FUNCTIONAL PROGRAMMING

Maths & Natural Sciences (MN) programme at Uppsala University, Sweden

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Chapter 1: Introduction

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1.1. Objectives

Introduction to the fundamental principles and methodologies of functional programming, using the programming language Standard ML (SML, or simply ML) as the teaching medium.

Theoretical focus, with many examples, on:

- Algorithms and data structures (how?)
- Programming methodology:
  - Importance of specifications (what?)
  - Importance of justifications (why?)
  - Importance of other documentation
  - Importance of rigour, explicitness, and elegance
- Complexity of algorithms

Some further practice of programming (in ML) is acquired through assignments, which are to be:

1. Prepared at home
2. Tried on the computer in labs under assistant supervision
3. Graded by an assistant
1.2. Functions

A function $f$ is a correspondence between two sets of values:

$$f : A \rightarrow B$$

To each element $a$ of the set $A$,
the function $f$ associates at most one value of the set $B$

**Notations**

$f(a) = b$: $f$ associates the value $b$ of $B$ to the element $a$ of $A$

$f(a) = \bot$ (or $f(a)$ is undefined): $f$ associates no value to $a$
Total functions and partial functions

Let $f : A \to B$ be a function:

- $f$ is a total function if $f$ is defined for every element of $A$
- $f$ is a partial function if $f$ is not total

Definition of functions

Definition by extension

Give the graph of the function: $(a_1, b_1) \ (a_2, b_2) \ldots$

Example: function $\text{double}$:

$(1,2) \ (2,4) \ (3,6) \ (4,8) \ldots$

Definition by intension (note the ‘s’!)

Define the function by a rule describing its graph

Example: function $\text{double}$:

$\text{double}(n) = 2 \times n$
Expressions

\[ 5 + 7 \]

\[
\begin{array}{c}
5 \\
+ \\
7 \\
\rightarrow 12
\end{array}
\]

\[ 3 \sim 4 + 7 \]

\[
\begin{array}{c}
4 \\
\sim \\
3 \\
* \\
7 \\
\rightarrow \\
+ \\
\rightarrow
\end{array}
\]

Definition of new functions

\[
\text{relative_error} (x,y) = \frac{\text{abs}(x - y)}{y}
\]

\[
\begin{array}{c}
x \\
- \\
y \\
\rightarrow \\
\text{abs} \\
\rightarrow \\
/ \\
\rightarrow
\end{array}
\]
1.3. Functional programming languages

Fundamental principles

- Execution by evaluation of expressions
- Declaration of functions
- Application of functions
- Recursion

Existing functional programming languages

- Lisp (Mc Carthy, 1962), Scheme
- FP (J. Backus, 1978)
- Miranda (D. Turner, 1986)
- Haskell (P. Hudack, 1990)
- LCF, ML (Meta Language) (Edinburgh, 1977)
- CAML (France, 1990)
- SML (Standard ML) (1990)