

CHAPTER 16

SOLUTIONS OF EXERCISES

Exercise 1.4.0. (a)

$$\begin{aligned}
 & c; \text{miracle} \cong \text{miracle} \\
 \equiv & \{(\bar{7}), \text{ let } wg \text{ range over } wp, wlp \text{ and } p \text{ over } \mathbb{P} \} \\
 & (\forall wg, p :: wg.(c; \text{miracle}).p = wg.\text{miracle}.p) \\
 \equiv & \{(13)\} \\
 & (\forall wg, p :: wg.c.(wg.\text{miracle}.p) = wg.\text{miracle}.p) \\
 \equiv & \{(10)\} \\
 & (\forall wg :: wg.c.\text{true} = \text{true}) \\
 \equiv & \{(2)\} \\
 & [wp.c.\text{true}] \wedge [wlp.c.\text{true}] \\
 \equiv & \{\text{by (4), the lefthand conjunct implies the other one}\} \\
 & [wp.c.\text{true}] .
 \end{aligned}$$

Exercise 2.3.0. (a) Clearly, t is an external variable threatened to be modified. Since t and y may change, we introduce specification constants T and Y and the postcondition $Q : t = T \wedge y = Y$. The precondition $wp.(\text{body}.h).Q$ is easily calculated. In this way we get the specification

$$\begin{aligned}
 & \{\text{ext } t!; \text{ all } T, Y \in \text{integer} :: \\
 & \quad \text{pre } P : y = T \wedge x + t = Y, \text{ post } Q : t = T \wedge y = Y\} .
 \end{aligned}$$

The verification of the conditions (a), (b), (c) of (7) is immediate.

(b) Since program variable w is modified by the call, we assume that the call is $h(E, w)$ for some expression E . Rule (10) yields

$$\{w = T \wedge E + t = Y \wedge R\} \quad h(E, w) \quad \{t = T \wedge w = Y \wedge R\}$$

for all values Y and T and all predicates R with $\text{Var}.R \cap \{t, w\} = \emptyset$. In particular, choosing $T := X$ and $Y := 0$ and $R := \text{true}$, we get

$$\{w = X \wedge E + t = 0\} \quad h(E, w) \quad \{t = X \wedge w = 0\} .$$

Programs Recursion And Unbounded Choice

Maria Manzano



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Free Choice Petri Nets Jorg Desel, Javier Esparza, 1995-01-12 Petri nets are a model for the analysis of concurrent systems

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

Concurrency Verification W.-P. de Roever, 2001-11-26 An advanced 2001 textbook on verification of concurrent programs using a semantic approach which highlights concepts clearly

Mathematics of Program Construction Johan Jeuring, 1998-05-27 This book constitutes 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 various approaches to formal methods for systems design and analysis are covered

Programs, Recursion and Unbounded Choice Wim H. Hesselink, 1992-05-21 This book is a complete account of the predicate transformation calculus semantics of sequential programs including repetitions recursive procedures computational induction and unbounded nondeterminacy Predicate transformation semantics are the best specification method for the development of correct and well structured computer programs The author develops this theory to a greater depth than has been achieved before and describes it in a way that makes it readily compatible with programming rules for partial and total correctness of repetitions and recursive procedures supplies new rules for proving incorrectness and a stronger rule for proving that two programs satisfy the same specifications Finally the semantics are extended so that non terminating programs can be specified as well This will be essential reading for all computer scientists working in specification and verification of programs

Propositional Logic Hans Kleine Büning, Theodor Lettmann, 1999-08-28 This account of propositional logic concentrates on the algorithmic translation of important methods especially of decision procedures for subclasses of propositional logic Important classical results and a series of new results taken from the fields of normal forms satisfiability and deduction methods are arranged in a uniform and complete theoretic framework The algorithms presented can be applied to VLSI design deductive databases and other areas After introducing the subject the authors discuss satisfiability problems and satisfiability algorithms with complexity considerations the resolution calculus with different refinements and special features and procedures for Horn formulas Then a selection of further calculi and some results on the complexity of proof procedures are presented The last chapter is

devoted to quantified boolean formulas The algorithmic approach will make this book attractive to computer scientists and graduate students in areas such as automated reasoning logic programming complexity theory and pure and applied logic

Algebraic Semantics of Imperative Programs Joseph Goguen, Grant Malcolm, 1996 Algebraic Semantics of Imperative Programs presents a self contained and novel executable introduction to formal reasoning about imperative programs The authors primary goal is to improve programming ability by improving intuition about what programs mean and how they run The semantics of imperative programs is specified in a formal implemented notation the language OBJ this makes the semantics highly rigorous yet simple and provides support for the mechanical verification of program properties OBJ was designed for algebraic semantics its declarations introduce symbols for sorts and functions its statements are equations and its computations are equational proofs Thus an OBJ program is an equational theory and every OBJ computation proves some theorem about such a theory This means that an OBJ program used for defining the semantics of a program already has a precise mathematical meaning Moreover standard techniques for mechanizing equational reasoning can be used for verifying axioms that describe the effect of imperative programs on abstract machines These axioms can then be used in mechanical proofs of properties of programs Intended for advanced undergraduates or beginning graduate students Algebraic Semantics of Imperative Programs contains many examples and exercises in program verification all of which can be done in OBJ

Refinement Calculus Ralph-Johan Back, Joakim Wright, 2012-12-06 Much current research in computer science is concerned with two questions is a program correct And how can we improve a correct program preserving correctness This latter question is known as the refinement of programs and the purpose of this book is to consider these questions in a formal setting In fact correctness turns out to be a special case of refinement and so the focus is on refinement Although a reasonable background knowledge is assumed from mathematics and CS the book is a self contained introduction suitable for graduate students and researchers coming to this subject for the first time There are numerous exercises provided of varying degrees of challenge

Object-Oriented Behavioral Specifications Haim Kilov, William Harvey, 2007-08-20 Object Oriented Behavioral Specifications encourages builders of complex information systems to accelerate their move to using the approach of a scientific discipline in analysis rather than the approach of a craft The focus is on understanding customers needs and on precise specification of understanding gained through analysis Specifications must bridge any gaps in understanding about business rules among customers Subject Matter Experts and computer people must inform decisions about reuse of software and systems and must enable review of semantics over time Specifications need to describe semantics rather than syntax and to do that in an abstract and precise manner in order to create software systems that satisfy business rules The papers in this book show various ways of designing elegant and clear specifications which are reusable lead to savings of intellectual effort time and money and which contribute to the reliability of software and systems Object Oriented Behavioral Specifications offers a fresh treatment of the object oriented paradigm by examining the limitations of traditional OO methodologies and by

describing the significance of competing trends in OO modeling The book builds on four years of successful OOPSLA workshops 1991 1995 on behavior semantics This book deals with precise specifications of what is accomplished by the business and what is to be done by a system The book includes descriptions of successful use of abstract and precise specification in industry It draws on the experience of experts from industrial and academic settings and benefits from international participation Collective behavior neglected in some treatment of the OO paradigm is addressed explicitly in this book The book does not take reuse of specifications or software for granted but furnishes a foundation for taking as rigorous an approach to reuse decisions as to precise specifications in original developments

Theories of Programming and Formal Methods Zhiming Liu, Jim Woodcock, Huibiao Zhu, 2013-07-24 This Festschrift volume dedicated to He Jifeng on the occasion of his 70th birthday in September 2013 includes 24 refereed papers by leading researchers current and former colleagues who congratulated at a celebratory symposium held in Shanghai China in the course of the 10th International Colloquium on Theoretical Aspects of Computing ICTAC 2013 The papers cover a broad spectrum of subjects from foundational and theoretical topics to programs and systems issues and to applications comprising formal methods software and systems modeling semantics laws of programming specification and verification as well as logics He Jifeng is known for his seminal work in the theories of programming and formal methods for software engineering He is particularly associated with Unifying Theories of Programming UTP the theory of data refinement and the laws of programming and the rCOS formal method for object and component system construction His book on UTP with Tony Hoare has been widely read and followed by a large number of researchers and it has been used in many postgraduate courses He was a senior researcher at Oxford during 1984 1998 and then a senior research fellow at the United Nations University International Institute for Software Technology UNU IIST in Macau during 1998 2005 He has been a professor and currently the Dean of the Institute of Software Engineering at East China Normal University Shanghai China In 2005 He Jifeng was elected as an academician to the Chinese Academy of Sciences He also received an honorary doctorate from the University of York He won a number of prestigious science and technology awards including a 2nd prize of Natural Science Award from the State Council of China a 1st prize of Natural Science Award from the Ministry of Education of China a 1st prize of Technology Innovation from the Ministry of Electronic Industry and a number awards from Shanghai government

Unifying Theories of Programming Andrew Butterfield, 2010-07-30 This book constitutes the thoroughly refereed post proceedings of the Second International Symposium on Unifying Theories of Programming UTP 2008 held at Trinity College Dublin Ireland in September 2008 The 15 revised full papers presented together with two invited talks were carefully reviewed and selected from 20 submissions Based on the pioneering work on unifying theories of programming of Tony Hoare He Jifeng and others the aims of this Symposium series are to continue to reaffirm the significance of the ongoing UTP project to encourage efforts to advance it by providing a focus for the sharing of results by those already actively contributing and to raise awareness of the benefits of

such a unifying theoretical framework among the wider computer science and software engineering communities

Basic Simple Type Theory J. Roger Hindley, 1997 Type theory is one of the most important tools in the design of higher level programming languages such as ML This book introduces and teaches its techniques by focusing on one particularly neat system and studying it in detail By concentrating on the principles that make the theory work in practice the author covers all the key ideas without getting involved in the complications of more advanced systems This book takes a type assignment approach to type theory and the system considered is the simplest polymorphic one The author covers all the basic ideas including the system's relation to propositional logic and gives a careful treatment of the type checking algorithm that lies at the heart of every such system Also featured are two other interesting algorithms that until now have been buried in inaccessible technical literature The mathematical presentation is rigorous but clear making it the first book at this level that can be used as an introduction to type theory for computer scientists

Derivation and Computation H. Simmons, 2000-05-18 Mathematics is about proofs that is the derivation of correct statements and calculations that is the production of results according to well defined sets of rules The two notions are intimately related Proofs can involve calculations and the algorithm underlying a calculation should be proved correct The aim of the author is to explore this relationship The book itself forms an introduction to simple type theory Starting from the familiar propositional calculus the author develops the central idea of an applied lambda calculus This is illustrated by an account of G del's T a system which codifies number theoretic function hierarchies Each of the book's 52 sections ends with a set of exercises some 200 in total These are designed to help the reader get to grips with the subject and develop a further understanding An appendix contains complete solutions of these exercises

Semantic Techniques in Quantum Computation Simon Gay, Ian Mackie, 2010 The study of computational processes based on the laws of quantum mechanics has led to the discovery of new algorithms cryptographic techniques and communication primitives This book explores quantum computation from the perspective of the branch of theoretical computer science known as semantics as an alternative to the more well known studies of algorithmics complexity theory and information theory It collects chapters from leading researchers in the field discussing the theory of quantum programming languages logics and tools for reasoning about quantum systems and novel approaches to the foundations of quantum mechanics This book is suitable for graduate students and researchers in quantum information and computation as well as those in semantics who want to learn about a new field arising from the application of semantic techniques to quantum information and computation

Extensions of First-Order Logic Maria Manzano, 1996-03-29 An introduction to many sorted logic as an extension of first order logic

Process Algebra: Equational Theories of Communicating Processes J. C. M. Baeten, M. A. Reniers, 2010 Presents a unified overview of the various process algebras currently in use and sets the standard for the field

Basic Proof Theory A. S. Troelstra, H. Schwichtenberg, 2000-07-27 This introduction to the basic ideas of structural proof theory contains a thorough discussion and

comparison of various types of formalization of first order logic Examples are given of several areas of application namely the metamathematics of pure first order logic intuitionistic as well as classical the theory of logic programming category theory modal logic linear logic first order arithmetic and second order logic In each case the aim is to illustrate the methods in relatively simple situations and then apply them elsewhere in much more complex settings There are numerous exercises throughout the text In general the only prerequisite is a standard course in first order logic making the book ideal for graduate students and beginning researchers in mathematical logic theoretical computer science and artificial intelligence For the new edition many sections have been rewritten to improve clarity new sections have been added on cut elimination and solutions to selected exercises have been included

Data Refinement W.-P. de Roever, Kai Engelhardt, 1998-12-03 The goal of this book is to provide a comprehensive and systematic introduction to the important and highly applicable method of data refinement and the simulation methods used for proving its correctness The authors concentrate in the first part on the general principles needed to prove data refinement correct They begin with an explanation of the fundamental notions showing that data refinement proofs reduce to proving simulation The book's second part contains a detailed survey of important methods in this field which are carefully analysed and shown to be either incomplete with counterexamples to their application or to be always applicable whenever data refinement holds This is shown by proving for the first time that all these methods can be described and analysed in terms of two simple notions forward and backward simulation The book is self contained going from advanced undergraduate level and taking the reader to the state of the art in methods for proving simulation

Communicating Sequential Processes. The First 25 Years Ali E. Abdallah, 2005-05-03 This book commemorates the work done by Tony Hoare and published under the title *Communicating Sequential Processes* in the 1978 August issue of the *Communications of ACM* The British Computer Society's specialist group *Formal Aspects of Computing Science* organized a meeting on July 7-8 2004 in London to mark the occasion of 25 years of CSP The 19 carefully reviewed and revised full papers by leading researchers celebrate reflect upon and look beyond the first quarter century of CSP's contributions to computer science The papers explore the impact of CSP on many areas ranging from semantics and logic through the design of parallel programming languages to applications varying from distributed software and parallel computing to information security Web services and concurrent hardware circuits

Integrated Formal Methods Jim Davies, Jeremy Gibbons, 2007-06-22 This book constitutes the refereed proceedings of the 6th International Conference on Integrated Formal Methods IFM 2007 held in Oxford UK It addresses all aspects of formal methods integration including of a process of analysis or design application of formal methods to analysis or design extension of one method based upon the inclusion of ideas or concepts from others and semantic integration or practical application

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