The Science of Functional Programming

A tutorial, with examples in Scala

This book is a pedagogical in-depth tutorial and reference on the theory of functional programming (FP) as practiced in the early 21st century. Starting from issues found in practical coding, the book builds up the theoretical intuition, knowledge, and techniques that programmers need for rigorous reasoning about types and code. Examples are given in Scala, but most of the material applies equally to other FP languages.

The book's topics include working with collections; recursive functions and types; the Curry-Howard correspondence; laws, structural analysis, and code for functors, monads, and other typeclasses; techniques of symbolic derivation and proof; parametricity theorems; and free type constructions.

Long and difficult, yet boring explanations are logically developed in excruciating detail and accompanied by 1481 Scala code snippets, 145 statements with step-by-step derivations, 96 diagrams, 196 solved examples with tested Scala code, and 223 exercises. Discussions further build upon each chapter's material.

Beginners in FP will find clear explanations about the `map` / `reduce` programming style, type parameters, disjunctive types, and higher-order functions. For more advanced readers, the book shows the practical uses of the Curry-Howard correspondence and the parametricity theorems without unnecessary jargon; proves that all the standard monads (e.g., `List` or `State`) satisfy the monad laws; derives lawful instances of `Functor` and other typeclasses from types; shows that monad transformers need 18 laws; and explains the use of Yoneda identities for reasoning about the Church encoding and the free type constructions.

Readers should have a working knowledge of programming; e.g., be able to write code that prints the number of distinct words in a small text file. The difficulty of this book's mathematical derivations is at the level of high-school calculus, similar to that of multiplying matrices and simplifying the expressions

$$\frac{1}{x-2} - \frac{1}{x+2} \quad \text{and} \quad \frac{d}{dx}\left((x+1)f(x)e^{-x}\right) \quad .$$

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