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Performance and Area Optimization of VLSI Floorplanning Systems Using Optimization in Bat Algorithms

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Abstract

A new performance and area optimization algorithm for complex VLSI systems is presented. The bat algorithm (BA) is a new bionic intelligent optimization algorithm to simulate the foraging behavior and the echolocation principle of the bats. The goal of this work is to suggest a new hybrid algorithm to solve integer programming by incorporating the bat algorithm with direct search methods. The suggested algorithm is named Hybrid Particle Swarm-Bat Algorithm (HPSB). In HPSB, the global diversification and the local intensification process are balanced. The bat algorithm has a good capability to make intensification and diversification search. The intensification ability of the suggested algorithm is increased by employing the pattern search method as a local search method instead of the random walk method in the classic bat algorithm. The computational results show that HPSB is a promising algorithm and outperforms the other algorithms in most cases.

Keywords: VLSI, Direct search methods, Pattern search, Hybrid Particle Swarm-Bat Algorithm (HPSB), MCNC benchmark, optimization.

1. INTRODUCTION

Very Large Scale Integration (VLSI) chips have more than tens of millions of transistors. The transistor size continues to shrink in the nanometer regime. The circuit complexity of the chip in terms of number of components is increasing rapidly. It is important that such complex VLSI chip design is experiencing remarkable growth due to advances in transistor technology and scaling in feature sizes. The Computer Aided Design (CAD) tools have become essential and play a vital role in VLSI chip design and verification process at different levels of abstraction. A flow diagram of VLSI design at different levels of abstraction (Das 2010).

The VLSI design flow can be broadly classified into two phases as logical and physical design phases. In the logical design phase, the design is created by using Hardware Description Language (HDL) to meet the functional requirements. Then, it is synthesized by considering the design constraints such as area, power and speed to generate a gate-level netlist, which is a description of the connectivity of an electronic circuit.

Floorplanning is the first step of the physical design in the VLSI design flow. It offers early feedback that assesses architectural decisions and estimates delay and congestion caused by wiring. It is a design step to estimate the chip area and wirelength by considering the optimal placement of digital blocks and their interconnections. The classical floorplanning methods are normally used for block packing to minimize the total chip area. They do not consider chip boundaries, i.e outline-free, but modern floorplanning methods deal with fixed-outline floorplanning.

There are many problems in the society which do not have exact solution and might be solved by finding the near-exact solution which is called optimization. Optimization is the act of achieving the best possible result under given conditions. The objective of an optimization algorithm is to minimize or maximize the objective function. Optimization algorithms follow the procedure of iteratively comparing various solutions to obtain a satisfactory solution for the given problem. They are mostly used in all engineering problems. Since VLSI floorplanning is a Non-deterministic Polynomial time - hard (NP-hard) problem, optimization techniques are used to yield the best possible result.

Heuristic techniques help problem solving, learning and discovery based on experience. In computer science, artificial intelligence and mathematical optimization, heuristic methods are tried wherever the conventional search method fails or is found inefficient. This method speeds up the process of finding a satisfactory solution. Different approaches such as, Genetic Algorithm (GA), Simulated Annealing (SA), Particle Swarm Optimization (PSO) and many other methods are developed. The use of these methods became very popular in several fields of science and engineering. In this research work, the following optimization methods are used for Floorplanning.

2. REVIEW OF RECENT RESEARCHES

Bat algorithm is a meta-heuristic search optimization algorithm developed by Yang (2010). It is based on the echolocation behavior of microbats with varying pulse rates of emission and loudness. The primary intention of a bat's echolocation is to act as a signal system to sense the distance. By comparing the outgoing pulse with the returning echoes, the brain and auditory nervous system of the bat produces detailed images of the surroundings which helps the bats to detect, localize and even classify their prey in complete darkness. When bats fly, they produce a constant stream of high-pitched sounds that can be heard only by them. The sound waves produced by these bats hit an insect or other animal; the echoes bounce back to the bats, and guide them to the source (Lauber 1968). Their pulses vary in properties and can be correlated with their hunting strategies, depending on the species.

Bat algorithm is one of new heuristic optimization algorithm was recently proposed by Yang (2010) and Yang (2011). The latest addition of bat algorithm is the Bat Inspired Search (BIS). The new algorithm use echolocation behavior of bats in searching for an optimum solution. Indeed, bats use several methods to detect theirs preys or other shapes around them and even in the dark places. Actually they achieve the prey by emitting a sound pulse to the air and they listen for the echoes reflect back from them. Generally echolocation calls are presented by three important features; the pulse emission rate, the frequency and the loudness. After that the information are collected and calculated in the brain to make a virtual image of their surroundings. The bat algorithm give satisfactory results in solving many dispatch problems related to biology medical, finance, 3d graphics, image processing and others.

A smart decision-making PSO-GA based hybrid method for thermal-aware non-slicing VLSI floorplanning was used by Sivaranjani & Kumar (2015). B*-tree representation has been used in this method. The placement of circuit blocks with alignment constraints are handled by Rani and Rajaram (2015) using B*-tree representation with DE algorithm. The feasibility conditions of non-slicing floorplan with alignment constraints had been examined to reduce the solution space.

An approach based on iterative Prototypes Optimization with Evolved iMprovement Steps (POEMS) algorithm was proposed by Singha et al. (2012). The GA was used for local search and a non-slicing structure B*-tree was adopted for the placement of modules. Funke et al. (2016) proposed an algorithm that finds the solutions to pack rectangular modules by minimizing the wirelength. Here the modules were placed optimally by avoiding given sets of blocked regions in reasonable runtime.

3. PROBLEM DEFINITION

Several meta-heuristics algorithms are used mainly for research of global optimal solutions for real and non-convex problems. Some of them are the Genetic Algorithms (GA), Cuckoo Search algorithms (CS), Particle Swarm Optimization (PSO). Some algorithms have achieved satisfactory results but not all of them. Therefore, new algorithms give better optimization to solve many problems having continuous search space like Bat Algorithm (BA). That's why we proposed a new hardware implementation on Field Programmable Gate Array (FPGA) of bat algorithm, it is a new proposed meta-heuristic for global optimization.

4. PROPOSED METHOD

4.1 Hybrid Particle Swarm-Bat Algorithm

PSO and Bat algorithms have their own advantages. But, metaheuristics like PSO do not guarantee an optimal solution. BA may lead to stagnation after some initial stage. The proposed HPSB algorithm contains the advantages of both algorithms and improves their performance. In this work, the initial population is considered as the mixture of microbats and megabats. Microbats are insectivores. They use echolocation to locate and catch their prey. Megabats are like normal birds. Half of the initial population uses the concept of BA.

The remaining half uses PSO concept. The best solution from microbats and megabats are shuffled and given as input to next iteration. This algorithm combines the advantages of both the algorithms. The Figure 1 shows the flowchart of proposed HPSB algorithm. The hybridization of evolutionary algorithms has gained extensive recognition over the decades. They can overcome their individual drawbacks while benefit from each other's strengths. Many hybrid algorithms have been proposed and widely employed to solve global optimization problems. In this work, the hybridization of PSO and BA called HPSB algorithm is proposed for VI constrained floorplanning.

- New hardware architecture of bat algorithm based on Finite State Machine (FSM) is implemented into FPGA.
- New approach for global engineering optimization using different search strategies to diversify the bat population.
- A modification for the local search of BA is executed to improve the bats' movement.
- A parallel bat algorithm was developed
- to solve the well-known benchmarks function using Field-Programmable Gate Arrays (FPGAs) which give better solutions compared to other algorithms in terms of execution time and material resources.

4.2 Fitness Function

In HPSB algorithm based floorplanning, the fitness function of an individual is determined by evaluating the total area and wirelength needed to place the modules. The fitness value of each particle/bat is calculated by using the Equation (1).

4.3 Velocity calculation

The modification of the particle position can be represented by the concept of velocity. The current position that is, the searching point in the solution space can be modified by the following Equation (1.1).

$$xid\ (new) = xid\ (old) + vid\ (new) \qquad (1)$$

vid(new) - Velocity of particle *i* in dimension *d* at time *t*

xid - Position of particle *i* in dimension *d* at time *t*

All swarm particles will have a tendency to move towards better positions. Hence the best position (i.e. optimum solution) can eventually be obtained through the combined efforts of the entire population.

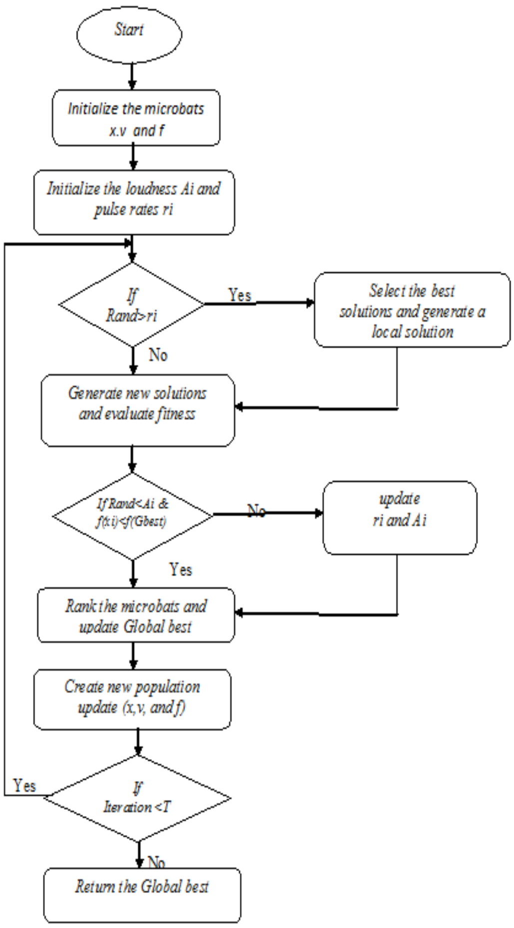


Figure 1. Proposed architecture of Bat Algorithm

5. EXPERIMENTAL RESULTS

In the process of floorplanning using HPSB algorithm each possible solution (floorplan) of the problem is represented by a particle/bat position. The quality of the solution is indicated by the best position (minimum area) of a particle/bat towards its prey. The candidate solution representation is same as BA. Here, instead of considering entire population as microbats, half of the population is considered as particles (megabats) and they follow the PSO algorithm.

The table 1 gives the average results obtained by the HPSB method for floorplanning. Table 2 present the minimum area, wirelength and run time attained by the proposed floorplanner.

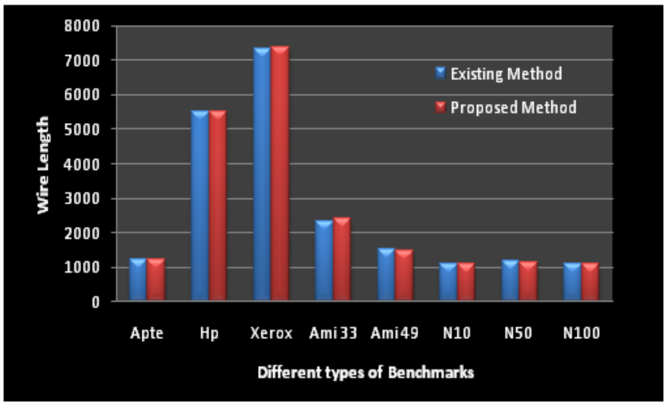
Table 1: Performance metrics applying different types of Benchmarks and using different α and β values

Benchmark	Hybrid Particle Swarm-Bat Algorithm					
	α = 0.2 and β = 0.2			α = 0.5 and β = 0.5		
	Area (mm^2)	Wirelength (e-06)m	Time (s)	Area(mm^2)	Wirelength (e-06)m	Time (s)
Apte	48.44	1228.75	28.15	49.09	1256.59	28.98
Hp	11.36	5526.92	26.19	11.39	5498.88	27.19
Xerox	20.24	7340.25	25.42	21.11	7289.66	26.35
Ami 33	01.48	1536.56	98.55	01.52	2355.66	118.42
Ami 49	38.89	2338.07	117.36	40.68	1589.25	99.62
N 10	25.14	1104.92	25.64	25.61	1114.92	25.87
N50	26.87	1168.29	102.88	27.68	1193.07	103.36
N100	22.77	1117.33	256.29	22.98	1131.22	257.70

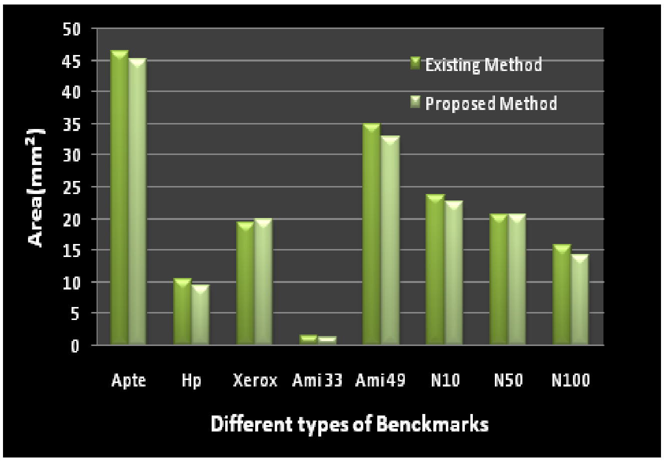
Table 2. Comparisons for Existing method and Proposed method**.**

Benchmark	Proposed method			Existing Method		
	Wire length	Area (mm^2)	Run Time (s)	Wire length	Area (mm^2)	Run Time (s)
Apte	1216.63	45.23	22.56	1228.75	46.36	28.15
Hp	5522.23	9.36	20.99	5526.92	10.33	26.19
Xerox	7389.21	19.91	15.62	7340.25	19.24	25.42
Ami 33	2402.99	01.20	48.69	2338.07	01.48	117.36
Ami 49	1465.32	32.89	21.22	1536.56	34.99	39.87
N10	1102.12	22.62	18.61	1104.92	23.77	25.64
N50	1151.36	20.53	46.33	1168.29	20.59	102.88
N100	1113.89	14.36	85.69	1117.33	15.75	256.29

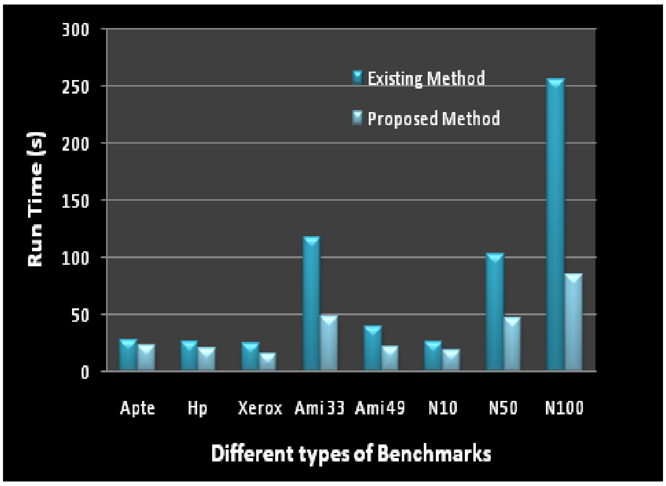
Graph 1, 2 and Graph 3 represent the different benchmark circuits value wire length, area and run times



Graph1. Wire length Comparisons for Existing and Proposed method



Graph 2. Area Comparisons for Existing and Proposed method



Graph 2. Run time comparisons for Existing and Proposed method.

6. CONCLUSION

The bat algorithm has superior features, including quality of solution, good computational efficiency and stable convergence characteristics. The comparison shows that bat algorithm performs better than the mentioned methods. The proposed architecture of bat algorithm proves that it has a favorable convergence speed compared to the most of other meta-heuristic techniques depends on the size of design space; it means the number of bats allocated and the complexity of the problem. The HPSB algorithms are proposed in this work for VI constrained fixed-outline non-slicing VLSI floorplanning. HPSB contains the advantages of both PSO and BA. The simulation results of the MCNC and GSRC benchmark circuits have good and reasonable solution for the non-slicing placement of mixed modules within fixed-die-outline constraints while considering VIs. From Table 1and Table 2, it is inferred that the performances of the proposed HPSB floorplanning methods are comparable to existing algorithms. The results have motivated that the proposed hybrid optimization models are demonstrated to be useful for floorplanning. . So, the BA's robustness is attached to its enhanced ability to achieve a satisfaction between two requirements, the size of memory and the processing time of algorithm to solve complex problems. Therefore, bat optimization is a promising technique for solving complicated problems in the real world applications.

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