Automatic Nonlinear Memory Power Modelling

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Abstract

Power estimation and optimization is an increasingly important issue in IC design. The memory subsystem is a significant aspect, since memory power can dominate total system power. Estimation and optimization hence rely heavily on models for embedded memories. We present an effective black box modelling methology for generating nonlinear memory models automatically. The resulting models are accuracte, computationally modest, and in analytical form. They outperform linear models by far. Average absolute relative errors are below 6%.

1. Discussion

Let $\underline{x} = [x_1, \ldots, x_t]'$ be the vector of t original variables, e.g. size parameters of the memory. The models consist of k product terms ξ_i. For each term the vector $\underline{l}_i = [l_{i,1}, \ldots, l_{i,p_i}]'$ contains an ordered subset of p_i indices of the original variables. The real vector $\underline{\alpha}_i$ of the same length holds an exponent for each variable designated by the elements of $\underline{l}_i$. This gives:

$$\xi_i(\underline{x}, \underline{\alpha}_i) = x_{l_{i,1}}^{\alpha_{i,1}} \cdot \ldots \cdot x_{l_{i,p_i}}^{\alpha_{i,p_i}} \qquad (1)$$

where

$$\forall 1 \le j \ne h \le p_i:\ 1 \le l_{i,j} \ne l_{i,h} \le t \qquad (2)$$

Without loss of generality we define:

$$x_q^0 := \ln x_q \qquad (3)$$

In other words: each term is a product of a subset of the variables with an individual exponent. The complete models now have the following simple structure:

$$f(\underline{\xi}, \underline{\beta}) = \sum_{i=1}^{k} \beta_i \cdot \xi_i \qquad (4)$$

We fit the coefficients β_i, the exponents $\underline{\alpha}_i$ and the subsets $\underline{l}_i$ by an iterative application of linear regression, stepwise variable selection and adaptive power transformations on the input variables [2].

Our approach is similar to [1], but extends it in three important points: I) Our models can reflect nonlinear dependencies. II) Our approach is completely automatic. No manual pre-transformation of variables ist necessary. III) We model the memory as a whole and not each structural part seperately.

2. Results

We compare our nonlinear approach to the one of [1] for three types of Philips embedded memories: a single-ported SRAM, a low-power ROM and a high-speed ROM. The data was obtained from a PStar (Spice like) simulation of critical path models of the memories. The results are presented in table 1. Our nolinear approach clearly ecxels on the results of linear modelling in coefficient of determination (r), mean square error (mse), maximum absolute relative error (mar), and average relative error (aar).

Table 1: Model errors our nonlinear approach (linear=no) and the one after [1] (linear=yes)

type	linear	r^2	mse	mar %	aar %
SRAM	**no**	0,9999	1,27E-23	8,0	1,3
SRAM	**yes**	0,9890	8,43E-22	46,7	12,5
HSROM	**no**	0,9999	2,95E-22	34,2	4,4
HSROM	**yes**	0,9994	6,91E-22	51,8	9,1
LPROM	**no**	0,9998	4,63E-22	19,9	5,2
LPROM	**yes**	0,9917	9,94E-21	67,9	23,5

3. References

[1] Coumeri, S.; Thomas, D.: Memory Modeling for System Synthesis, IEEE Tansactions on VLSI Systems, Vol. 8, No. 3, pp.327-334, June 2000

[2] Box, P.; Tidwell, P.; Transformation of the Independent Variables, Technometrics, Vol. 4, No. 4, Nov. 1962