Review

An overview of term rewriting systems

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It is well-known that termination of finite term of rewriting systems is generally undecidable. Notwithstanding, a remarkable result is that, rewriting systems are *Turing complete*. A number of methods have been developed to establish termination for certain term of rewriting systems, particularly occurring in practical situations. In this paper, we present an overview of the existing methods used for termination proofs. We also outline areas of applications of term rewriting systems along with recent developments in regard to automated termination proofs.

Key words: Confluence, rewriting, term, termination, turing complete.

INTRODUCTION

Rewriting is a very powerful method for dealing computationally with equations. However, applying effectively this approach is in general not straightforward. Alternatively, oriented equations, called rewrite rules, are used to replace equals by equals, but only in one direction. A rewrite system is a set of rules used to compute, by repeatedly replacing parts of a given formula with equal ones until the simplest possible form, called normal form, is obtained. For instance, an equation $2 + 3 \rightarrow 5$ can be interpreted as "5 is the result of computing $2 + 3$", but not vice versa. This directional replacement is expressed by $2 + 3 \rightarrow 5$ which reads "$2 + 3$ reduces to 5".

This computational aspect of equations naturally leads to term rewriting systems (TRSs, for short). Depending on the kinds of objects that are rewritten, there are different kinds of rewrite systems such as string rewrite (Thue or semi-Thue) systems, TRSs and graph rewriting to mention a few (Baader and Nipkow, 1998; Terese, 2003; Dershowitz, 2005).

The formal study of rewriting and its properties began in 1910 with a paper by Axel Thue (Book, 1987). Significantly, most early models of computation were based on notions of rewriting strings or terms. The emergence of Thue systems; Alonzo Church's lambda Calculus; Andrei Markov's normal algorithms, just to mention a few, led to sustained study of rewriting in the context of programming language semantics (Book, 1987). To be more specific, the study of TRSs originated in combinatory logic (CL) and lambda calculus (Curry and Feys, 1958) developed and deeply analyzed half a century ago to investigate the foundation of functions. CL is actually a TRS. One could say that the paradigmatic example of a TRS is the system of CL. As a matter of fact, the roots of the very notion of term rewriting and much of its theory can be found in the system of CL.

In the recent years, a strong impulse for the study of TRSs (including extensions of the usual rewriting format) is given by the design of functional languages such as Miranda (Terese, 2003). Another strong impulse is given by efforts of many researchers to combine logic programming with functional programming (Toyama, 1990; Marché and Zantema, 2007). In this direction, Toyama (1990) proposed and applied Knuth-Bendix completion algorithm for a better performance. The compiling technique proposed in this algorithm is dynamic in the sense that, rewriting rules are repeatedly compiled in the completion process. The execution time of the completion with dynamic compiling is ten or more times faster than the one obtained with a traditional TRS interpreter.

Two of the most central properties of TRSs are

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Term Rewriting And Applications

Hanan A. Mohamed

Term Rewriting And Applications:

　　Term Rewriting and Applications Frank Pfenning,2006-07-26 This book constitutes the refereed proceedings of the 17th International Conference on Rewriting Techniques and Applications RTA 2006 held in Seattle WA USA in August 2006 The book presents 23 revised full papers and 4 systems description papers together with 2 invited talks and a plenary talk of the hosting FLoC conference Topics include equational reasoning system verification lambda calculus theorem proving system descriptions termination higher order rewriting and unification and more 　　Term Rewriting and Applications Franz Baader,2007-06-21 The 18th International Conference on Rewriting Techniques and Applications held in Paris France in June 2007 featured presentations and discussions centering on some of the latest advances in the field This volume presents the proceedings from that meeting Papers cover current research on all aspects of rewriting including applications foundational issues frameworks implementations and semantics 　　Term Rewriting and Applications Jürgen Giesl,2005-03-31 This volume contains the proceedings of the 16th International Conference on Rewriting Techniques and Applications RTA2005 whichwasheldonApril19 21 2005 at the Nara Ken New Public Hall in the center of the Nara National Park in Nara Japan RTA is the major forum for the presentation of research on all aspects of rewriting PreviousRTAconferenceswereheldinDijon 1985 Bordeaux 1987 Chapel Hill 1989 Como 1991 Montreal 1993 Kaiserslautern 1995 Rutgers 1996 Sitges 1997 Tsukuba 1998 Trento 1999 Norwich 2000 Utrecht 2001 Copenhagen 2002 Valencia 2003 and Aachen 2004 This year there were 79 submissions from 20 countries of which 31 papers were accepted for publication 29 regular papers and 2 system descriptions The submissions came from France 10 accepted papers of the 23 1 submitted papers USA 5 6 of 11 7 Japan 4 of 9 Spain 2 7 of 6 5 UK 2 7 of 4 7 The Netherlands 1 7 of 3 8 Germany 1 3 of 2 3 Austria 1 of 1 Poland 1 of 1 Israel 0 5 of 0 8 Denmark 0 5 of 0 5 China 0 of 4 Korea 0 of 4 Taiwan 0 of 1 3 Australia 0 of 1 Brazil 0 of 1 Russia 0 of 1 Switzerland 0 of 1 Sweden 0 of 1 and Italy 0 of 0 3 Each submission was assigned to at least three Program Committee m bers who carefully reviewed the papers with the help of 111 external referees 　　Rewriting Techniques and Applications Vincent van Oostrom,2004-08-24 This volume contains the proceedings of the 15th International Conference on Rewriting Techniques and Applications RTA 2004 which was held June 2 5 2004 at the RWTH Aachen in Germany RTA is the major forum for the presentation of research on all aspects of rewriting Previous RTA conferences took place in Dijon 1985 Bordeaux 1987 Chapel Hill 1989 Como 1991 Montreal 1993 Kaiserslautern 1995 Rutgers 1996 Sitges 1997 Tsukuba 1998 Trento 1999 Norwich 2000 Utrecht 2001 Copenhagen 2002 and Valencia 2003 The program committee selected 19 papers for presentation including ve system descriptions from a total of 43 submissions In addition there were invited talks by Neil Jones Aart Middeldorp and Robin Milner Many people helped to make RTA 2004 a success I am grateful to the m bers of the program committee and the external referees for reviewing the s missionsandmaintainingthehighstandardsoftheRTAconferences Itisagreat pleasure to thank the conference chair Jurgen Giesl and the other members of the local organizing committee They were in charge of the

local organization of all events partaking in the Federated Conference on Rewriting Deduction and Programming RDP Apart from RTA 2004 these events were 2nd International Workshop on Higher Order Rewriting Delia Kesner Femke van Raamsdonk and Joe Wells 5th International Workshop on Rule Based Programming Slim Abdennadher and Christophe Ringeissen 13thInternationalWorkshoponFunctionaland Constraint LogicProgr ming Herbert Kuchen IFIP Working Group 1

Advanced Topics in Term Rewriting Enno Ohlebusch,2002-04-12 Unlike current survey articles and textbooks here the so called confluence and termination hierarchies play a key role Throughout the relationships between the properties in the hierarchies are reviewed and it is shown that for every implication X Y in the hierarchies the property X is undecidable for all term rewriting systems satisfying Y Topics covered include the newest techniques for proving termination of rewrite systems a comprehensive chapter on conditional term rewriting systems a state of the art survey of modularity in term rewriting and a uniform framework for term and graph rewriting as well as the first result on conditional graph rewriting *Term Rewriting and Applications* ,2005 Term Rewriting and All That Franz Baader,Tobias Nipkow,1999-08-05 This textbook offers a unified and self contained introduction to the field of term rewriting It covers all the basic material abstract reduction systems termination confluence completion and combination problems but also some important and closely connected subjects universal algebra unification theory Gr bner bases and Buchberger s algorithm The main algorithms are presented both informally and as programs in the functional language Standard ML an appendix contains a quick and easy introduction to ML Certain crucial algorithms like unification and congruence closure are covered in more depth and Pascal programs are developed The book contains many examples and over 170 exercises This text is also an ideal reference book for professional researchers results that have been spread over many conference and journal articles are collected together in a unified notation proofs of almost all theorems are provided and each chapter closes with a guide to the literature

Rewriting Techniques and Applications Robert Nieuwenhuis,2003-05-27 This volume contains the proceedings of the14thInternationalConferenceon RewritingTechniquesandApplications RTA2003 It was held June 9 11 2003 in Valencia Spain as part of RDP theFederatedConferenceonRewriting ductionandProgramming together with the International Conference on Typed Lambda Calculi and Applications TLCA2003 the International Workshop on First order Theorem Proving FTP2003 the annual meeting of the IFIP Working Group 1 6 on Term Rewriting the International Workshop on Rule Based Programming RULE2003 the International Workshop on Uni cation UNIF2003 the International Workshop on Functional and Constraint Logic Programming WFLP2003 the International Workshop on Reduction Stra gies in Rewriting and Programming WRS2003 and the International Wo shop on Termination WST2003 RTA is the major forum for the presentation of research on all aspects of rewr ing Previous RTA conferences were held in Dijon 1985 Bordeaux 1987 Chapel Hill 1989 Como 1991 Montreal 1993 Kaiserslautern 1995 New Brunswick NJ 1996 Sitges Barcelona 1997 Tsukuba 1998 Trento 1999 Norwich 2000 Utrecht 2001 and Copenhagen 2002 This year there were 61 submissions of which 57 regular

research papers and 4 system descriptions with authors from institutions in France 19 6 authors of submitted papers of which 11 3 were accepted USA 6 5 of 9 UK 3 5 of 4 5 Japan 3of6 Germany 2 5 of 4 TheNetherlands 2 2 of 5 2 Spain 1 5 of 4 Austria 1 of 1 Israel 0 5 of 2 5 Portugal 0 of 1 Algeria 0 of 1 Denmark 0 of 1 Canada 0 of 1 Brazil 0 of 0 6 and Poland 0 of 0 5

Typed Lambda Calculi and Applications Marc Bezem,1993-03-03 The lambda calculus was developed in the 1930s by Alonzo Church The calculus turned out to be an interesting model of computation and became theprototype for untyped functional programming languages Operational and denotational semantics for the calculus served as examples for otherprogramming languages In typed lambda calculi lambda terms are classified according to their applicative behavior In the 1960s it was discovered that the types of typed lambda calculi are in fact appearances of logical propositions Thus there are two possible views of typed lambda calculi as models of computation where terms are viewed as programs in a typed programming language as logical theories where the types are viewed as propositions and the terms as proofs The practical spin off from these studies are functional programming languages which are mathematically more succinct than imperative programs systems for automated proof checking based on lambda caluli This volume is the proceedings of TLCA 93 the first international conference on Typed Lambda Calculi and Applications organized by the Department of Philosophy of Utrecht University It includes29 papers selected from 51 submissions **Term Rewriting Systems** Terese,2003-03-20 Term rewriting systems developed out of mathematical logic and are an important part of theoretical computer science They consist of sequences of discrete transformation steps where one term is replaced with another and have applications in many areas from functional programming to automatic theorem proving and computer algebra This 2003 book starts at an elementary level with the earlier chapters providing a foundation for the rest of the work Much of the advanced material appeared here for the first time in book form Subjects treated include orthogonality termination completion lambda calculus higher order rewriting infinitary rewriting and term graph rewriting Many exercises are included with selected solutions provided on the web A comprehensive bibliography makes this book ideal both for teaching and research A chapter is included presenting applications of term rewriting systems with many pointers to actual implementations *Termination and Applications of Term Rewriting Systems* Hanan A. Mohamed,1989 **Handbook Of Graph Grammars And Computing By Graph Transformations, Vol 2: Applications, Languages And Tools** Grzegorz Rozenberg,1999-10-20 Graph grammars originated in the late 60s motivated by considerations about pattern recognition and compiler construction Since then the list of areas which have interacted with the development of graph grammars has grown quite impressively Besides the aforementioned areas it includes software specification and development VLSI layout schemes database design modeling of concurrent systems massively parallel computer architectures logic programming computer animation developmental biology music composition visual languages and many others The area of graph grammars and graph transformations generalizes formal language theory based on strings and the theory of term rewriting based on trees As a

matter of fact within the area of graph grammars graph transformation is considered as a fundamental computation paradigm where computation includes specification programming and implementation Over the last three decades graph grammars have developed at a steady pace into a theoretically attractive and important for applications research field Volume 2 of the indispensable Handbook of Graph Grammars and Computing by Graph Transformations considers applications to functional languages visual and object oriented languages software engineering mechanical engineering chemical process engineering and images It also presents implemented specification languages and tools and structuring and modularization concepts for specification languages The contributions have been written in a tutorial survey style by the top experts in the corresponding areas This volume is accompanied by a CD Rom containing implementations of specification environments based on graph transformation systems and tools whose implementation is based on the use of graph transformation systems   *Processes, Terms and Cycles: Steps on the Road to Infinity* Aart Middeldorp,2005-12-13 This Festschrift is dedicated to Jan Willem Klop on the occasion of his 60th birthday The volume comprises a total of 23 scientific papers by close friends and colleagues written specifically for this book The papers are different in nature some report on new research others have the character of a survey and again others are mainly expository Every contribution has been thoroughly refereed at least twice In many cases the first round of referee reports led to significant revision of the original paper which was again reviewed The articles especially focus upon the lambda calculus term rewriting and process algebra the fields to which Jan Willem Klop has made fundamental contributions   Automated Deduction - CADE-14 William McCune,2005-07-06 This book constitutes the strictly refereed proceedings of the 14th International Conference on Automated Deduction CADE 14 held in Townsville North Queensland Australia in July 1997 The volume presents 25 revised full papers selected from a total of 87 submissions also included are 17 system descriptions and two invited contributions The papers cover a wide range of current issues in the area including resolution term rewriting unification theory induction high order logics nonstandard logics AI methods and applications to software verification geometry and social science   **Languages and Compilers for Parallel Computing** Utpal Banerjee,David Gelernter,Alex Nicolau,David A. Padua,1992 This volume contains the proceedings of the Fourth Workshop on Languages andCompilers for Parallel Computing held in Santa Clara California in August1991 The purpose of the workshop held every year since 1988 is to bring together the leading researchers on parallel programming language designand compilation techniques for parallel computers The papers in this book cover several important topics including 1 languages and structures to represent programs internally in the compiler 2 techniques to analyzeand manipulate sequential loops in order to generate a parallel version 3 techniques to detect and extract fine grain parallelism 4 scheduling and memory management issues in automatically generated parallel programs 5 parallel programming language designs and 6 compilation of explicitly parallel programs Together the papers give a good overview of the research projects underway in 1991 in this field   **Handbook of Automated Reasoning** Alan

J.A. Robinson,Andrei Voronkov,2001-06-22 Handbook of Automated Reasoning   *Compiler Compilers and High Speed Compilation* Dieter Hammer,1989 Advances and problems in the field of compiler compilers are the subject of the 2nd CCHSC Workshop which took place in Berlin GDR in October 1988 The 18 papers which were selected for the workshop are now included in this volume among them three invited papers They discuss the requirements properties and theoretical aspects of compiler compilers as well as tools and metatools for software engineering The papers cover a wide spectrum in the field of compiler compilers ranging from overviews of existing compiler compilers and engineering of compiler compilers to special problems of attribute evaluation generation and code generation In connection with compiler compiler projects means of supporting high speed compilation are pointed out Special attention is given to problems of incremental compilation   Logic-Based Program Synthesis and Transformation Santiago Escobar,Laura Titolo,2025-09-12 This volume constitutes the proceedings of 35th International Symposium on Logic Based Program Synthesis and Transformation LOPSTR 2025 held in Rende Italy during September 9 10 2025 The 17 full papers and 4 short paper included in this book were carefully reviewed and selected from 21 submissions These papers cover all aspects of logic based program development all stages of the software life cycle and issues of both programming in the small and programming in the large   *10th International Conference on Automated Deduction* Mark E. Stickel,1990 This volume contains the papers presented at the 10th International Conference on Automated Deduction CADE 10 CADE is the major forum at which research on all aspects of automated deduction is presented Although automated deduction research is also presented at more general artificial intelligence conferences the CADE conferences have no peer in the concentration and quality of their contributions to this topic The papers included range from theory to implementation and experimentation from propositional to higher order calculi and nonclassical logics they refine and use a wealth of methods including resolution paramodulation rewriting completion unification and induction and they work with a variety of applications including program verification logic programming deductive databases and theorem proving in many domains The volume also contains abstracts of 20 implementations of automated deduction systems The authors of about half the papers are from the United States many are from Western Europe and many too are from the rest of the world The proceedings of the 5th 6th 7th 8th and 9th CADE conferences are published as Volumes 87 138 170 230 310 in the series Lecture Notes in Computer Science PUBLISHER S WEBSITE   *Algebraic and Logic Programming* Helene Kirchner,Giorgio Levi,1992-08-19 This volume contains the proceedings of the Third International Conference on Algebraic and Logic Programming held in Pisa Italy September 2 4 1992 Like the two previous conferences in Germany in 1988 and France in 1990 the third conference aims at strengthening the connections betweenalgebraic techniques and logic programming On the one hand logic programming has been very successful during the last decades and more and more systems compete in enhancing its expressive power On the other hand concepts like functions equality theory and modularity are particularly well handled in an algebraic framework Common

foundations of both approaches have recently been developed and this conference is a forum for people from both areas to exchange ideas results and experiences The book covers the following topics semantics ofalgebraic and logic programming integration of functional and logic programming term rewriting narrowing and resolution constraintlogic programming and theorem proving concurrent features in algebraic and logic programming languages and implementation issues

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