International Conference on VLSI, Communication & Instrumentation (ICVCI) 2011
Proceedings published by International Journal of Computer Applications® (IJCA)

An Effective Memetic Algorithm for Solving Channel Routing Problems

Varatharajan.R
Department of ECE
Bharath University
Chennai.

Dr.A.Kumaravel
Department of CSC
Bharath University
Chennai.

Dr.Perumal Sankar
Research Director
Cape Institute of Tech
Kanyakumari

ABSTRACT

The task of VLSI physical design is to produce the layout of an integrated circuit. The layout problem in VLSI-design can be broken up into the subtasks partitioning, floor planning, placement and routing. Routing can be classified into two types. One is Global routing and another one is detailed routing. In detailed routing, the Connections between blocks or cells, respectively, have to be generated under consideration of certain constraints, e.g., different Nets are not allowed to intersect because such intersections produce short circuits. As routing is NP-complete, in general it cannot be solved exactly within reasonable time bounds for large Problem instances. Some problems are arises during the routing process .The routing constraints are Minimize total wire length, Minimize knees in path, Meet timing budget. To overcome these problems Memetic algorithm has been used. Combining global and local search is a strategy used by many successful hybrid optimization approaches. Memetic Algorithms (MAs) are Evolutionary Algorithms (EAs) that apply some sort of local search to further improve the fitness of individuals in the population. Memetic Algorithms have been shown to be very effective in solving many hard combinatorial optimization problems. This algorithm combines Genetic Algorithms and advanced local search to solve VLSI circuit Routing. The effect of local search, clustering and good initial solution on the overall Memetic algorithm by using the circuit routing as a paradigm.

Key words: channel routing, memetic algorithm, wire length minimization, crosstalk and via minimization

1.INTRODUCTION

1.1 Routing

One of the important problems in the design and implementation of layout system for integrated circuits is the routing problem. Routing is a complete the interconnections between the modules. Factors like critical paths, wire spacing, size is considered. As the routing in standard cells is a very complex combinational optimization problem, routing process can be carried out in two phase they are as global routing and detailed routing.

1.2 Global routing

Following the placement stage, the exact locations of cells are determined. The goal of global routing is to decide the connection pattern for each net and satisfy different objectives. The inputs to the global routing problem consist of a net list that indicates the interconnections between terminals and placement information including the terminal positions and the locations of wiring channels in between them. The typical objective of global routing involves wire length and congestion minimization.

1.3 Detailed routing

Detailed routing is also known as local routing. Local routing joins the logic cells with interconnections. Information on which interconnection area to use comes from the global router. Only at this stage of layout do we finally decide on the width, mask layer, and exact location of the interconnections. Objectives of this detailed routings are minimizing the interconnect length, propagation delay and reducing the search space. Detailed routing has many types. In this paper we consider the channel routing only.

1.3 Channel routing

In VLSI design the problem of completing the necessary interconnections among different modules is known as the routing problem. There exist several routing strategies for achieving efficient interconnections among different modules. One of the most important routing strategies is channel routing. The channel routing problem (CRP) is the problem of interconnecting all the nets in a channel using minimum possible routing area. So, it is unlikely that there exists an efficient algorithm that computes a routing solution using a minimum number of tracks and/or a minimum amount of total wire length. As a consequence, memetic algorithms are used for computing minimum area routing solutions.

2. PROBLEM DESCRIPTIONS

The channel routing problem is defined as follows, consider a rectangular routing region, called channel, with a number of pins located either on the upper or the lower boundary of the channel. The pins that belong to the same net have to be connected subject to certain constraints and quality factors. The connections have to be made inside the channel on a symbolic routing area consisting of horizontal rows and vertical columns.

Two quality factors are used in this work to judge the quality of the routing result:

- Wire length
- Number of vias.

2.1 Wire length minimization

The objective of the wire length minimization is thus defined as follows

The trivial lower bound on the number of tracks is greater than the height of a selected vertex v_i (corresponding to net n_i) in vc_t i.e.

Max (d^t_{max}, v^t_{max})>ht_{vi}

Then we can postpone the current assignment of n_i.

Where d_{max}= channel density
VC= (V, A) is constructed to represent the vertical constraints
h= height of the vertex
t_{vi}= selected vertex

2.2 Via minimization

In general, for a given cell of n horizontal and m vertical tracks (referred to as an n x m cell), there is a maximum number of vias that can be allowed for each via placement restriction

Let m=m(k,r) is the maximal integer such that in any cell with k horizontal and r vertical tracks m(k,r) vias may always be realized. Then the values M (k, r) are determined as

$$M\ (k, r) = m\ (k, r) * C\ (n)$$
$$C(x) = x+1/2x.$$

3. MEMETIC ALGORITHM

Combining global and local search is a strategy used by many successful hybrid optimization approaches. Memetic Algorithms (MAs) are Evolutionary Algorithms (EAs) that apply some sort of local search to further improve the fitness of individuals in the population. Memetic Algorithms have been shown to be very effective in solving many hard combinatorial optimization problems. The approach combines a hierarchical design technique, Genetic Algorithms, constructive techniques and advanced local search to solve VLSI circuit Layout in the form of circuit routing. Results obtained indicate that Memetic Algorithms based on local search, clustering and good initial solutions improve solution for the VLSI circuit routing problem.

The traditional approach in routing is to construct an initial solution by using constructive heuristic algorithms. A final solution is then produced by using iterative improvement techniques where a modification is usually accepted if a reduction in cost occurs, otherwise it is rejected. Constructive heuristic algorithms produce an initial solution from scratch. It takes a negligible amount of computation time compared to iterative improvement algorithms and provides a good starting point for them (SM91). However, the solution generated by constructive algorithms may be far from optimal. Thus, an iterative improvement algorithm is performed next to improve the solution.

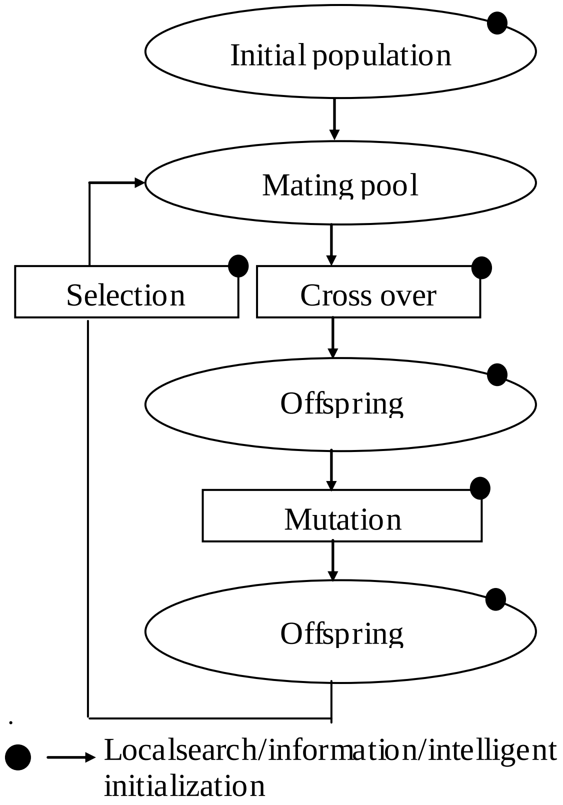


Figure 1: A memetic algorithm template

Although iterative improvement algorithms can produce a good final solution, the computation time of such algorithms is also large. Therefore, a hierarchical approach in the form of multilevel clustering is utilized to reduce the complexity of the search space. A bottom-up technique gradually clusters cells at several levels of the hierarchy. At the top level a Genetic Algorithm is applied where several good initial solutions are injected to the population

A local search technique with dynamic hill climbing capability is applied to the chromosomes to enhance their quality. The system tackles some of the hard constraints imposed on the problem with intermediate relaxation mechanism to further enhance the solution quality. The pseudo-code for memetic algorithm is presented given below.

```
Begin
   For j: =1 to $\mu$ do
      I: =generate solution ();
    I: =local search (I);
    Add individual I to P;
   endfor
   Repeat
    For i: = 1 to $p_{cross}$. $\mu$ do
       Select two parents $I_A$,$I_b$ Є P randomly;
       $I_c$: =recombine ($I_a$, Ib);
       $I_{c:=}$local-search($I_c$);
       Add individual $I_c$ to P';
         endfor;
                    For i:= 1 to $p_{mut}$. $\mu$ do
                    Select an individual I Є P randomly;
                    $I_m$: =mutate (I);
```

```
                $I_m$: =local-search ($I_m$);
                Add individual $I_m$ to P';
        endfor
        P: =select (P υ P')
If converged (P) then P: =local-search (mutate (P));
Until terminate=true;
end;
```

Figure 2: Procedure for memetic algorithm

3.1 Genetic algorithm

Genetic algorithms are optimization strategies that imitate the biological evolution process. A population of individuals representing different problem solutions is subjected to genetic operators, such as, selection, crossover and mutation that are derived from the model of evolution. Using these operators the individuals are steadily improved over many generations and eventually the best individual resulting from this process is presented as the best solution to the problem.

An overview of the genetic algorithm presented in this paper is shown in figure.

```
create initial population ($P_c$)
fitness_calculation ($P_c$)
$p_{best}$ = best_individual ($P_c$)
for generation = 1 until max_generation
    Pn = 0
    for off spring = 1 until max_descendant
            $P\alpha$= selection ($P_c$)
        $P\beta$= selection ($P_c$)
$P_n$= $P_n$ U crossover ($p_\alpha$, $p_\beta$)
endfor
fitness-calculation ($p_n$)
$P_c$ = reduction (Pc U $P_n$)
$P_{best}$ = best_individual ($p_{best}$ U $p_c$)
Mutation ($P_c$) fitness_calculation (Pc)
endfor
optimize ($P_{best}$)
```

Figure 3: Outline of the genetic algorithm

3.1.1 Creation of initial population

The initial population is constructed from randomly created routing structures, i.e .individuals. First, each of these individuals is assigned a random initial row number $y_{ind.}$ Let $S = \{s_1 \dots s_i \dots s_k\}$ be the set of all pins of the channel which are not connected yet and let $T = \{t_1 \dots t_j \dots t_l\}$ be the set of all pins having at least one connection to other pin. Initially T = 0. A pin Si Є S is chosen randomly among all elements in S. If T contains pins $\{t_u \dots t_j \dots t_v\}$ (with $1 \le u < v \le l$) of the same net, a pin t_j is randomly selected among them. Otherwise a second pin of the same net is randomly chosen from S and transferred into T. Both pins (s_i, tj) are connected with a so-called "random routing". Then si is transferred into T. The process continues with the next random selection of s_i Є S until S = 0. The creation of the initial population is finished when the number of completely routed channels is equal to the population size $|P_c|$. As a consequence of our strategy, these initial individuals are quite different from each other and scattered all over the search space.

.

3.1.2 Calculation of fitness

The fitness F (p) of each individual p Є P is calculated to assess the quality of its routing structure relative to the rest of the population P. The selection of the mates for crossover and the selection of individuals which are transferred into the next generation are based on these fitness values. First, two functions Fl (p) and $F_2(p)$ are calculated for each individual p Є P according to equations (1) and (2).

$$F_1 (p) = 1/n_{row} \qquad (1)$$

Where n_{row} = number of rows of p.

$$F_2 (p) = 1/\Sigma^{nind}_{i=1}(l_{acc} (i) + a * l_{opp} (i)) + b * v_{ind}$$

Where lacc (i) = net length of net i of net segments according to the preferred direction of the layer,

l_{opp} (i) = net length of net i of net segments opposite to the preferred direction of the layer

a = cost factor for the preferred direction,
n_{ind} = number of nets of individual p,
v_{ind}= number of vias of individual p and
b = cost factor for vias.

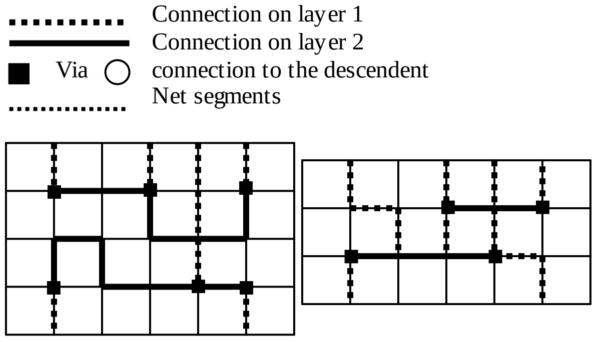
The final fitness F (p) is derived from Fl (p) and F_2 (p) in such a way that the area minimization, i.e. the number of rows, always predominates the net length and the number of vias. After the evaluation of F (p) for all individuals of the population P these values are scaled linearly as described in order to control the variance of the fitness in the population.

3.1.3 Selection strategy

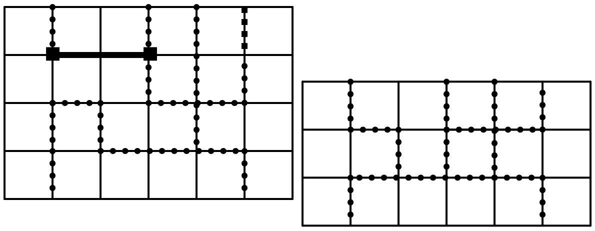
The selection strategy is responsible for choosing the mates among the individuals of the population Pc.
According to the terminology of our selection strategy is actually stochastic sampling with replacement. That means any individual p_i Є p_c is selected with a probability

$$F (p_i)/\Sigma_{p \in pc} F (p)$$

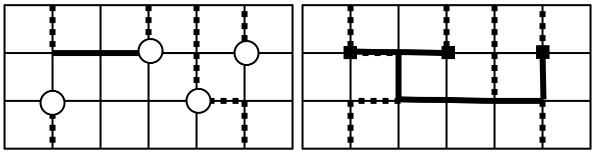
The two mates needed for one crossover are chosen of each other. An individual may be independently selected any number of times in the same generation.



(a) Mode P_α (b) Mode P_β



(c) Part of P_α to be transformed (d) part of P_β to be transformed



(e) Descendent P_γ (f) final descendent P_γ

Figure 4: crossover operator

3.1.4 Crossover operator

During the crossover, two individuals are combined to create a descendant. Let p_α and p_β be copies of the mates and p_γ be their descendant (Figure 4 (a, b)).

First, a cut column x_c is randomly selected with $1 \leq x_c < x_{ind}$, where x_{ind} represents the number of columns of the individuals. The individual p_α (p_β) transfers the routing structure to p_γ which is located to the left (right) of the cut column x_c and not touched by x_c(see figure 4(c,d)). Assume that the part of p_α (or p_β) which has to be transferred into p_γ contains rows not occupied by any horizontal segments. Then the row number of p_α (or p_β) is decremented by deleting this row until no empty row is left. The initial row number $y_{ind\gamma}$ of p_γ is equal to the maximum of ($y_{ind\alpha}$, yindβ). The mate which now contains fewer rows than p_γ is extended with additional row(s) at random position(s) before transferring its routing structure to p_γ.

The routing of the remaining open connections in p_γ is done in a random order by our random routing
Strategy (see Figure4 (e, f)).

If the random routing of two points does not lead to a connection within a certain number of extension Lines, the extension lines are deleted and the channel is extended at a random position y_{add} with $1 \leq y_{add} \leq y_{ind\gamma}$. If the repeated extension of the channel also does not enable a connection, p_γ is deleted entirely and the crossover process starts again with a new random cut column x_c applied to p_α and p_β.

The crossover process of creating p_γ is finished with deleting all rows in p_γ that are not used for any horizontal routing segment.

3.1.5 Reduction strategy

Our reduction strategy simply chooses the P_c fittest individuals of (P_c υ P_n) to survive as p_c intothe next generation

3.1.6 Mutation operator

Mutation operators perform random modifications on an individual. The purpose is to overcome local Optima and to exploit new regions of the search space. Our mutation operator works as follows. Define a surrounding rectangle with random sizes (x_r, y_r) around a random centre position (x, y, z).All routing structures inside this rectangle are deleted. The remaining net points on the edges of this rectangle are now connected

3.2 Local search

Local search is a general-purpose optimization method that works with fully specified solutions f Є F of a problem instance (F, c). it makes use of the notion of a neighborhood N(f) of a feasible solution f, which consist of a subset of f that is close to f in some sense neigborhood is a function that assigns a number of feasible solutions to each feasible solution: N : F
$2^{F.}$ Here 2^F denotes the power set of F, the set of all its subsets. Any g Є N (f) is called a neighbor of f. →

```
Local_search ()
{
      Struct feasible_solution f;
      Set of struct feasible_solution G;
      F ← initial_solution ();
      Do
 {
            G ← {g|g Є N (f), c (g) < c (f)};
            If (G! =0)
                  F ← any element of G;
}
while (G! =0);
Report f;
}
```

Figure 5: the pseudo-code description of local search

The principle of local search is too subsequently Visit a number of feasible solutions in the search space, each solution being in the neighborhood of the previous one. Such a transition from one solution to the next is called a move or a local transformation. One starts with a feasible solution f and then moves to some g ЄN (f), such that c (g) < c (f).This is repeated until some feasible solution is found.

4 .EXPERIMENTAL RESULTS

The memetic algorithm has been implemented in C++ on a sun-4 personal computer. In this paper, it will compare the performance of a pure genetic algorithm to a memetic technique that combines GA with simple local search techniques and also a more advanced hill climbing technique. The performance of the algorithm has been tested on different benchmarks. It has been evaluated wire length minimization and via minimization.

5.CONCLUSIONS

This paper presented several approaches to integrating Evolutionary Computation models with local search techniques (i.e. Memetic Algorithms) for efficiently solving underlying VLSI circuit routing problems. The methodology presented in the paper explained how clustering reduces the complexity of the circuit and thereby enables the Evolutionary technique to explore the solution space more effectively. Constructive heuristic techniques in the form of GRASP (greedy randomized adaptive search procedure) and Cluster Growth were utilized to inject the initial population with good initial solutions to diversify the search and exploit the solution space. Furthermore, the local search technique was able to enhance the convergence rate of the Evolutionary Algorithm by finely tuning the search on the immediate area of the landscape being considered.

6.ACKNOWLEDGEMENT

It is to note here that this topic-specific article for the easy reference of VLSI Routing Problem, optionally beingused together with the all the problems in VLSI PhysicalDesign. Author Varatharajan.I thank the anagementof Bharath University,India toconduct is research in this area.

7. REFERENCES

[1]. Natalio Krasnogor and Jim Smith, "A Tutorial for competent memetic algorithms: model, taxonomy and design issues", IEEE transaction on evolutionary computation, vol a, no. b, CCC 200d, 2005.

[2]. Nabin ghoshal, university of kalyani, Parlay mitra, Bengal engineering college, Rajat K.pal, university of Calcutta, "A two and three layer dogleg channel routing algorithm for minimizing total wire length" 2004 ieee.

[3]. Frank Schmiedle, RolfDrechsler, SeniorMember, ieee, and Bernd Becker, SeniorMember, ieee "Exact routing with search space reduction",: ieee transactions on computers, vol 52, no.6, june 2003.

[4]. Pralay Mitra "A Graph Theoretic Approach to Minimize Total Wire Length in Channel Routing", Dept. Of Computer Sc. & Tech. Bengal Engineering College (D.U.) Howrah-711 103, West Bengal, India, 2003.'

[5]. R. M. Smey, W. Swartz, and P. H. Madden, "Crosstalk Minimization during Detail Routing," Design Automation and Test Europe, March 2003, pp. 862—

[6]. Hawkiareibi, School of Engineering, University of Guelph, Guelph, Ontario, N1G2W1,Canada, Zhen Yang ,School of Engineering, University of Guelph, Guelph, Ontario, N1G2W1,Canada "Effective Memetic Algorithms for VLSI Design".

[7]. Maolin tang, kamran eshraghian and hon nin cheung, centre for very high speed micro electronics systems, Edith Cowan university, joondalup, WA 6027, Australia, "A genetic algorithm for constrained via minimization", 1999 ieee.

[8]. Vladimir N. Davidenko, Victor M.Kureichik, Victor V. Miagkikh, "Genetic Algorithm for Restrictive Channel Routing Problem", Proceedings of the Seventh International Conference on Genetic Algorithms (ICGA97)

[9].Nicole gockel, gregor pudelko, rolf drechsler, bernd becher, "A hybrid genetic algorithm for the channel routing problem", ieee international symposium on circuits and systems pp.IV:675—IV: 678, Atlanta, 1996

[10]. Jens lienig and k.Thulasiraman, department of electrical and computer engineering, Concordia university, "A new genetic algorithm for the channel routing problem"1994 IEEE.

[11].Jens lienig and K.Thulasiraman, Department of electrical and computer engineering, Concordia University, "A genetic algorithm for channel routing in VLSI circuits", 1994.

[12]. B. B. Prahlada Rao, L. M. Patnaik and R. C. Hansdah, Department of Computer Science and Automation Indian Institute of Science , "A Genetic Algorithm for Channel Routing using Inter-Cluster Mutation" 1994 ieee.

[13]. Haklin Kim, department of math and computer science, university of Tennessee martin, "An application algorithm for the via minimization problem in channel routing"1990 IEEE.

[14].Jitender s. deogun and bhargab b.Bhattacharya, "via minimization in VLSI routing with movable terminals", IEEE transactions on computer aided design, vol. 8, no. 8, august 1989.

[15].Michael Burstein, Richard pelavin, "hierarchical wire routing" IEEE transaction on computer aided design, vol, cad-2, no. 4, October 1983

Varatharajan.R is the research Scholar of Bharath University,Chennai, India. He has completed his Bachelor Degree in Electronics and Communication(2006), Masters in VLSI Design(2008) .He has published many journals and attended many Conferences in National and International Level. His research area is VLSI Physical Design.

Dr.A.Kumaravel, Head of the Department . He has completed his PhD from Anna University,Chennai..He has published more than 15 journals in International Level.He is the Chief Coordinator for many UGC Projects.His reaerch areas are Networking,Grid computing and VLSI.

Dr.S.Perumal Sankar, Research Director Cape institute of technology . He has completed his PhD from Anna University ,Chennai.He has published more than 20 journals in International Level.He is the Chief Coordinator for many Government Projects.His reaerch areas are Optical MEMS,Digital image processing,Communication Systems.