Autocorrelation Coefficients in the Representation and Classification of Switching Functions

Reductions in the cost and size of integrated circuits are allowing more and more complex functions to be included in previously simple tools such as lawn-mowers, ovens, and thermostats. Because of this, the process of synthesizing such functions from their initial representation to an optimal VLSI implementation is rarely hand-performed; instead, automated synthesis and optimization tools are a necessity. The factors such tools must take into account are numerous, including area (size), power consumption, and timing factors, to name just a few. Existing tools have traditionally focused upon optimization of two-level representations. However, new technologies such as Field Programmable Gate Arrays (FPGAs) have generated additional interest in three-level representations and structures such as Kronecker Decision Diagrams (KDDs). The reason for this is that the cost of implementing exclusive-or logic is no more than that of AND or OR gates when using FPGAs. My dissertation investigates the use of the autocorrelation coefficients in logic synthesis for these types of structures; specifically, whether it is possible to pre-process a function to produce a subset of its autocorrelation coefficients and make use of this information in the choice of a three-level decomposition or of decomposition types within a KDD.

This work began as a general investigation into the autocorrelation coefficients of switching functions. Much work has centered around the use of a function's spectral coefficients in logic synthesis; however, very little work has used a function's autocorrelation coefficients. Their use has been investigated in the areas of testing [Abo89], optimization for Programmable Logic Arrays (PLAs) [Tom96], identification of types of complexity measures [TS93], and in various DD-related applications [CMS99, KSA01a, KSA01b], but in a limited manner. This is most likely due to the complexity in their computation. In order to investigate the uses of these coefficients, a fast computation technique was required, as well as knowledge of their basic properties. Both areas are detailed as part of my dissertation, and the work published in [RM00] demonstrates that it is feasible to quickly compute the autocorrelation coefficients. With these investigations as a foundation for the work, we further apply the autocorrelation coefficients to the development of a classification technique. The autocorrelation classes encompass the spectral classes, thus resulting in larger classes. The advantage of this is that in developing optimal implementations for the class representatives, there are fewer functions to optimize [RM02].

As a further development of the investigation into the properties of the autocorrelation coefficients, links between patterns in the first and second order coefficients and the existence of exclusive-OR logic within the function were found. A major contribution of this work has involved the design and implementation of algorithms based on these links. The first of these algorithms is used to identify three-level decompositions for functions, and the second to determine decomposition type lists for KDD-representations. Each of these implementations compare very favourably with existing tools, requiring on average less than one second to complete, and performing as well as the existing tools 74% and 63% of the time, respectively.

References

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