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# Application of Fuzzy Logic to Layout of Integrated Circuits

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**Abstract:** Application of fuzzy logic structures in Computer Aided Design (CAD) of digital electronics substantially improves quality of design solutions by providing designers with flexibility in formulating goals and selecting tradeoffs. In addition, the following aspects of a design process are positively impacted by application of fuzzy logic: Utilization of domain knowledge, interpretation of uncertainties in design data and adaptation of design algorithms. We successfully applied fuzzy logic structures in VLSI cells placement algorithm for physic stage of the design process. We are modified the matrix connection by using fuzzy relation. Attempts to apply the fuzzy set theory to problems of physical design, the connectivity matrix was modified and then the fuzzy set theory was used to construct clusters for placement.

**Key words:** Layout, integrated circuits, designs

## INTRODUCTION

Placement is one of the important steps in VLSI design. Many placement algorithms[1,2], have been introduced in the past few years. All these algorithms do not explicitly consider two important aspects of the placement problem: Presence of multiple conflicting objectives and utilization of expert knowledge in decision-making. These aspects of the placement problem can be addressed by the technique based on the fuzzy set theory[3-5]. Attempts to apply the fuzzy set theory to problems of physical design were made in[6,7], the connectivity matrix was modified and then the fuzzy set theory was used to construct clusters for placement.

**Part I: Basics of fuzzy set theory:** A fuzzy set A, as defined by Zadeh, is a class of objects with continuum of grades of membership. An element may partially belong to a fuzzy set. This is contrary to the ordinary set theory, where an element is either in a set or not in a set.
Formally, a fuzzy set is defined as follows[3]:

**Definition I:** A fuzzy subset A of a universe of discourse X is defined as $A = \{ ( x, \mu_A(x) ) | \text{all } x \in X\}$, where X is a space of points and $\mu_A(x)$ is a membership function of $x \in X$ being an element of A. In general, a membership function $\mu_A(.)$ is a mapping from X to the interval [0, 1]. If $\mu_A(x)= 1$ or 0 for all $x \in X$, the fuzzy set A becomes an ordinary set. One possible membership function for the fuzzy set A is illustrated by Fig. 1. On this figure point x1 belongs to the fuzzy set A with a degree of membership $\mu_A(x1)$.

**Operations over fuzzy sets:** Set operations such as union, intersection and complementation, etc., are naturally introduced into the theory of fuzzy sets. Due to the nature of membership functions, results of fuzzy set operations are also fuzzy sets. The membership function of the resulting fuzzy set for basic operations on two fuzzy sets A and B with the universe of discourse X is usually defined in one of the following forms:

$$\mu_{A\cap B}(x) = \min (\mu_A(x), (\mu_B(x)) \quad (1)$$

$$\mu_{A\cup B}(x) = \max (\mu_A(x), (\mu_B(x)) \quad (2)$$

$$\mu_{\neg A}(x) = 1.0 - \mu_A(x) \quad (3)$$

$\cap$, $\cup$ and $\neg$ are also called and, or and not, respectively. Some other algebraic operators may also be used to define these fuzzy set operations. For instance, the algebraic product of A and B is denoted by AB with the membership function defined as $\mu_{AB}(x)= \mu_A(x).\mu_B(x)$; the algebraic sum is denoted by A + B with the membership function defined as $\mu_{A+B}(x)= \mu_A(x)+\mu_B(x)$. The shaded region in Fig. 2 shows the membership function of the fuzzy set $A \cap B$, which results from the intersection of fuzzy sets A and B . Here a $\mu_A(.)$ and $\mu_B(.)$ are the membership functions for the fuzzy sets A and B, respectively.

**The placement problem:** The layout of an integrated circuit involves partitioning and assignment of logic circuits to physical modules (i.e., functional blocks), placement of the modules onto designated locations or slots on the chip and finally interconnecting (or routing)

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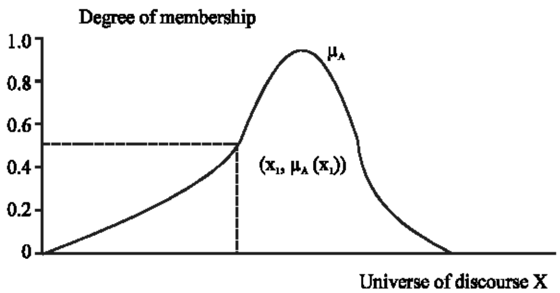


Fig. 1: Membership function for fuzzy set A

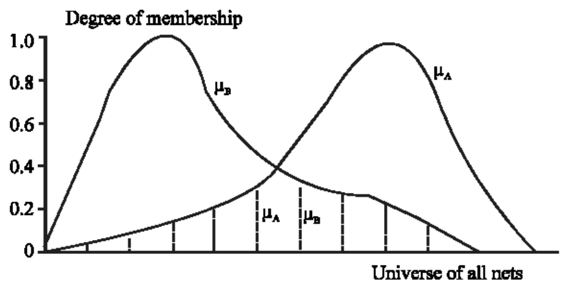


Fig. 2: Membership function for fuzzy set A ∩ B

these modules. Due to the complexity involved in this design process, the layout problem is treated in two different stages, namely placement and routing and each problem is tackled separately. In this study we look at the application of fuzzy logic to the placement problem; it is equally applicable to the routing.

Various heuristic placement algorithms have been reported in the literature. Mathematically the placement problem can be defined as follows. We are given a set of *modules* (functional blocks) $B = \{b_1, b_2 ....., b_N\}$, a set of input/output pins or signals $S = \{s_1, s_2,....., s_j\}$ and a set of cells (i.e., specific locations or slots on a chip) $L = \{L_1, L_2, ...., L_p\}$, where $P \geq N$.

The placement problem is to assign each module, say, $b_i$ to a unique cell $L_j$ on the chip in order to optimise some objective. In practice, simpler and more precise objectives are used such as total routing lengths, maximum number of cut lines and maximum density. Finding an optimum solution for a given objective is considered to be a NP hard problem (or simply put it, the computation time grows exponentially with the problem size). Therefore heuristic algorithms are used instead. There are a variety of rules for interconnecting modules which are often dictated by the specific technology and design styles used for chip fabrication.

The modules and their interconnections in a placement problem are related through a connection matrix. This matrix can also be represented as a module-connection graph which is sometimes referred to as the placement configuration. For example Fig. 3 shows

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 5 | 0 | 5 | 2 | 0 | 0 | 0 | 0 |
| 1 | 5 | 0 | 5 | 0 | 5 | 0 | 0 | 0 | 0 |
| 2 | 0 | 5 | 0 | 0 | 2 | 5 | 0 | 0 | 0 |
| 3 | 5 | 0 | 0 | 0 | 5 | 0 | 5 | 0 | 0 |
| 4 | 2 | 5 | 2 | 5 | 0 | 5 | 2 | 5 | 2 |
| 5 | 0 | 0 | 5 | 0 | 5 | 0 | 0 | 0 | 5 |
| 6 | 0 | 0 | 0 | 5 | 2 | 0 | 0 | 5 | 0 |
| 7 | 0 | 0 | 0 | 0 | 5 | 0 | 5 | 0 | 5 |
| 8 | 0 | 0 | 0 | 0 | 2 | 5 | 0 | 5 | 0 |

Fig. 3: Matrix connection

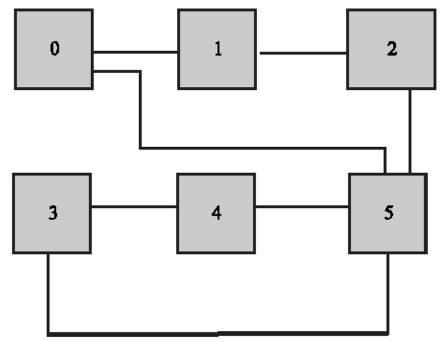


Fig. 4: Circuit with 6 cells

the connection mamx of a placement problem with 9 modules[1-9], each matrix element represents the connectivity between two elements in the set.

**Fuzzy relation and connection matrix:** A crisp relation in the context of set theory represents the absence or presence of interaction or association between the elements of two or more crisp sets. However a fuzzy relation extends this concept of crisp relation to permit various strengths or degrees between elements of sets and it indicates this degrees of association by its membership grades in the same way as membership grades are represented in a fuzzy set. When the fuzzy relation is defined on two sets X and Y, i.e., R(X, Y) it is called a binary relation and can be represented by a membership matrix whose elements are membership grades of the relation. It follows that a fuzzy binary relation R(X, X) defined on a single set X shows the degrees of association between element of the same set X.

In order to be able to apply fuzzy set theory to a placement problem we have appropriately modified the associated connection matrix to represent a fuzzy relation on the set of modules B to be placed. The elements of this modified matrix are then the membership grades of the fuzzy relation.

We have developed the algorithms using the connection matrix of a placement problem as a fuzzy relation. The simplest algorithm is to keep the same selection and positioning rules as in conventional placement algorithms but exploit the property of the modified matrix. This fuzzy algorithm generally results in a better final placement configuration than a conventional algorithm.

## RESULTS AND DISCUSSION

The fuzzy algorithms have been successfully applied to a variety of placement problems. Here we present some typical experimental results. Figure 5 shows the best placement configuration constructed for the connection matrix shown in Fig. 3.

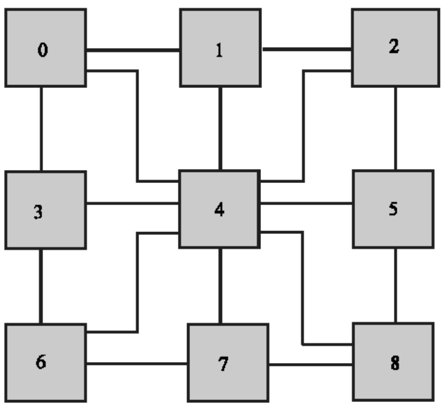


Fig. 5: Circuit with 9 cells

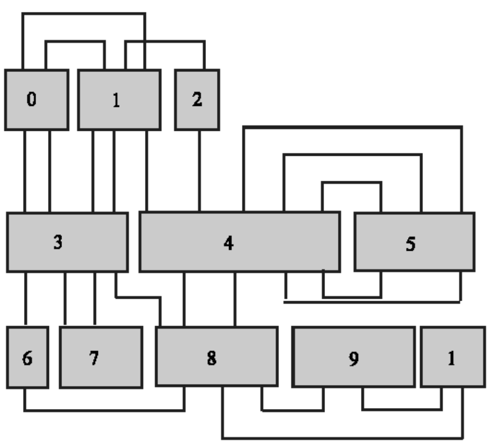


Fig. 6: Circuit with 11 cells

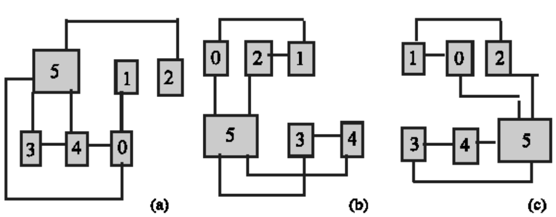


Fig. 7: Ordinary placement for circuit Fig. 4 with various networks (a) 4x4 (b) 6x6 (c) 8x8

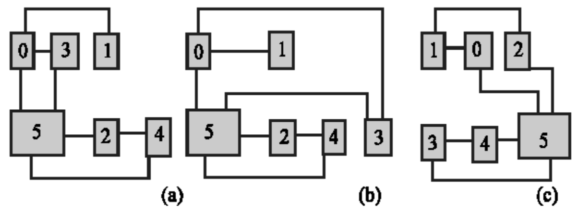


Fig. 8: Fuzzy placement for circuit Fig. 4 with various networks (a) 4x4 (b) 6x6 (c) 8x8

Table 1: Results of circuit with 6 cells

| Network (neurons number) | Fuzzy placement | | Ordinary placement | |
|---|---|---|---|---|
| | Iteration | Density | Iteration | Density |
| 4 x 4 | 28 | 4 x 4 | 20 | 4 x 4 |
| 6 x 6 | 27 | 5 x 4 | 16 | 5 x 4 |
| 8 x 8 | 24 | 4 x 4 | 16 | 4 x 4 |

Table 2: Results of circuit with 9 cells

| Network (neurons number) | Fuzzy placement | | Ordinary placement | |
|---|---|---|---|---|
| | Iteration | Density | Iteration | Density |
| 10 x 10 | 65 | 6 x 10 | 41 | 10 x 8 |
| 12 x 12 | 65 | 6 x 10 | 41 | 10 x 8 |
| 14 x 14 | 65 | 6 x 10 | 41 | 10 x 8 |
| 16 x 16 | 65 | 6 x 10 | 41 | 10 x 8 |

Table 3: Results of circuit with 11 cells

| Network (neurons number) | Fuzzy placement | | Ordinary placement | |
|---|---|---|---|---|
| | Iteration | Density | Iteration | Density |
| 12 x 12 | 42 | 6 x 12 | 38 | 8 x 11 |
| 14 x 14 | 38 | 6 x 12 | 38 | 8 x 11 |
| 16 x 16 | 38 | 6 x 12 | 38 | 8 x 11 |

We carried out a series of tests, with the algorithm using the Kohonen network[8], on three circuits, respectively with 6, 9 and 11 cells. The results show that the modified matrix connection reveals implicit connections between cells and of this fact a better placement gives by optimizing certain criteria such as the length of connections and the size of the circuit (density).

The results are illustrated in Tables 1, 2 and 3.

## CONCLUSION

Fuzzy logic was successfully applied to solving problems of VLSI placement. It was shown that they can be easily used the matrix connection modified. Such system gives designers much greater flexibility in problem formulations and allows them to consider wide range of tradeoffs. It also demonstrates that the fuzzy logic decisionmaker can be incorporated into traditional constructive or iterative design flow, where each subproblem can be solved by an analytic method, but their relations are described by fuzzy logic rules.

## REFERENCES

1. Mehmet Can Yildiz and Patrick H. Madden 2001. Global objectives for standard cell placement ACM Great Lakes Symposium on VLSI, pp: 68-72.
2. Shahooker, K. and Pinaki Mazumder, 1991. VLSI Cell Placement Techniques ACM Comput. Surv., 23,pp: 143-220.
3. Zadeh, L.A., 1965. Fuzzy sets Information Contr., pp: 338-353.
4. The concept of a linguistic variable and its application to approximate reasoning-I Inform, 1975. Sci., pp: 199-249.
5. Zimmermann, H.J., 1985. Fuzzy set theoryand its applications Boston, MA: Kluwer-Nijhoff, Fuzzy sets, decision making and expert systems. Boston, MA.
6. Razz, M. and J. Can, 1990. Fuzzy set based initial placement for IC layout in Proc. European Design Auromarion Conf, pp: 655-659.
7. Lin R. and E. Shragowitz, 1992. Fuzzy logic study to placement problem" in Proc. 29th DAC, pp: 153-158.
8. Azizi, H. and Al, 2006. VLSI cells placement using the Kohonen Networks AJIT, 5,pp: 183-198.