Master in Artificial Intelligence (UPC-URV-UB)

Master's Thesis Proposal[1]

General Information

Title:	Optimization Modulo Theories
Expiry Date:	15/2/2012
Modality:	☐ technological project ☒ research work
Advisor/s:	Albert Oliveras, Enric Rodríguez Carbonell
Advisor's Dept. & Univ.:	Departament de Llenguatges i Sistemes Informàtics, Universitat Politècnica de Catalunya
Advisor/s e-mail:	oliveras@lsi.upc.edu (Albert Oliveras), erodri@lsi.upc.edu (Enric Rodríguez Carbonell)
Observations:	
Student's Name: (if already known)	Roc Oliver Vendrell

M.Sc. Thesis Description

Main issues / Brief Description [Mandatory]:

The goal of this work is to study how to equip theory solvers in the context of SMT (Satisfiability Modulo Theories) with optimization features and design and implement an OPT (Optimization Modulo Theories) system for arithmetic theories for solving combinatorial optimization problems.

1 **Each M.Sc. Th. Proposal should be in a separate file, named as follows: "MSc-Th-Proposal-2-or-3-title-first-words-Advisor/s-AcademicYear.pdf".**
For Example: "MSc-Th-Proposal-Syntactic-and-Semantic-LluisMarquez&JesusGimenez-1011.pdf"
The proposal could be elaborated with any text processor (Word, Openoffice, etc.), but **the file electronically delivered** to LSI Dept. Secretary (merce@lsi.upc.edu) **MUST BE a single PDF file**

Detailed Description including a task planning [Mandatory]:

The problem of SAT consists in, given a propositional formula, to decide whether or not it is *sat*isfiable. Over the last ten years, SAT solvers have seen an enormous progress, thanks both to deeper theoretical insights and sophisticated implementation techniques. This has led to the sucessful application of SAT to industrial problems coming from Electronic Design Automation (EDA) and Hardware Verification.

Nevertheless, propositional logic is a too low-level language in some contexts, e.g. in Software Verification. Very often it is more natural to consider the problem of SMT (Satisfiability Modulo Theories), where one has to decide whether a given ground formula in a fragment of first-order logic is satisfiable or not modulo a background fixed theory, for instance real/integer linear arithmetic. State-of-the-art SMT solvers follow the DPLL(T) scheme [1], consisting of a SAT solver that enumerates propositional models of a boolean abstraction of the input formula and a theory solver that checks that the propositional models are consistent with the theory. SMT solvers following this architecture are currently being used with great success in Hardware and Software Verification.

Given the success of SMT solvers in Verification, a natural question is whether these tools can be applied to problems from other areas of practical interest, e.g. Combinatorial Optimization and Operations Research. The aim of this work is to study if SMT theory solvers can be equipped with optimization features so that an OPT (Optimization Modulo Theories) system can be obtained which is competitive with more traditional Mixed Integer Linear Programming (MILP [3]) tools.

In order to achieve this goal, we plan the following tasks:

1) To develop the theoretical framework for Optimization Modulo Theories along the lines of [2] and design the interface between the SAT engine and the theory optimizer.

2) Based on our SAT solver Barcelogic, to implement a SAT optimizer by means of a branch & bound algorithm.

3) Based on existing MILP tools such as CPLEX or GPLK, to implement a theory optimizer conforming to the designed interface for the theories of real linear arithmetic and integer linear arithmetic.

4) To study if specialized theory optimizers can be designed for particular fragments of linear arithmetic (e.g., difference logic [4], where constraints are of the form x - y >= k)

5) To identify problems for which the proposed approach is better than state-of-the-art tools. Good candidate problems are, for instance, those that feature a rich logical structure.

References [Mandatory]:

[1] Robert Nieuwenhuis, Albert Oliveras, Cesare Tinelli: Solving SAT and SAT Modulo Theories: From an abstract Davis--Putnam--Logemann--Loveland procedure to DPLL(T). J. ACM 53(6): 937-977 (2006)

[2] Javier Larrosa, Robert Nieuwenhuis, Albert Oliveras, Enric Rodríguez-Carbonell: A Framework for Certified Boolean Branch-and-Bound Optimization. J. Autom. Reasoning 46(1): 81-102 (2011)

[3] Alexander Schrijver. 1986. Theory of Linear and Integer Programming. John Wiley & Sons, Inc., New York, NY, USA.

[4] Robert Nieuwenhuis, Albert Oliveras: DPLL(T) with Exhaustive Theory Propagation and Its Application to Difference Logic. CAV 2005: 321-334

Minimal Requirements & Previous Knowledge [Optional]:

Other comments [Optional]:

Location and Date: Barcelona, 1/3/2011

To the Academic Commission of the Master in Artificial Intelligence (CAIMIA)