

Design of Digital Circuits Using Evolutionary Algorithms

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Objective

É To provide an overview of the current use of evolutionary techniques to automate the design of combinational circuits.

É Discuss what are the possible areas of improvements.

Introduction

- É Design = Knowledge + Creativity
- É Artificial Intelligence (AI) is expensive.
- É Karnaugh Maps & Quine-McCluskey method (mechanical).
- É Evolutionary techniques in design of digital circuits **is a very new area.**

Statement of the Problem

- É Design a combinational circuit that performs a certain specified function (truth table).
- É Using a set of logic gates (AND, OR, í etc).
- É Should meet a certain minimal-cost **criteria which may be a single/multiple objective.**

What is Given?

É Truth table.

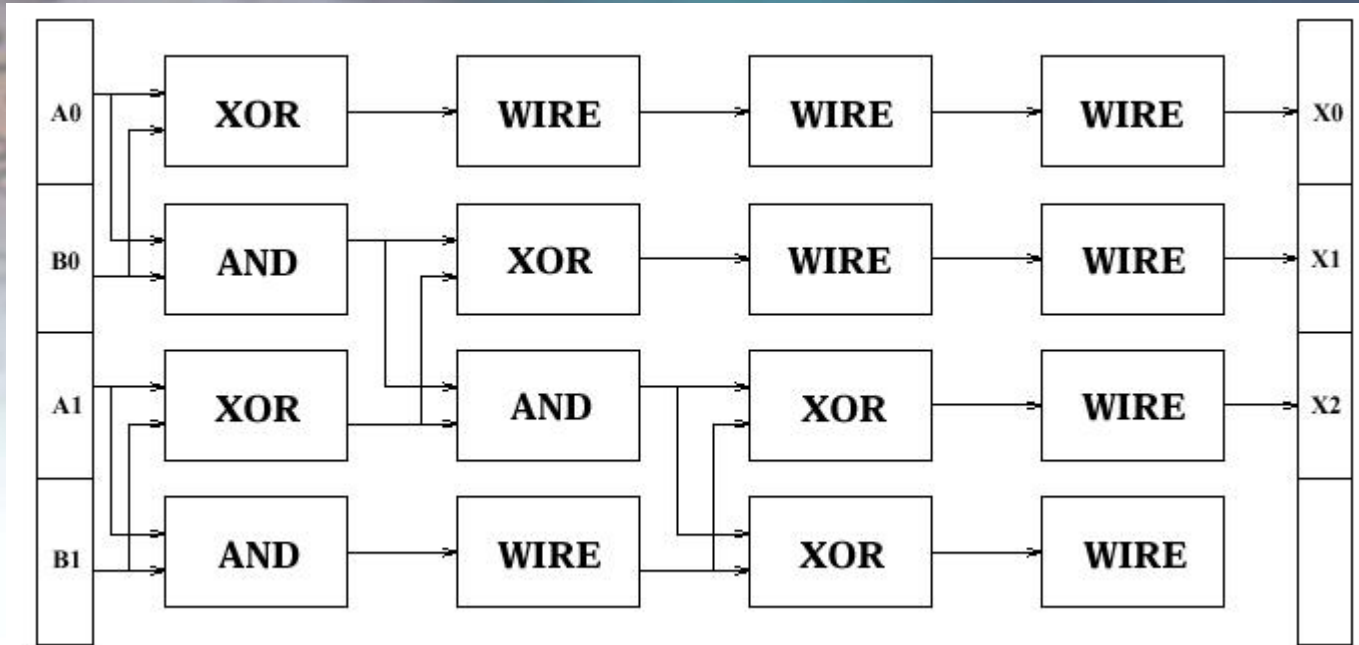
É Types of logic gates (AND, OR, XOR, í etc).

É Any Evolutionary Algorithm (GA, SimE, GP, EP, í ect).

Circuit Design Example

- É Done using GA (by Coello).
- É Digital circuit is represented as a matrix.
- É A single chromosome is built from the matrix.

Circuit Design Example



Every gate type is encoded (AND = 0, OR = 1, XOR = 2, NOT = 3, WIRE = 4).

The chromosome for the above 5x5 matrix:

0 1 2, 0 1 0, 2 3 2, 2 3 0, 4 4 4, 5 6 2, 5 6 0, 7 7 4, 8 8 4, 9 9 4, 10 11 2, 10 11 2, 12 12 4, 13 13 4, 14 14 4, 15 15 4, 16 17 18

Circuit Design Example

É Genetic operation used are:

ó Crossover operation

É Two-point crossover.

ó Mutation.

Circuit Design Example

É Fitness function used as follows:

- ó Check for 100% functionality first
- ó Maximize number of wire (min # of gates).

Circuit Design Example

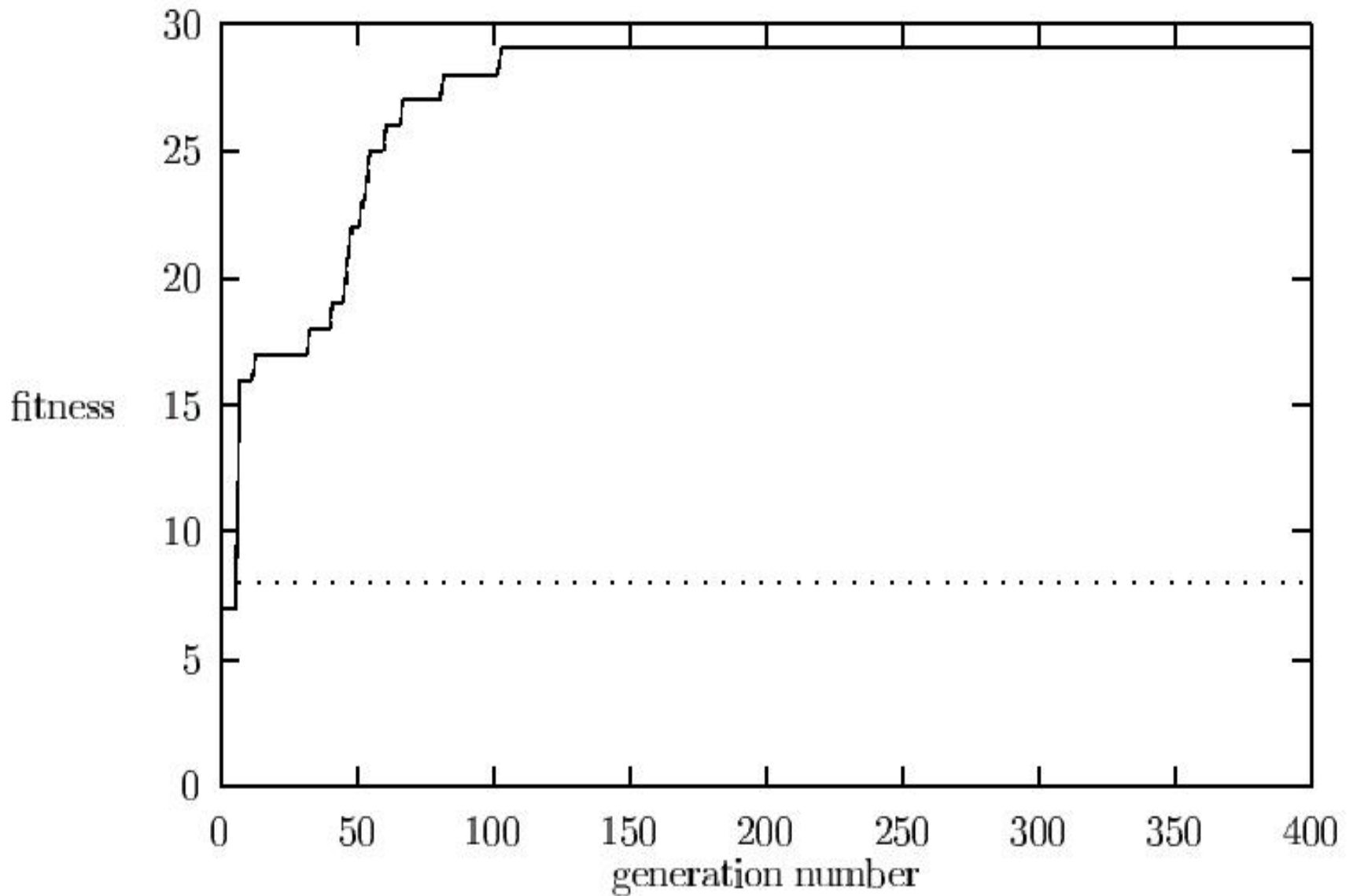
X	Y	Z	F
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	0

Circuit Design Example

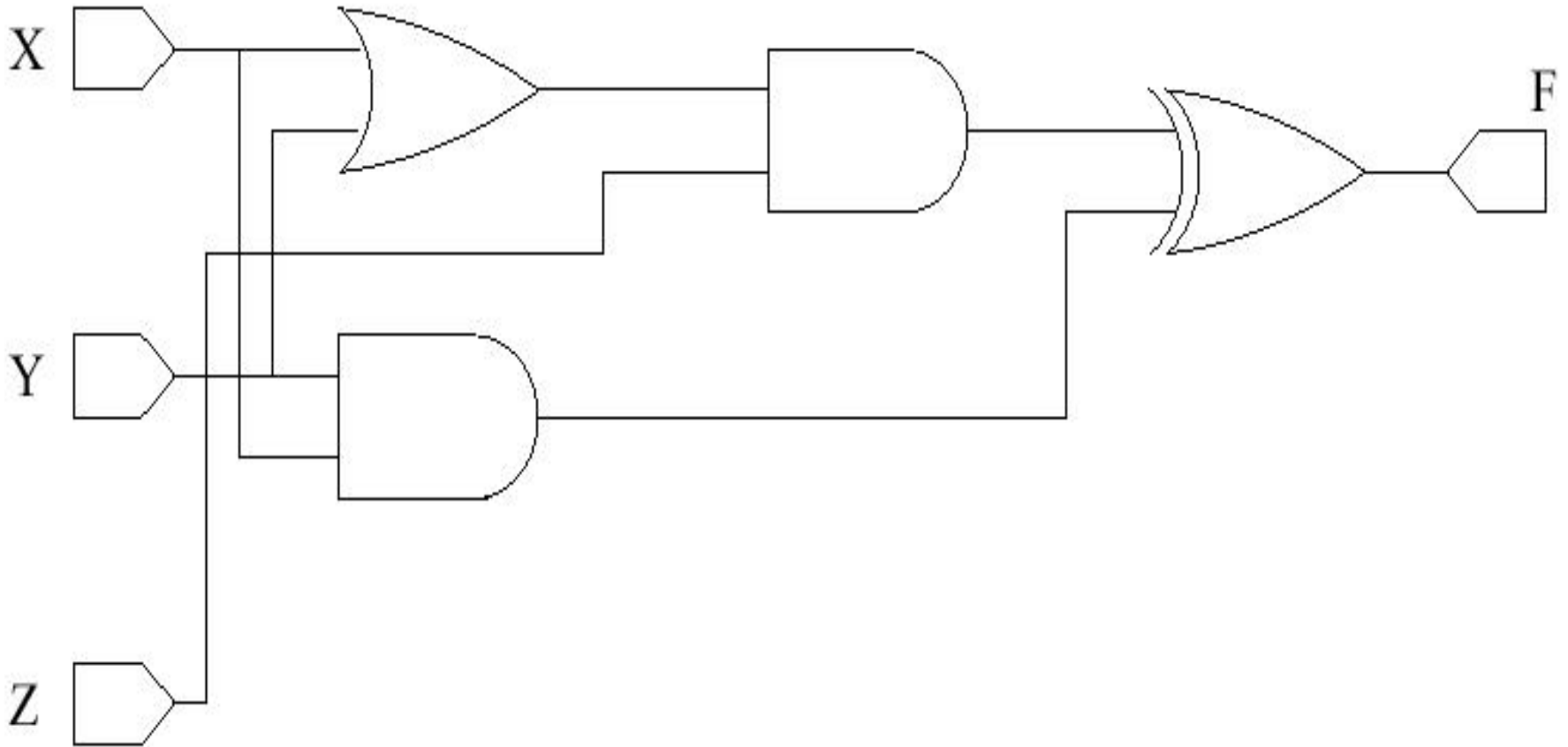


Genetic Algorithm	Human Designer 1	Human Designer 2
$F = Z(X + Y) \oplus (XY)$	$F = Z(X \oplus Y) + Y(X \oplus Z)$	$F = X'YZ + X(Y \oplus Z)$
4 gates	5 gates	6 gates
2 ANDs, 1 OR, 1 XOR	2 ANDs, 1 OR, 2 XORs	3 ANDs, 1 OR, 1 XOR, 1 NOT

Circuit Design Example



Circuit Design Example



Circuit Design Example

É This solution is not entirely obvious for a human designer.

É The GA tends to use nested XOR which reduces the number of gates.

É GA produces circuits that are difficult for a human designer to design and even to understand.

Conclusion

É A technique to design combinational logic circuit using GA is shown.

É There is much to be improved::

- ó Consider other evolutionary algorithms such as SimE and Tabu Search
- ó A better chromosomal representation
- ó Use of multiobjective fitness function
- ó Genes fitness evaluation instead of chromosome fitness
- ó Intelligent crossover operation and mutation



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