OBJECTS FOR CONCURRENT CONSTRAINT PROGRAMMING

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OBJECTS FOR CONCURRENT CONSTRAINT PROGRAMMING

by

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TO KELLY

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FOREWORD

The Oz Project started in 1991 as an effort to better understand the relationship between existing programming paradigms and to design a unified language supporting constraint programming, concurrency, and object-orientation. Our starting point was Logic Programming, then a thriving research area, from which we took many of the ideas for Oz. Other ideas came from functional programming and concurrency theory.

The goals of the Oz Project were mainly practical, not so much theoretical. Early on, it became clear that we could not reach our goals with a purely declarative language. So we took the best ideas from the declarative paradigms and integrated them with state and explicit control. This integration led to a new, surprisingly simple computation model with amazing expressivity. Having grown up with the dogma of the declarative churches “do not consider the impure,” it took some time until we felt comfortable with the integration of non-declarative features.

Our goal to support object-oriented abstractions had a severe impact on the design of Oz. Since objects typically do have state, Oz had to have state. Since object-oriented abstractions are too complex and too diverse to appear as computational primitives, we needed first-class procedures and lexical scoping to express them. Since objects come with first-class identity and classes come with complex visibility rules, we invented a notion of name that can express these features, among many others. Much inspiration for Oz came from our attempt to reconstruct objects and classes from a minimal set of general purpose primitives.

Dr. Martin Henz was one of the young researchers with whom I started the Oz Project. His first contribution was the beautiful name Oz. His most tedious duty was the consolidation of the Oz syntax from the conflicting wish lists of the project members. His main task, however, was the design and implementation of an object system for the envisioned language. He did a marvelous job. This book, a slight revision of his doctoral thesis, gives a first hand account of “objects in Oz.” It will be of great interest to language designers, language implementors, and serious Oz programmers.

Gert Smolka
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PREFACE

Object-oriented programming had a tremendous impact on the world of software in the last 15 years. Numerous approaches have been proposed to support this successful programming paradigm in other programming language families such as logic and functional programming.

Concurrent constraint programming (ccp) is a recent development in programming language design. Its central contribution is the notion of partial information provided by a shared constraint store. The constraint store serves as communication medium between concurrent threads of control and as vehicle for their synchronization.

In this work, we analyse the possibilities to support object-oriented programming in ccp. Starting from known approaches, we cover various object models and discuss their properties. As model language for the analysis, we use the language Small Oz, a sublanguage of the ccp language Oz. We present a general-purpose object system for Small Oz, describe its implementation and its expressivity for concurrent computation.

The book is written for programming language researchers with interest in programming language aspects of concurrency, object-oriented programming or constraint programming. Programming language implementors will benefit from the rigorous treatment of the efficient implementation of Small Oz. Oz programmers get a first-hand view of the design decisions that lie behind the Oz object system.

From the perspective of ccp, this work introduces the notion of passive objects—the central notion of object-oriented programming—to the ccp framework. It builds a bridge from essential ideas of ccp to main-stream programming languages.

From the perspective of object-oriented and functional languages, a central contribution is that partial information as provided by logic variables can be integrated in the framework of both of these paradigms in a straightforward manner. From this integration, concurrent objects benefit through simple and elegant synchronization techniques.

The language Oz was designed in the Programming Systems Lab, Saarbrücken, Germany, as an attempt to integrate essential aspects of the paradigms of constraint (logic), object-oriented and functional programming. This book gives account of this integration from the perspective of (concurrent) object-oriented programming. It is based on the author's doctoral thesis "Objects in Oz," accepted by the Universität des Saarlandes in June 1997.

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Research is a dynamic and interactive activity which thrives in an environment that fosters exchange of ideas and intense collaboration between researchers. I found such an environment in the Programming Systems Lab in Saarbrücken. It was the cooperation with the enthusiastic, knowledgeable and cooperative researchers of this lab that led to the results reported in this monograph. To say that without them this work would not have been possible would miss the point. This is *their work* as well as it is mine.

For my doctoral thesis work on which this monograph is based, I was fortunate to be supervised by Gert Smolka. His work on Oz laid the base for this monograph. His tireless striving for simplicity as a chief goal of scientific endeavor was truly inspiring. Ralf Scheidhauer implemented the emulator support and contributed several ideas to the implementation of the object system that I describe. Christian Schulte contributed countless ideas to the design of Objects in Oz, and Jörg Würtz helped lay the base for its initial design. Christian Schulte and Konstantin Popov were the first object-oriented programmers in Oz and shared their programming experience with me. Martin Müller and Michael Mehl contributed concurrent programming examples. Michael Mehl helped with comments and suggestions and shared his experience with object-oriented programming. Martin Müller and Joachim Niehren shared their knowledge concerning a few fundamental aspects that I discuss in passing. Denys Duchier contributed an elegant syntactic detail. I thank Seif Haridi for several fruitful discussions on the design of object systems. Leif Kornstaedt, Kelly Reedy, Ralf Scheidhauer, Christian Schulte, Gert Smolka and Joachim Walser commented on earlier versions of this work. The following people provided advice and assistance for the performance measurements in Section 8.6: Hubert Baumeister, Seif Haridi, Michael Mehl, Tobias Müller, Jérôme Vouillon, Peter Van Roy, and Joachim Walser.

The work that led to this book was carried out at the Programming Systems Lab in Saarbrücken from January 1992 to June 1997. From January 1992 to March 1996, I was funded by DFKI (German Research Center for Artificial Intelligence) under contract ITW 9105 with the Bundesminister für Bildung, Wissenschaft, Forschung und Technologie, and from April 1996 to June 1997 by the Universität des Saarlandes, Saarbrücken, Germany, under the Special Research Division “Resource-Adaptive Cognitive Processes”, Sonderforschungsbereich 318.

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