CS 135

September 5, 2019
Programming language design
Values, expressions, & functions
The DrRacket environment
Programming in DrRacket
Defining functions

Functions
Readings

• HTDP, sections 1 – 3
• Survival and Style guides
Programming language design
Programming language paradigms

1. Imperative: based on changes to data, e.g.,
   - Machine language
   - Java
   - C++
Programming language paradigms

1. Imperative: based on changes to data, e.g.,
   - Machine language
   - Java
   - C++

2. Functional (sub-set of Declarative): based on the computation of new values rather than the transformation of old ones, e.g.,
   - Lisp, Haskell, Erlang, Clojure
   - Mathematica, R

More closely connected to mathematics
Easier to design and reason about programs
Programming language paradigms

1. Imperative: based on changes to data, e.g.,
   - Machine language
   - Java
   - C++

2. Functional (sub-set of Declarative): based on the computation of new values rather than the transformation of old ones, e.g.,
   - Lisp, Haskell, Erlang, Clojure
   - Mathematica, R
   More closely connected to mathematics
   Easier to design and reason about programs

3. And many, many more...

Many programming languages mix paradigms!
Functional vs. imperative programming languages

Functional and imperative programming languages share many concepts. However, they require you to think differently about your programs.
Functional vs. imperative programming languages

Functional and imperative programming languages share many concepts. However, they require you to think differently about your programs.

If you have had experience with imperative programming (e.g., C, C++, Java, and Python), you may find it difficult to adjust initially.
Functional vs. imperative programming languages

Functional and imperative programming languages share many concepts. However, they require you to think differently about your programs.

If you have had experience with imperative programming (e.g., C, C++, Java, and Python), you may find it difficult to adjust initially.

By the end of CS 136, you will be able to express computations in both these styles and understand their advantages and disadvantages.
Racket

- a functional programming language
- minimal but powerful syntax
- small toolbox with ability to construct additional required tools
- interactive evaluator
- used in education and research since 1975
- a dialect of Scheme
- graduated set of teaching languages are a subset of Racket
Values, expressions, & functions
Values, expressions, & functions

Values are numbers or other mathematical objects.
  • 5
  • $\frac{2}{5}$
  • $\pi$
Values, expressions, & functions

Values are **numbers** or other mathematical objects.

- 5
- $\frac{2}{5}$
- $\pi$
Values, expressions, & functions

Values are numbers or other mathematical objects

- 5
- $\frac{2}{5}$
- $\pi$
Values, expressions, & functions

Values are numbers or other mathematical objects.
  • 5
  • $\frac{2}{5}$
  • $\pi$

Expressions combine values with operators and functions.
  • $5 + 2$
  • $\sin(2\pi)$
  • $\frac{\sqrt{2}}{100\pi}$
Values, expressions, & functions

**Values** are numbers or other mathematical objects.

- $5$
- $\frac{2}{5}$
- $\pi$

**Expressions** combine **values** with **operators** and **functions**.

- $5 + 2$
- $\sin(2\pi)$
- $\frac{\sqrt{2}}{100\pi}$
Values, expressions, & functions

Values are numbers or other mathematical objects.

- 5
- $\frac{2}{5}$
- $\pi$

Expressions combine values with operators and functions.

- $5 + 2$
- $\sin(2\pi)$
- $\frac{\sqrt{2}}{100\pi}$
Values, expressions, & functions

**Values** are numbers or other mathematical objects.

- 5
- \( \frac{2}{5} \)
- \( \pi \)

**Expressions** combine **values** with **operators** and **functions**.

- 5 + 2
- \( \sin(2\pi) \)
- \( \frac{\sqrt{2}}{100\pi} \)
Values, expressions, & functions

Values are numbers or other mathematical objects.

- 5
- $\frac{2}{5}$
- \(\pi\)

Expressions combine values with operators and functions.

- 5 + 2
- \(\sin(2\pi)\)
- $\frac{\sqrt{2}}{100\pi}$

Functions generalize similar expressions.
Values, expressions, & functions

**Values** are numbers or other mathematical objects.

**Expressions** combine **values** with **operators** and **functions**.

**Functions** generalize similar **expressions**.

\[ 3^2 + 4 \times 3 + 2 \]
\[ 6^2 + 4 \times 6 + 2 \]
\[ 7^2 + 4 \times 7 + 2 \]
Values, expressions, & functions

Values are numbers or other mathematical objects.

Expressions combine values with operators and functions.

Functions generalize similar expressions.

\[ 3^2 + 4 \times 3 + 2 \]
\[ 6^2 + 4 \times 6 + 2 \]
\[ 7^2 + 4 \times 7 + 2 \]
Values, expressions, & functions

Values are numbers or other mathematical objects.

Expressions combine values with operators and functions.

Functions generalize similar expressions.

\[
\begin{align*}
3^2 + 4 \times 3 + 2 \\
6^2 + 4 \times 6 + 2 \\
7^2 + 4 \times 7 + 2
\end{align*}
\]
Values, expressions, & functions

Values are numbers or other mathematical objects.

Expressions combine values with operators and functions.

Functions generalize similar expressions.

\[ 3^2 + 4 \times 3 + 2 \]
\[ 6^2 + 4 \times 6 + 2 \]
\[ 7^2 + 4 \times 7 + 2 \]

are generalized by the function

\[ f(x) = x^2 + 4x + 2 \]
Functions in mathematics – Definition

Definitions: $f(x) = x^2$, $g(x, y) = x + y$

These definitions consist of:
Functions in mathematics – Definition

Definitions: $f(x) = x^2$, $g(x, y) = x + y$

These definitions consist of:

• the **name** of the function (e.g., $g$)
Functions in mathematics – Definition

Definitions: $f(x) = x^2$, $g(x, y) = x + y$

These definitions consist of:

• the **name** of the function (e.g. $g$)
• its **parameters** (e.g. $x, y$)
Definitions: \( f(x) = x^2, \ g(x, y) = x + y \)

These definitions consist of:
- the **name** of the function (e.g. \( g \))
- its **parameters** (e.g. \( x, y \))
- an **algebraic expression** using the parameters as placeholders for values to be supplied in the future
Functions in mathematics – Application

Definitions: \( f(x) = x^2, g(x, y) = x + y \)

An application of a function supplies arguments for the parameters, which are substituted into the algebraic expression.

Example: \( g(1,3) = 1 + 3 = 4 \)
Functions in mathematics – Application

Definitions: \( f(x) = x^2, g(x, y) = x + y \)

An application of a function supplies arguments for the parameters, which are substituted into the algebraic expression.

Example: \( g(1,3) = 1 + 3 = 4 \)

The arguments supplied may themselves be applications.

Example: \( g(g(1,3), f(3)) \)
Functions in mathematics – Application

Definitions: \( f(x) = x^2, \ g(x, y) = x + y \)

We evaluate each of the arguments to yield values.

Evaluation by substitution:
\[ g(g(1, 3), f(3)) \]
Functions in mathematics – Application

Definitions: \( f(x) = x^2, \ g(x, y) = x + y \)

We evaluate each of the arguments to yield values.

Evaluation by substitution:

\[
g\left(g(1, 3), f(3)\right) = \\
g(1 + 3, f(3))
\]
Functions in mathematics – Application

Definitions: \( f(x) = x^2 \), \( g(x, y) = x + y \)

We evaluate each of the arguments to yield values.

Evaluation by substitution:

\[
g(g(1, 3), f(3)) = \\
g(1 + 3, f(3)) = \\
g(4, f(3))
\]
Functions in mathematics – Application

Definitions: $f(x) = x^2$, $g(x, y) = x + y$

We evaluate each of the arguments to yield values.

Evaluation by substitution:

$g(g(1, 3), f(3)) = \ldots$

$g(1 + 3, f(3)) = \ldots$

$g(4, f(3)) = \ldots$

$g(4, 3^2) = \ldots$
Functions in mathematics – Application

Definitions: $f(x) = x^2$, $g(x, y) = x + y$

We evaluate each of the arguments to yield values.

Evaluation by substitution:

\[
g(g(1, 3), f(3)) = \\
g(1 + 3, f(3)) = \\
g(4, f(3)) = \\
g(4, 3^2) = \\
g(4, 9)
\]
Functions in mathematics – Application

Definitions: \( f(x) = x^2 \), \( g(x, y) = x + y \)

We evaluate each of the arguments to yield values.

Evaluation by substitution:

\[
g(g(1, 3), f(3)) = \\
g(1 + 3, f(3)) = \\
g(4, f(3)) = \\
g(4, 3^2) = \\
g(4, 9) = 4 + 9
\]
Functions in mathematics – Application

Definitions: $f(x) = x^2$, $g(x, y) = x + y$

We evaluate each of the arguments to yield values.

Evaluation by substitution:

$$g(g(1, 3), f(3)) =$$

$$g(1 + 3, f(3)) =$$

$$g(4, f(3)) =$$

$$g(4, 3^2) =$$

$$g(4, 9) =$$

$$4 + 9 =$$

$$13$$