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An Enhanced Algorithm for Floorplan Design Using Hybrid Ant Colony and Particle Swarm Optimization

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Abstract— Floorplanning is the very first stage of the Very Large Scale Integrated-circuit (VLSI) physical design process, the resultant quality of which is very important for successive design stages. Floorplanning deals with position, shape and movement of the circuit modules and make sure that no of them overlaps. It aims at minimizing the total layout area and interconnection wire length. Several algorithms have been deployed for floorplanning optimization problems. Here we use a hybrid Ant Colony and Particle Swarm optimization algorithm. Although PSO has simple principle and easy to be implemented and can eventually locate the desired solution, however, its practical use in solving engineering optimization problems is severely limited by the high computational cost and slow convergence rate. Hence, Ant Colony optimization is employed to speed up local search and to improve the precision of the solution. Adding some abilities of ACO to the PSO algorithm improves the performance of the resultant hybrid algorithm.

Keywords— Floorplanning, Ant colony optimization, Particle Swarm optimization, Dead space, wirelength.

I. INTRODUCTION

A. Floorplanning

Floorplanning is an essential design step for hierarchical, building-module design methodology, since it provides early feedback that evaluates architectural decisions; estimates chip areas, and estimates delay and congestion caused by wiring. It is the process of identifying structures that should be placed close together, and allocating space for them in such a manner as to meet the sometimes conflicting goals of available space (cost of the chip), required performance, and the desire to have everything close to everything else[5].

We can classify floorplans into two categories for discussions: (1) Slicing floorplan and (2) Non-slicing floorplans. A slicing floorplan can be obtained by repetitively cutting the floorplan horizontally or vertically, whereas a non-slicing floorplan cannot. The floorplanning problem can be stated as: Let B = $\{b_1, b_2. . . b_m\}$ be a set of m rectangular modules whose respective width, height, and area are denoted by w_i, h_i, and a_i, $1 \le i \le m$. The objectives of floorplan optimization problem are to minimize the area of B and reduce wire lengths of interconnects subject to the constraints that no pair of blocks overlaps.

B. Ant Colony Optimization

The field of ''ant algorithms'' studies models derived from the observation of real ants' behavior, and uses these models as a source of inspiration for the design of novel algorithms for the solution of optimization and distributed control problems. VOAS (Variable –Order Ant System) showed improved results in terms of purely area optimization as well as composite function of area and wire length [3].The general procedure of the ACO algorithm manages the scheduling of four steps [7]:

Step 1: Initialization. Initialize the ACO parameters and the initial positions of the ants.

Step 2: Solution construction. Each ant constructs a complete solution to the problem according to a probabilistic state transition rule. The state transition rule depends mainly on the state of the pheromone and visibility of ants.

Step 3: Pheromone updating rule. When every ant has constructed a solution, the intensity of pheromone trails on each edge is updated by the pheromone updating rule.

Step 4: Terminating criterion controlling. Steps 2 and 3 are iterated until a terminating criterion.

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C. Particle Swarm Optimization

The particle swarm optimization (PSO), originally introduced by Kennedy and Eberhart [11], is an optimization technique inspired by swarm intelligence and theory in general such as bird flocking, fish schooling and even human social behavior. The PSO algorithm works by simultaneously maintaining several candidate solutions in the search space. During each iteration of the algorithm, each candidate solution is evaluated by the objective function being optimized, determining the fitness of that solution. Each candidate solution can be thought of as a particle "flying" through the fitness landscape finding the maximum or minimum of the objective function. Since the PSO algorithm was proposed, it has aroused great interest among the academic community, massive research results have been presented in only a few years [10]. The steps of the detailed working of PSO algorithm can be described as follows:

Step 1: Load modules data and initial the parameters of the PSO algorithm (such as population size, generations, inertia factor, self confidence, swarm influence, etc.).

Step 2: Generate the initial population, initialize the position and velocity of each particle, and set the pBest of each particle and the gBest population.

Step 3: Calculate the fitness value of each particle.

Step 4: Check each particle, if its fitness value is better than its pBest, update its pBest with the fitness value.

Step 5: Check each particle, if its fitness value is better than the population's gBest, update the gBest with the fitness value.

Step 6: Adjust the position and velocity of each particle.

Step 7: If termination condition is satisfied, the algorithm stops and the inputs which gave gBest fitness is given as output; otherwise, go to Step 3.

II. Related Work

Shanavas et al[6] in their research article 'Wirelength Minimization in Partitioning and Floorplanning Using Evolutionary Algorithms' depicted that minimizing the wirelength played an important role in physical design automation of very large-scale integration (VLSI) chips. The objective of wirelength minimization can be achieved by finding an optimal solution for VLSI physical design components like partitioning and floorplanning. In VLSI circuit floorplanning, the problem of minimizing silicon area was also a hot issue. MA applied some sort of local search for optimization of VLSI partitioning and floorplanning. The algorithm combined a hierarchical design technique like genetic algorithm and constructive technique like Simulated Annealing for local search to solve VLSI partitioning and floorplanning problem. MA can quickly produce optimal solutions for the popular benchmark.

Patel et al[1] in their paper 'A hybrid ACO/PSO based algorithm for QoS multicast routing problem' mentioned that many internet multicast applications such as videoconferencing, distance education, and online simulation require to send information from a source to some selected destinations. In this paper, they presented a swarming agent based intelligent algorithm using a hybrid Ant Colony Optimization (ACO)/Particle Swarm Optimization (PSO) technique to optimize the multicast tree. The algorithm started with generating a large amount of mobile agents in the search space. The ACO algorithm guided the agents' movement by pheromones in the shared environment locally, and the global maximum of the attribute values were obtained through the random interaction between the agents using PSO algorithm. The performance of the proposed algorithm was evaluated through simulation. The simulation results revealed that their algorithm performed better than the existing algorithms.

Sowmya et al [2] in their publication 'Minimization of Floorplanning Area and Wire Length Interconnection Using Particle Swarm Optimization' described that floorplanning is an essential design step for hierarchical building module design methodology. From the computational point of view, VLSI floorplanning is NP-hard. The solution space will increase exponentially with the growth of circuits scale, thus it is difficult to find the optimal solution by exploring the global solution space. To handle this complexity swarm based optimization method has opted in this proposed work. A generalize solution has developed to take care of area as well as interconnection wire length. To achieve this weighted objective function has defined. The advantages of PSO like simplicity in implementation, not depends upon the characteristics of objective function and better performance have given support to include it as a solution method.

Emre Ugur [8] presented a project report on Particle Swarm Optimization (PSO) and PSO with Cross-over. In this work,

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Particle Swarm Optimization (PSO) method was implemented and applied to various mathematical functional optimization and engineering problems. Although, implemented exactly as described in [9], he could not obtain similar results, especially with increasing problem space. Then, he extended the original PSO method, and added the cross-over operator of the evolutionary computation techniques. Instead of applying the cross-over operator in every iteration, he evolved completely different swarms using PSO, and then later cross-overed particles from these different swarms. As a result, he obtained much better results with PSO-Cross, especially when the problem size was increased in the pure mathematical optimization problems.

III. Problem Formulation

Given a rectangular floorplanning region P with width W and height H, a set of modules M= {r_1, r_2, r_3, ..., r_m}, in which module r_i is a rectangular block with fixed width W_i and height h_i, and given a net list N specifying interconnections between the modules in M, the problem is to pack all the modules into the rectangular region P, such that they meet the following conditions:

(a) Each module lies parallel to the coordinate axes;

(b) No module overlaps with one other;

(c) All modules must be in a rectangular frame.

Given M and N, the goal of floorplanning is to optimize a predefined cost metric such as a combination of the area and wire length induced by a floorplan. In this work, the cost of a floorplan F, cost (F), consists of two parts: one is the area, area (F), which the minimum bounding rectangle of the floorplan F; the other is the sum of all interconnection lengths of the floorplan, wirelength(F), which is the wire length of all the nets specified by N. The wire length of a net is calculated by the half perimeter of the minimal rectangle which encloses the centers of the modules connected by the net.

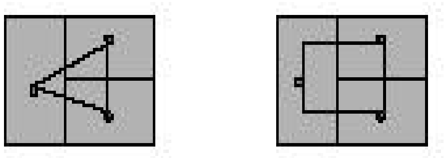

Fig.1 Calculation of wirelength

More specifically, the cost function is defined as follows:

Cost = $*A_{tot} + *W_{tot}$

$$cost(F) = w \times \frac{area}{area^*} + (1 - w) \times \frac{wirelength}{wirelength^*}$$

Where w is a weight, w {0, 1}, area and wirelength are the area and the interconnection cost of a floor plan, respectively. In the above equation, area* and wire length* represent the minimum area and the interconnection wirelength costs, respectively.

IV. Proposed Work

The purposed method is not only taking care of required area for the floorplanning but also minimization of the interconnected wire length is also involved.

Numerous hybrid PSO algorithms published in the literature where researchers combine the benefits of PSO with other heuristic algorithms such as genetic algorithm (GA), ant colony optimization (ACO) just to name a few [4].In order to optimize the wirelength and area in floorplanning process of VLSI design circuits, the two optimization algorithm viz. Particle Swarm Optimization and Ant Colony Optimization are combined into one hybrid algorithm. This hybrid algorithm adds the abilities of both the algorithms and hence improves the performance of the resultant hybrid algorithm in a more efficient way.

Pseudo code for Hybrid ACPSO

Initialize ants;

Initialize swarms;

Use ACO algorithm for evaluating local best position;

Use the PSO algorithm to adjust the movement of the particle agent in this iteration ;

Update the position and velocity of each swarm;

If fitness of current position < their best neighbors’ fitness value,

Then move to the neighbor’s position;

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If the fitness value in the last position is higher than the new position,

Then replace those lower-fitness-value block with the higher-fitness-value block from last position;

If the newly generated floorplan has more fitness than the earlier fitness, then update the floorplan with higher fitness.

V. Results and Discussions

In this work hybrid ACO PSO is implemented in C compiler using Oracle VM VirtualBox. The simulation is performed on Ubuntu 10.04 and this work is being compared with the Simple PSO algorithm in order to optimize three parameters namely dead space, wirelength and CPU processing time. One scenario is hereby summarized as follows:

Scenario: Number of modules = 33

The following table signifies the comparison of the parameters using simple PSO algorithm and that of hybrid PSO-ACO algorithm in the floorplanning process of 33 modules.

TABLE I
PARAMETER COMPARISON OF 33 MODULES

Parameter	Simple PSO algorithm	Hybrid ACO & PSO algorithm
CPU Processing time(sec)	2.270	1.840
Wire length(mm)	50592	15834
Dead Space	13.4861%	10.2487%

Conclusion: It is visible that hybrid PSO-ACO algorithm shows a required reduction in CPU processing time along with wirelength and dead space reduction . The figure here shows dead space and wirelength optimization.

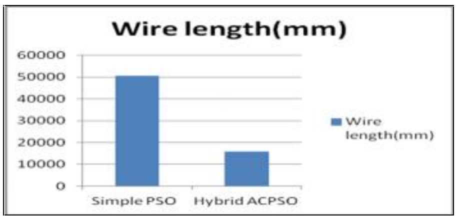

Fig. 2 Wirelength comparison of 33 modules

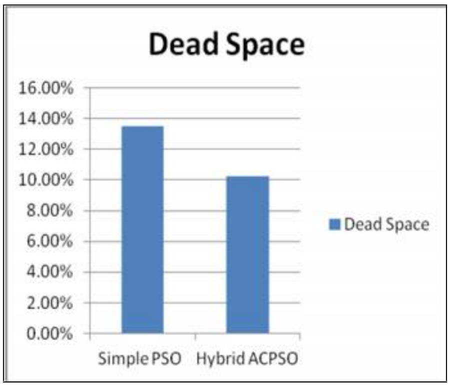

Fig. 3 Dead space comparison of 33 modules

VI. Conclusions

The problem in physical design has lot of diversity. Floorplanning is one of the process which results in time consumption and less efficient. The problem of the floorplanning has been transferred as a problem of constraint optimization to take care of non overlapping requirement. The proposed method is not only taking care of required area for the floorplanning but also how to minimize the interconnected wire length as also involved. Generally researchers see these two objectives separately which is very difficult to optimize the final circuit and costlier process.

The solution has been proposed in the respect of defining the floorplanning by means of hybrid Ant Colony optimization and particle swarm optimization; always there is a scope of having some improvement irrespective of what method have applied for solution. PSO is inspired by social behavior of bird flocking or fish or swarm schooling, while ACO duplicates foraging behavior of real life ants. In this study, we explore a simple guided mechanism to improve the performance of PSO method for optimization of multimodal continuous functions. The proposed hybrid algorithm is tested on several benchmark functions from the usual literature. Numerical results comparisons with simple PSO demonstrate the effectiveness and efficiency of the proposed hybrid method.

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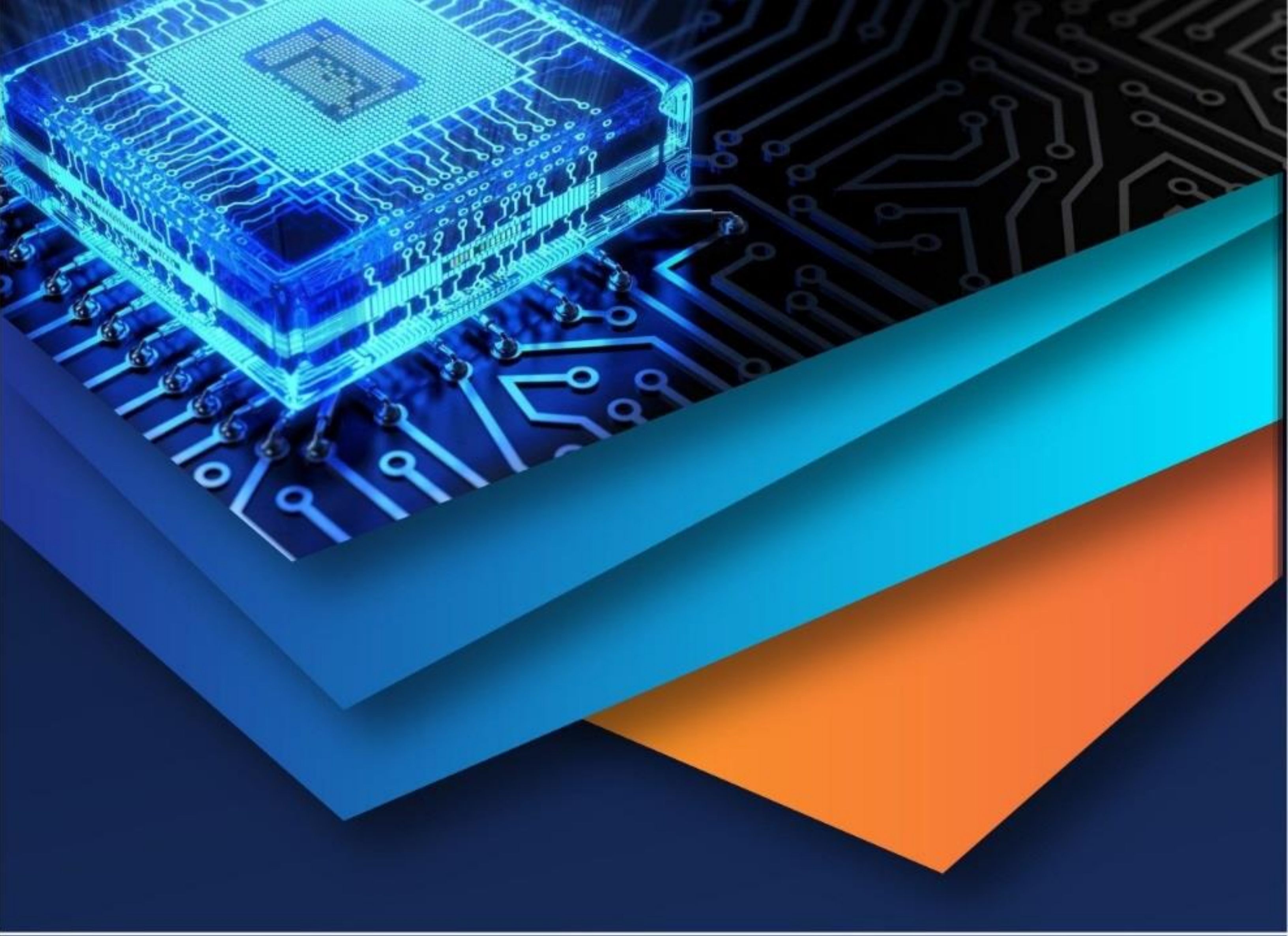

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