move in the optimum positions found the next particles.

In our case the position xi (t) is set by means of chromosome Hi (t) = {gij | j=1,2, …, (n-1)} which structure is considered above. We will notice, that speed vi (t) chromosome Hi (t) has the same structure, as. The position xi (t) that is chromosome Hi (t) is the decision, and speed vi (t+1) is considered as means of change of a chromosome, that is the decision.

Distinctive feature of a position xi (t) = Hi (t) is that possible values of a gene gij depend on a locus and vary in the range of 1 □ gij □ j+1. We will designate, as xci (t) and vci (t) a position and speed for which are carried out specified above restriction. We will consider a reception technique xci (t) and vci (t). Calculation is carried out in two stages. In the beginning pays off vij (t+1).

vij (t+1) =w·vcij (t)+k1·rnd (0,1)·(xc*ij (t)-xcij (t))+k2·rnd (0,1)·(xcj (t)-xcij (t)). (3)

Then on vij (t+1) pays off vcij (t+1).

□1, if 0,5 □ vcij (t+1);
vcij (t+1)=□ 0, if-0,5 <vcij (t+1) <0,5;
□-1, if vcij (t+1) □-0,5. (4)

The new position is calculated as follows.

In the beginning pays off

xij (t+1) = xcij (t) + vcij (t+1) (5)

Then the position with the integer value concluded in the set range is defined.

□j+1, if j+1 □ xcij (t+1);
xcij (t+1)=□xij (t+1), if 1 □ xij (t+1) □ j+1;
□1, if xcij (t+1) □□1. (6)

The work scheme swarm algorithm of placing includes following steps:

1. According to statement of a problem of placing and initial data the structure of data particles (chromosome) is formed and ranges of values for each measurement (axis) of space of search are established.

2. Initial "casual" population of particles, t=0 is created. For each particle the initial position xci (0) and initial speed of moving vci (0) is in a random way set. With that end in view in each formed chromosome corresponding to a position xci (0), to each gene, laying in a locus j, the integer value laying in a range 1 □ gj □ j+1 is in a

random way appropriated. To genes of the chromosome corresponding to speed of moving vci (0) rather small values are set.

3. t = t+1.

4. Criterion function fi (t) for each particle pays off.

5. For each particle positions xc*i (t+1) which she visited from the beginning of the first iteration, and value of criterion function f*i (t+1) in this position are defined the best.

7. Are defined the best position of a plenty on a step t and value of criterion function F (t) in this position.

8. The best particles from the point of view of criterion function appears "centre of gravity". Vectors of speeds of all particles direct to these centres. The further the particle is from the centre, the it possesses the big acceleration. Under formulas (3,4) for all particles speeds of an increment pay off.

9. New positions of particles in space of decisions pay off.

10. Steps 3-9 repeat the set number of times.

11. Last "centre of gravity" corresponds to the found local optimum.

Thus, according to algorithm digging after casual initialization of population of particles for each of them value of criterion function fi (t+1) is calculated. If it appears better, than f*i (t), f*i (t+1) = fi (t+1), otherwise f*i (t+1) = f*i (t). Further, among fi (t+1) the best value F (t) gets out and then new values of speeds of particles and their new positions in space of decisions are calculated according to the formulas resulted above. Iterative process repeats. We will notice, that the formula (1) actually is the operator (we name it роевым) with which help the current decision changes.

Hybridization swarm intelligence with genetic search

The composit architecture multi agent system of bionic search for the decision of a problem of placing on a basis swarm intelligence [8] and genetic evolution [8] is offered. Three approaches to construction of such architecture are considered.

The first and most simple approach to hybridization consists in the following. From the beginning decision search is carried out by genetic algorithm [9]. Then on the basis of the population received on last iteration of genetic search, population for swarm algorithm is formed. Formed population joins the best, but excellent from each other chromosomes.

At the second approach the method of a particles swarm is used in the course of genetic search and plays a role similar to genetic operators. In this case on each iteration of genetic algorithm synthesis of new chromosomes on the one hand is carried out with the help crossover and mutations, and on the other hand by means of operators of a method of particles swarm under formulas (5,6) and the modified formula (3). The modified formula turns out by removal in the formula (3) second components and looks like

$$vij\ (t+1) = w \cdot vcij\ (t) + k \cdot rnd\ (0,1) \cdot (xcj\ (t) - xcij\ (t)). \qquad (7)$$

The estimation of time complexity of operators of a particles swarm does not exceed an estimation of time complexity of genetic operators. The estimation of time complexity of genetic algorithm does not exceed an estimation of time complexity of algorithm of a particles swarm. In this connection the general estimation of time complexity at any approach to hybridization does not exceed an estimation of time complexity of genetic algorithm and lays in limits O(n2).

Conclusions

On the basis of the comparative analysis of existing approaches and methods for the decision of a problem of placing are used the multiagents methods of intellectual optimization which are based on modeling of adaptive behaviour of a biological system. In work the placing problem is presented in the form of a set a component of Particle Swarm.

Unlike a standard paradigm of swarm method instead of a metric (numerical) scale are used a disorder linguistic scale of measurements. Efficiency increases swarm algorithm can achieve by adaptive management in parameters of procedure of placing, Experimental researches were spent on IBM PC. For the analysis of accuracy of received decisions a number of examples with a priori known optimum value of criterion function has been synthesized. The examples containing to 1000 elements were exposed to research. Presented swarm algorithm of placing finds decisions for problems of the big dimension, not conceding on quality, and sometimes and surpassing the analogues with smaller time expenses, the Probability of reception of the optimum decision has made 0.9. Comparison with known algorithms has shown, that at a smaller operating time at the decisions of value of criterion function received by means of beer algorithm it is better (less) on the average on 6 %. On the average program start provides findings of the decision differing from optimum less, than on 1 %.

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