Introduction to Electronic Design Automation

Spring 2011
National Taiwan University

Problem Set 1

Due on 3/29/2011 before lecture

1 [Design Flow]

[12 pt]

(a) Please sketch a typical VLSI design flow starting from the behavioral level to the layout level.
(b) What are typical optimization stages and their inputs and outputs? Please list the main synthesis steps and/or optimization tasks at each stage.
(c) Where does verification (including simulation, formal verification, and testing) enter the design flow?

2 [Design Style]

[12 pt] Please given three example products (being or have been on the market) that respectively use full-custom, standard-cell, and FPGA design styles. Please analyze the reasons that the design style were adopted for each product.

3 [Algorithm and Complexity]

[20 pt] Given a sequence of real numbers $a_n, a_{n-1}, \ldots, a_1, a_0$, and a real number x, we would like to compute the value of the polynomial

$$P_n(x) = a_n x^n + a_{n-1} x^{n-1} + \cdots + a_1 x + a_0.$$

(a) Analyze the computational complexity of the recursive computation

$$P_n(x) = P_{n-1}(x) + a_n x^n,$$

where $P_{n-1}(x) = P_{n-2}(x) + a_{n-1} x^{n-1}$, ..., and $P_0(x) = a_0$. In particular, how many multiplications and additions are needed?

(b) Analyze the computational complexity of the recursive computation

$$P_n(x) = x \cdot P'_{n-1}(x) + a_0,$$

where $P'_{n-1}(x) = x \cdot P'_{n-2}(x) + a_1, \ldots,$ and $P'_0 = a_n$. In particular, how many multiplications and additions are needed?

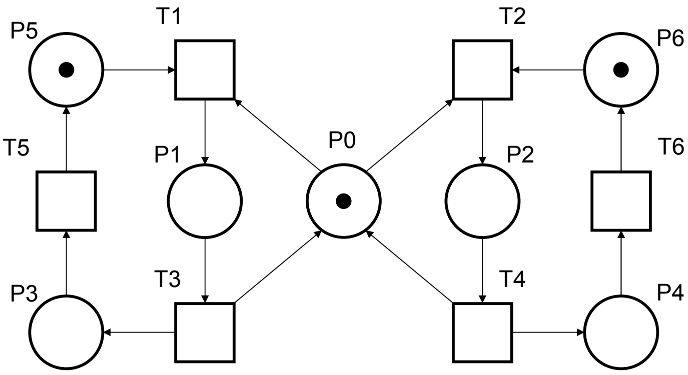

Fig. 1. A Petri net.

4 [Approximation Algorithm]

[15 pt] For any set of points on a plane, please show that a minimum rectilinear spanning tree has length at most twice that of the minimum rectilinear Steiner tree.

5 [Integer Linear Programming]

[15 pt] The inequality

$$\sum_{i=1}^{n} |x_i - y_i| \geq 1, \text{ for } x_i, y_i \in \{0, 1\},$$

characterizes a set of feasible solutions on variables x_i, y_i for $i = 1, \ldots, n$.

(a) [8 pt] Please formulate the above constraint in terms of SAT solving on a CNF (conjunctive normal form) formula.

(b) [7 pt] Please formulate a 0-1 ILP (integer linear programming with variables taking on values in $\{0, 1\}$) problem such that an assignment on x_i, y_i for $i = 1, \ldots, n$ satisfies the above inequality if and only if it yields some particular optimal value in your 0-1 ILP formulation.

(c) [bonus 5 pt] Please modify your 0-1 ILP formulation such that an assignment on x_i, y_i for $i = 1, \ldots, n$ satisfies the above inequality if and only if it yields a feasible solution to the set of 0-1 ILP constraints regardless of the objective function.

The number of variables/constraints in your formulation should be polynomial in n. (Note that the constraints of ILP are conjunctive, that is, all of them are to be satisfied simultaneously.)

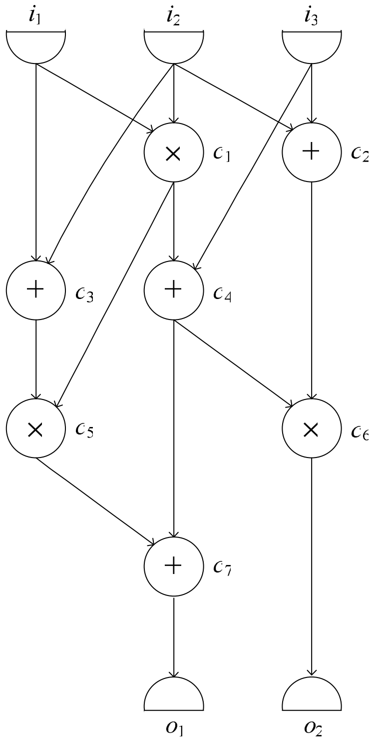

Fig. 2. A data flow graph.

6 [Model of Computation]

[5 pt] Given the Petri net of Figure 1, what kind of property does the system have?

7 [Data Flow]

[6 pt] For the iterative data flow of Slide 42 of High Level Synthesis, how can you place the initial tokens (and possibly have extra assumptions) to realize the while-loop computation?

8 [High-level Synthesis]

[15 pt] Given the data-flow graph of Figure 2, assume that multiplication takes 3 clock cycles and addition takes 1 clock cycle. Perform scheduling based on

(a) ASAP scheduling,

(b) ALAP scheduling, and
(c) critical-path list scheduling under the allocation of one ALU (that can perform both multiplication and addition) and one adder.