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# Improved Particle Swarm Optimization Algorithm for Circuit Partitioning Problems

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## Abstract

Partitioning is the vital part of VLSI Physical design stage. Particle Swarm Optimization algorithm is proposed for minimization of cut size, as it is the major objective of partitioning. PSO is inspired by the social behavior of animals. The proposed algorithm is based on inertia weight results in high efficiency and converge to the global optimal solution in short time. The algorithm is tested with various benchmark functions and an example circuit. Experimental results shows that PSO algorithm with inertia weight and boundary conditions minimize the interconnect between the partitions.

**Keywords:** Particle swarm optimization, inertia weight, boundary conditions, cutsize, partitioning

## 1. Introduction

Partitioning is the major area of research for several decades. The main reason that partitioning has become vital is the advancement in modern fabrication technology that makes smaller feature sizes, which leads to chip complexity, as the silicon chip accommodates million transistors. Circuit Partitioning is the technique of breaking down a circuit or system into smaller, more manageable blocks or modules(sub-circuits).The main objective of partitioning is to minimize the interconnections at any level of partitioning, thus making it easier for independent design. Minimizing the number of interconnections between the modules is called min cut problem.

In this paper the PSO Inertia weight and boundary conditions in solving bi-partitioning problem is evaluated. Many algorithms have been proposed to minimize the delay between the partitions, kernighan and lin proposed a heuristic for graph partitioning which is the iterative algorithm based on vertices swapping. Schweikert and Kerninghan extended KL algorithm to hypergraphs so that it can partition real time circuits, this method is inefficient due to time complexity. Tabu search approach for circuit partitioning has been proposed by Areibi et.al[1].

## 2. Circuit Formulation

The circuit is modeled as a graph (or hyper graph) and then partitioning is carried out using the modeling graph. In general a circuit can be represented by a hyper graph H(V,E), where V is the set of nodes (logic gates) and E is the set of hyper edge (nets) between the modules.

**Cut-size**: The cut size cost function is written as

$$f = \sum_{e=\psi} w(e) \text{ is minimized} \qquad (1)$$

where ψ=e is the interconnection between the modules, w(e) is the weight of the edge.

**Delay:**In general the interconnect delay is considered because currently in submicron technology interconnect delay dominates the gate delay.

$$\text{Delay} = \max_{pi \in p}(H(pi)) \quad \text{is minimized} \qquad (2)$$

Where H(pi) is the number of times a hyper path pi is cut.

**Area or balance constraint :** Area of the die should be kept small. The area function is written as

$$Ai^{min}<Area(V_i)<A_i^{max} \quad (3)$$

Where $A_i^{min}$ and $A_i^{max}$ represents the maximum and minimum area that a partition $V_i$ can occupy.

## 3. Particle swarm optimization

### 3.1 Simple PSO Algorithm:

Particle swarm optimization (PSO) is a random search technique inspired by the social behavior of bird flocking or animal hording. In PSO algorithm, each individual of the population is termed as a particle and the population is swarm. PSO starts with a random particles, each particle fly through the search space and remember the previous best position of itself and its neighbours[2].In every iteration, each particle is updated by the best solution achieved by the particle is called particle best(pbest) and the best value, obtained so far by any particle in the swarm. This best value is a global best (gbest).In each generation, the velocity of each particle and the best position encountered by any particle is updated based on the respective following equations[2

$$V_{is}=v_{is}+c_1 *rand_1(\ )*(p_{is}-x_{is})+c_2 *rand_2(\ )*(p_{gs}-x_{is}) \quad (4)$$

$$x_{is}=x_{is}+v_{is} \quad (5)$$

Consider the search space with S dimension. The $c_1$ and $c_2$ are constant values, which are generally set to 2,$rand_1$ and $rand_2$ are the random numbers. The randomness provide energy to the particles. $p_{is}$ is the best position of the particle and $p_{gs}$ is the best position found by the neighbours. The particle position is updated by the eq(5),velocity is added to the past position of the particle[3]. The velocity and position update process continues until the stopping criterion is met. The best particle found so far is taken as the best solution.

### 3.2 Improved algorithm:

In PSO algorithm, the balance between the exploration and exploitation is important the success of the algorithm. The concept of inertia weight was proposed to control the exploration and exploitation tradeoff, and to converge accurately and efficiently[4].During initialization the inertia weight is high, which allow the particles to move freely in the S dimensional space and gradually reduced overtime. In our approach, the inertia weight is set in the range of 0.9 to 0.4.Researchers have proved that decreasing inertia weight will produce good results[4].

$$V_{is}=w*v_{is}+c_1 *rand_1(\ )*(p_{is}-x_{is})+c_2 *rand_2(\ )*(p_{gs}-x_{is}) \quad (6)$$

where w is the inertia weight. Boundary conditions are proposed to enforce the particles to search within the solution space [5] and to prevent swarm explosion. In our approach reflecting boundary conditions is used, when a particle moves out of the search space, the sign of the velocity component is reversed and reflected back to the search space. Neighbourhood determines the range, the particles interact within the swarm[6].Our approach adopts the Ring topology, in this the particle communicates with K immediate neighbor(k=2 in our approach).

### 3.3 Algorithm model for circuit partitioning:

The algorithm steps for circuit partitioning is as follows:

1. Load the circuit net list in the matrix form.
2. Initialize the swarm particles and parameters(population size,iterations,inertia weight).
3. Calculate the interconnections between the partitions(bi-partition in our approach) and the fitness value.
4. Set the boundary conditions for the particles.
5. Update the best fitness value.
6. Update the particle's velocity and position based on equation 4 and 5.
7. Calculate interconnections among the partitions and fitness value of the particle.
8. Update the global best solution.
9. If the stopping criterion is met,declare the global best solution or otherwise go to step 6.

### 3.4 Benchmark functions:

Quality of the optimization algorithm is analysed using standard benchmark functions.These test functions are continuous,unimodal or multimodal and they are used in various particle swarm optimization research[6].

*Rosenbrock's valley function:*

$$f(x) = [100(x_{2i-1}^2 - x_{2i})^2 + (x_{2i} - 1)^2] \quad (7)$$

*Rastrigin function*

$$f(x) = A_n + [x_i^2 - A \cos(2\prod x_i)] \quad (8)$$

*De jong's function:*

$f(x) = {}_i^2$ (9)

*Griewangk's function:*

$f(x) = {}_i^2/4000 -(x_i/\sqrt{i})+1 \quad -600<x_i<600$ (10)

## 4. Experimental results

The proposed algorithm is analyzed using the standard benchmark functions and the algorithm is implemented using MATLAB 7.10 version. The experiment is tested with the example circuit shown in figure 1.The pso algorithm is tested for four benchmark functions,DeJong,Rastrigin,Rosenbrock,Greiwank.The algorithm is run for 50 iterations and the dimension of the search space is 10.Table 1 illustrates the experimental results of the proposed algorithm tested using the benchmark circuits.

The example circuit consists of 4 nodes and Min cut obtained by the algorithm is minimized by simultaneously increasing the iterations.

**Table 1:Experimenal results**

| Function | Dimension | Iteration | Gbest | Best mean |
|---|---|---|---|---|
| De Jong | 10 | 50 | 348.46 | 313.7242 |
| Rastrigin | 10 | 50 | 227.6 | 227.6038 |
| Rosenbrock | 10 | 50 | 1.9921e+006 | 1.9921e+006 |
| Griewank | 10 | 50 | 1.1713 | 1.1188 |

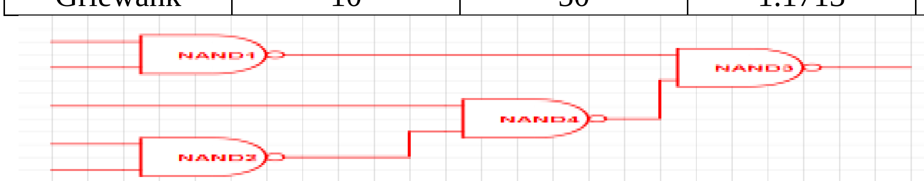


**Figure 1: Example circuit**

## 5. Conclusion

Improved PSO algorithm is applied VLSI circuit partitioning problems. The experimental results shows that the improved algorithm accelerates the particles towards the global best solution and converge to the optimal solution, and can obtain better partitioning results. In-cut obtained by improved PSO algorithm is minimized. The future work focus on the multi-partitioning on sequential circuits.

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