Constraint Programming Applied to High-level and System-level Synthesis of Application-Specific Systems

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EXTENDED ABSTRACT

The present work investigates how state-of-art constraint programming techniques and software packages can be successfully applied to solve mathematical models used to formalize several problems found in the fields of high-level and system-level synthesis of application-specific systems (e.g. application-specific integrated circuits-ASICs). The models considered in this paper typically use one of the following modeling techniques: integer linear (ILP), integer non-linear (INLP), mixed-integer linear (MILP) and mixed-integer non-linear programming (MINLP). These techniques have been proved to be able to represent in a compact and elegant way many different design trade-offs (e.g. cost versus performance) sought by designers of application-specific systems.

Integer and mixed-integer programming models, despite being very powerful tools for capturing and representing design issues, generally demand a high computational cost in order to be solved – several hours for medium size problems or even days to large ones. Industry software developers of electronic design automation (EDA) tools, although also fond of these techniques but fearing their low computational performance, have recently avoided them in their products, opting instead to use heuristic approaches coded directly into software but lacking concise mathematical formulations.

Constraint Programming is an offspring of the research carried out by the logic programming community in the past twenty years. Constraint Programming is a paradigm of logic programming where symbolic resolution methods such as unification are not used when dealing with variables that have finite domains that are isomorphic to finite subsets to Z (set of integer numbers). In constraint programming, such a type of variable are resolved (bounded) by the use of numeric (constraints) based approaches, which allows a much faster performance compared to traditional logic programming (e.g. Prolog compilers and interpreters).

On the contrary of traditional logic programming, constraint programming has recently gained wide acceptance in the industry as a powerful tool for solving optimization problems of commercial relevance. This paradigm has been commercially used, for example, in constraint-based scheduling of airplanes and railways, production planning, military logistics, aerospace applications, and VLSI design (floorplanning). The increasing interest in constraint programming has led to the creation of major commercial software packages, such as ILOG (France) and CHIPS (Germany), for development of industry-grade constraint-programming based tools.

A limited number of experiments showed that constraint-programming solvers, such as ILOG and CHIPS, are able to compete against commercial ILP solvers. In some cases, the speed-up ratio was of one or more orders of magnitude faster than ILP solvers in solving ILP problems translated to a constraint-programming format. On the contrary of ILP solvers, constraint programming solvers do not need that all constraints to be linearized, what is an additional plus when dealing with problems represented by integer nonlinear (INLP) and mixed-integer nonlinear programming (MINLP) models.

The present paper investigates how constraint programming can be used in speeding-up the resolution of ILP, INLP, MILP and MINLP models used in representing several problems involving simultaneous

allocation, binding and scheduling of operations and tasks in high-level and system-level synthesis of digital systems. Emphasis is given in using constraint programming only as tool to solve the synthesis problem instead of a representation mechanism. The possibility to merge scheduling and allocation problems with floorplanning considerations for deep sub-micron designs is investigated, through the formulation of an integrated space-time mixed-integer nonlinear programming model to be solved by the use of constraint programming techniques.