

## CONSTRUCTING PROGRAMS WITH A PLAN FORMATION SYSTEM

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**Abstract.** This paper describes a robot planning system for constructing manipulator programs from task descriptions. Plan formation and program generation techniques are used to transform task specifications into executable programs. The plan formation operates on a data base of knowledge about the world to produce the sequence of actions needed to execute the task. The program generation transforms the sequence of actions into an executable program, written in MAL, using knowledge about the robot and its control system.

**Keywords.** Robot programming, plan formation.

### INTRODUCTION

Robots are today operating on a wide variety of tasks, such as object handling, painting, and welding. Even though assembly is still considered a difficult area more and more robots are used in manufacturing to perform assembly tasks. New areas outside manufacturing, like exploration of unknown environments and medical applications, are being considered.

All these new developments raise crucial problems. Programming robots, which was very easy when tasks were simple like pick and place, becomes an important issue. Sensors provide a huge amount of potentially useful data that have to be interpreted to be of any use. Computer programming, which was non-existent in the early stages of robotics, becomes one of the central issues.

Programming a computer controlled robot is really different than programming a computer. Robot programs run in a world which is incompletely known and imperfectly

modeled. This requires strategies to detect and prevent potential catastrophes, like collisions, and to recover from errors. Many actions are irreversible, making it difficult to detect causes of errors and to fix them. Currently users must depend on their experience, intuition, and common sense to decide how to write programs.

This paper presents an approach to robot programming based on the automatic generation of programs from task oriented specifications. The specifications are given to a plan formation module which produces the plan of actions. The plan is then transformed into a program by a program generation module.

We discuss in this paper both plan formation and program generation. These two activities are performed using a knowledge base that contains knowledge about the arm (work area, arm model, sensors), about different tasks (inserting, grasping, fitting), about the programming language of the robot (syntax and semantics), as well as geometric knowledge about the objects involved.

This organization allows to capture part of the experience that experienced programmers employ when they develop new programs. We hope

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Maria Gini is now with the Department of Computer Science, University of Minnesota, Minneapolis.

# Constructing Programs From Specifications

**Nicolas Halbwachs**

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*Algebraic and Coalgebraic Methods in the Mathematics of Program Construction* Roland Backhouse, Roy Crole, Jeremy Gibbons, 2003-07-31 Program construction is about turning specifications of computer software into implementations Recent research aimed at improving the process of program construction exploits insights from abstract algebraic tools such as lattice theory fixpoint calculus universal algebra category theory and allegory theory This textbook like tutorial presents besides an introduction eight coherently written chapters by leading authorities on ordered sets and complete lattices algebras and coalgebras Galois connections and fixed point calculus calculating functional programs algebra of program termination exercises in coalgebraic specification algebraic methods for optimization problems and temporal algebra

KORSO: Methods, Languages, and Tools for the Construction of Correct Software Manfred Broy, Stefan Jähnichen, 1995-11-08 This book constitutes the final report of the work carried out in the project KORSO Korrekte Software funded by the German Federal Ministry for Research and Technology KORSO is an evolutionary prototype oriented project aimed at improving the theoretical foundations of quality driven software engineering and at implementing known techniques for applications of practical relevance The 21 strictly refereed papers presented are organized in five sections on methods for correctness languages development systems and logical frameworks tools and case studies In addition the preface and introductory paper give valuable background information and a concise state of the art overview Mathematics of Program Construction Bernhard Möller, 1995-07-10 This volume constitutes the proceedings of the Third International Conference on the Mathematics of Program Construction held at Kloster Irsee Germany in July 1995 Besides five invited lectures by distinguished researchers there are presented 19 full revised papers selected from a total of 58 submissions The general

theme is the use of crisp clear mathematics in the discovery and design of algorithms and in the development of corresponding software and hardware among the topics addressed are program transformation program analysis program verification as well as convincing case studies

**Program Specification** J. Staunstrup, 1982-04 *Mathematics of Program Construction* Jan L.A. van de Snepscheut, 1989-06-07 The papers included in this volume were presented at the Conference on Mathematics of Program Construction held from June 26 to 30 1989 The conference was organized by the Department of Computing Science Groningen University The Netherlands at the occasion of the University's 375th anniversary The creative inspiration of the modern computer has led to the development of new mathematics the mathematics of program construction Initially concerned with the posterior verification of computer programs the mathematics have now matured to the point where they are actively being used for the discovery of elegant solutions to new programming problems Initially concerned specifically with imperative programming the application of mathematical methodologies is now established as an essential part of all programming paradigms functional logic and object oriented programming modularity and type structure etc Initially concerned with software only the mathematics are also finding fruit in hardware design so that the traditional boundaries between the two disciplines have become blurred The varieties of mathematics of program construction are wide ranging They include calculi for the specification of sequential and concurrent programs program transformation and analysis methodologies and formal inference systems for the construction and analysis of programs The mathematics of specification implementation and analysis have become indispensable tools for practical programming

Mathematics of Program Construction Ralf Hinze, Janis Voigtländer, 2015-06-09 This book constitutes the refereed proceedings of the 12th International Conference on Mathematics of Program Construction MPC 2015 held in K nigswinter Germany in June July 2015 The 15 revised full papers presented together with two invited talks were carefully reviewed and selected from 20 submissions The papers are about mathematical methods and tools put to use in program construction They range from algorithmics to support for program construction in programming languages and systems Some typical areas are type systems program analysis and transformation programming language semantics security and program logics

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Formal Methods in Programming and Their Applications Dines Bjorner, Manfred Broy, Igor V. Pottosin, 1993-10-05 This volume comprises the papers selected for presentation at the international conference on Formal Methods in Programming and Their Applications held in Akademgorodok Novosibirsk Russia June July 1993 The conference was organized by the Institute of Informatics Systems of the Siberian Division of the Russian Academy of Sciences and was the first forum organized by the Institute which was entirely dedicated to formal methods The main scientific tracks of the conference were centered around formal methods of program development and program construction The papers in the book are grouped into the following parts formal semantics methods algebraic specification methods semantic program analysis and abstract interpretation semantics of parallelism logic of programs software specification and verification transformational development and program synthesis

**Automated Deduction - A Basis for Applications Volume I Foundations - Calculi and Methods Volume II Systems and Implementation Techniques Volume III Applications** Wolfgang Bibel, P.H. Schmitt, 2013-03-09 We are invited to deal with mathematical activity in a systematic way one does expect and look for pleasant surprises in this requirement of a novel combination of psychology logic mathematics and technology Hao Wang 1970 quoted from Wang 1970 The field of mathematics has been a key application area for automated theorem proving from the start in fact the very first automatically found theorem was that the sum of two even numbers is even Davis 1983 The field of automated deduction has witnessed considerable progress and in the last decade automated deduction methods have made their way into many areas of research and product development in computer science For instance deduction systems are increasingly used in software and hardware verification to ensure the correctness of computer hardware and computer programs with respect to a given specification Logic programming while still falling somewhat short of its expectations is now widely used deductive databases are well developed and logic based description and analysis of hard and software is commonplace today

**The PBS Building Systems Program and Performance Specification for Office Buildings** United States. Public Buildings Service, United States. Public Buildings Service. Office of Construction

Management,1975      Mathematics of Program Construction Claude Bolduc,Jules Desharnais,Bechir Ktari,2010-06 This book constitutes the refereed proceedings of the 10th International Conference on Mathematics of Program Construction MPC 2010 held in Qu bec City Canada in June 2010 The 19 revised full papers presented together with 1 invited talk and the abstracts of 2 invited talks were carefully reviewed and selected from 37 submissions The focus is on techniques that combine precision with conciseness enabling programs to be constructed by formal calculation Within this theme the scope of the series is very diverse including programming methodology program specification and transformation program analysis programming paradigms programming calculi programming language semantics security and program logics      Tools and Algorithms for the Construction and Analysis of Systems Nicolas Halbwachs,2005-03-23 This book constitutes the refereed proceedings of the 11th International Conference on Tools and Algorithms for the Construction and Analysis of Systems TACAS 2005 held in Edinburgh UK in April 2005 as part of ETAPS The 33 revised full research papers and 8 revised tool demonstration papers presented together with an invited paper were carefully reviewed and selected from a total of 161 submissions The papers are organized in topical sections on regular model checking infinite state machines abstract interpretation automata and logics probabilistic systems and probabilistic model checking satisfiability testing abstraction and reduction specification and program synthesis and model checking      *Algebraic Methodology and Software Technology* Martin Wirsing,Maurice Nivat,1996-06-19 Content Description Includes bibliographical references and index

Mathematics of Program Construction Johan Jeuring,1998-05-27 This book consitutes the refereed proceedings of the 4th International Conference on Mathematics of Program Construction MPC 98 held in Marstrand near Goteborg Sweden in June 1998 The 17 revised full papers presented were selected from 57 submissions also included are three invited contributions The volume is devoted to the use of crisp clear mathematics in the discovery and design of algorithms and in the development of corresponding software and hardware varoius approaches to formal methods for systems design and analysis are covered      *Automatic Program Development* Olivier Danvy,Fritz Henglein,Harry Mairson,Alberto Pettorossi,2008-01-12 This work a tribute to renowned researcher Robert Paige is a collection of revised papers published in his honor in the Higher Order and Symbolic Computation Journal in 2003 and 2005 Among them there are two key papers a retrospective view of his research lines and a proposal for future studies in the area of the automatic program derivation The book also includes some papers by members of the IFIP Working Group 2.1 of which Bob was an active member      **Mathematics of Program Construction** Eerke A. Boiten,Bernhard Möller,2003-08-02 This book constitutes the refereed proceedings of the 6th International Conference on Mathematics of Program Construction MPC 2002 held in Dagstuhl Castle Germany in July 2002 The 11 revised full papers presented were carefully reviewed and selected for inclusion in the book also presented are one invited paper and the abstracts of two invited talks Among the topics covered are programming methodology program specification program transformation programming paradigms programming calculi and programming language semantics

Program Construction F.L. Bauer, E.W. Dijkstra, S.L. Gerhart, D. Gries, M. Griffiths, J. V. Guttag, J. J. Horning, S. S. Owicki, C. Pair, H. Partsch, P. Pepper, M. Wirsing, H. Wössner, 2005-11-23      **Tools and Algorithms for the Construction and Analysis of Systems** Stefan Kowalewski, Anna Philippou, 2009-03-09 This book constitutes the refereed proceedings of the 15th International Conference on Tools and Algorithms for the Construction and Analysis of Systems TACAS 2009 held in York UK in March 2009 as part of ETAPS 2009 the European Joint Conferences on Theory and Practice of Software The 27 full papers and 8 tool demonstrations included in the volume were thoroughly reviewed and selected from 131 submissions The papers are organized in topical sections on Model Checking Tools Verification of Concurrent Programs Parametric Analysis Program Analysis and Hybrid Systems

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