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Некоторые характеристики алгоритма размещения электронных элементов методом обмена случайно выбранных пар

Оптимальное размещение электронных компонентов играет важную роль при использовании программ автоматического проектирования. В противном случае эффективность наилучших алгоритмов трассировки может быть сведена к нулю. Этим объясняется появление в последнее десятилетие большого количества работ по проблемам размещения.

В данной работе проводится исследование некоторых особенностей метода обмена случайно выбранных пар. Этот метод является распространенным и простым вариантом итеративных методов размещения электронных элементов.

Программа была успешно применена к решению ряда практических задач проектирования печатных плат и соединения разъемов проводниками. В работе приводится несколько решений задачи Штейнберга, как наиболее известной из литературы, с указанием скорости итераций и машинного времени при получении субоптимумов и локальных оптимумов размещения.

Рассматривается влияние начального размещения электронных элементов на конечный результат и делается неожиданный вывод, что применение алгоритма к "случайному" начальному размещению может привести к лучшим результатам по сравнению с "качественным" начальным размещением.

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Some Properties of Module-Placement Algorithms Using the Pairwise-Interchange Method

In the case of computer aided design program systems the optimal placement of electronic components is extremely important because an unsatisfactory placement may obstruct the effectiveness even of the best wiring algorithms. That is the reason why in the last ten years so many works deal with the placement problem.

This paper examines some properties of the method of pairwise interchange of randomly chosen elements as a characteristic and not complicated example of iterative placement-improvement methods.

Several practical problems (printed circuit board and mother board design) were investigated, but this paper gives some results of computer runs only of the so-called Steinberg problem as it is most commonly known from the literature. The examinations of suboptimum and local optimum placements, iteration speed and computer run times are given.

We assume as the most interesting result the effects of "good" and "random" initial placements on the resulting (i.e., optimum)placement and on the run times, i.e., the good initial placement does not improve the effectiveness of the iterative procedure however it is generally supposed.

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INTRODUCTION

Several computer programs which calculate the optimal placement of electronic components use one of the simplest iterative placement-improvement methods, the pairwise interchange of randomly chosen elements (e.g., refs. [1,2]). A lot of results published in the international literature prove that this method can be effectively used for placement of components on printed circuit boards and for the placement of connectors of the PCBs in larger units (e.g., racks) as well. This latter task doesn't concern CAMAC systems where the mother-board wiring is fixed.

The result of the optimal placement procedures for both types of tasks ensures that the next step of automatic design, the wiring could be done. On the other hand, a poor placement may obstruct the effectiveness even of the best wiring methods.

SUBOPTIMUM, LOCAL OPTIMUM AND ABSOLUTE OPTIMUM PLACEMENT

The method of pairwise interchange of randomly chosen elements works in the following way:

Based on a given initial placement (or it may be randomly defined), the program randomly (by means of a random number generator) chooses two modules, and their places will be interchanged. The interchange is called successful and it is accepted if it causes a decrease in the goal function characterizing the module placement. If the interchange is not successful, the two modules go back to their previous place, i.e., the previous placement is retained. Then a new pair is selected for interchange and so on. The process is finished based on the number of consecutive unsuccessful trial interchanges or based on the variation of the goal function value.

If we want to place N modules on $M>N$ positions and it is supposed thal all elements fit to all places, the condition of finding the so-called LOCAL OPTIMUM PLACEMENT is to have

$$K=\binom{N}{2}+(M-N)N \qquad (1)$$

consecutive unsuccessful nonequivalent trial interchanges, as K is the maximal number of different pairs which can be selected. If the program run is halted when the number of consecutive unsuccessful interchanges, $L<K$, or the program halts based on the variation of the goal function value, we get the so-called SUBOPTIMUM PLACEMENT.

To find the ABSOLUTE or GLOBAL OPTIMUM PLACEMENT, the program should evaluate all possible $P=\binom{M}{N}N!$ placements which is quite impossible with the recently available computer capacities if $N>10$, thus we can say that in most practical cases there is no hope to find the absolute optimum placement.

The GOAL FUNCTION calculation is a crucial point of placement algorithms. In most cases the total wire length of interconnections is calculated, and the procedure tries to find the placement which is characterized by the smallest value of this total length. A commonly accepted method is to use the model of the quadratic assignment problem, where

$$G(s) = \sum_{1 \leq i \leq j \leq N} f_{ij} \, d_{s(i)s(j)} \qquad (2)$$

is to be minimized, where $d_{s(i)\,s(j)}$ is the distance between the modules placed on the positions $s(i)$ and $s(j)$, $(i, j = 1, 2, \ldots, N)$

$(s(i), s(j) = 1, 2, \ldots, M)$

$F = [f_{ij}]$ is the connection matrix which gives the number of interconnections between the modules i and j.

SOME RESULTS OF OUR INVESTIGATIONS

Most papers of the literature use the Steinberg problem /3/ to show the effectiveness of their placement algorithms.

In this problem $N=34$ modules should be placed on $M=4\times9=36$ positions. Matrix F is symmetric and contains 2620 interconnections.

Table 1 shows some goal function values obtained by different authors.

Steinberg /3/	4894
Kurtzberg /6/	4873
Gilmore /7/	4547
Heider /8/	4419
Gashutz-Ahrens /9/	4142
Heider /10/	4138

The value of K is the following:

$$K = \binom{N}{2} + (M-N)N$$

$$K = \binom{34}{2} + (36-34)34 = 629$$

Table 2 contains data of 6 different local optima calculations using the pairwise interchange method.

Nº	IG	L1=K/4=157			L2=K/2=315			L3=K=629		
		IT	C	EG	IT	C	EG	IT	C	EG
1	9191	65	749	4701	76	1704	4424	81	3107	4364
2	8757	37	613	5078	55	2434	4699	57	3280	4676
3	8637	68	1330	4684	74	2285	4515	75	3010	4491
4	4894	8	430	4526	10	851	4470	19	3769	4434
5	4894	7	353	4527	10	910	4470	13	2220	4392
6	5029	12	784	4597	13	1148	4568	17	2730	4560

IG is the goal function value of initial placements, EG is the goal function value of improved and resulting placements, IT is the number of iterations, i.e., the number of successful interchanges, C is a number that is proportional to the computer run time.

The data under L1 and L2 belong to sub-optimum placements which could have been gotten by halting the program run after L1 and L2 consecutive pairwise interchanges, respectively. In the case of L3=K the data are that of local optimum placements.

Based on the given and several further runs on the Steinberg problem and on 8 other different problems/4/ using the algorithm of pairwise interchange of randomly chosen modules, one can say that the main characteristics of all results were similar to those of table 2.

These are the following:

1. The EG values of the local optima show that our simple algorithm gave better results than some of more complicated expensive procedures (see Table 1), but the best results could not be reached.

2. The best result in Table 2 is the first one, and it shows that the "good" initial placement (small IG value) of the 5-th, 6-th and 7-th run did not help to get better results than the randomly chosen initial placement.

3. The "good" initial placements resulted in getting local optima with a low iteration number (IT), but this did not mean savings in rum-time (C). This is explained by the fact that every successful interchange is preceded by a great number of unsuccessful ones when the algorithm is getting closed to the optimum placement.

4. Examining the mean values of EG and C belonging to L1, L2 and L3, respectively, we got that a saving of 76.69% of run-time would have caused a 4.26% increase of the goal function value (L1), and a saving of 48.48% of run-time would have resulted only in a 0.67% deterioration of the results (in case of L2). If we had calculated with L1 instead of L3, the worst case (2nd run) would have resulted only in a 8.95% higher EG value. These data suggest that it is not worth-while to calculate local optima placements (L3 = K), but suboptima (L<K) placements should be good enough.

5. The effects shown in point 4 are caused by the fact that after reaching L=K/4 the program can find only a few successful interchanges and all of them need a lot of search time-similarly to the experiences given in point 3.

CONCLUSION

As the most interesting result of our investigations, it seems to be proven that a good initial placement does not necessarily help to get good results using iterative placement-improvement methods, i.e., the method of pairwise interchange. Thus it is not worth-while to use constructive initial placement procedure if iterative procedure follows it.

Another experience is that in most cases, instead of calculating one or two local optima (L=K), it is more advantageus to calculate more suboptima placements.

The results show that the pairwise interchange method does not converge slowlier than several complicated-sophisticated methods known from the literature (e.g., [3] and [5]).

The method examined in this paper is used for computer programs written by the author for automatic design of printed circuit boards and for mother board design. The usage of these programs gave satisfactory results both technically and concerning the computer run times.

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