**CS252 – Midterm Exam Study Guide**

**By: Zayd Hammoudeh**

**Lecture #01 – General Introduction**

|  |  |  |  |
| --- | --- | --- | --- |
| **Reasons for Different**  **Programming Languages**   1. **Different domains** (e.g. web, security, bioinformatics) 2. **Legacy code and libraries** 3. **Personal preference** | **Programming Language Design Choices**   1. **Flexibility** 2. **Type safety** 3. **Performance** 4. **Build Time** 5. **Concurrency** | **Features of Good Programming Languages** | |
| 1. **Simplicity** 2. **Readability** 3. **Learnability** | 1. **Safety** (e.g. security and can errors be caught at compile time) 2. **Machine independence** 3. **Efficiency** |
| **Goals almost always conflict** | |

|  |  |  |  |
| --- | --- | --- | --- |
| **Conflict: Type Systems**   * **Advantage:** Prevents bad programs. * **Disadvantage:** Reduces programmer flexibility. | **Blub Paradox:** Why do I need advanced programming language techniques (e.g. monads, closures, type inference, etc.)? My language does not have it, and it works just fine. | **Current Programming Language Issues**   * **Multi-code “explosion”** * **Big Data** * **Mobile Devices** | **Advantages of Web and Scripting Languages**   * **Examples:** Perl, Python, Ruby, PHP, JavaScript * **Highly flexible** * **Dynamic typing** * **Easy to get started** * **Minimal typing** (i.e. type systems) |

|  |  |  |  |
| --- | --- | --- | --- |
| **Major Programming Language Research Contributions**   * **Garbage collection** * ***Sound* type systems** * **Concurrency tools** * **Closures** | **Programs that Manipulate Other Programs**   * **Compilers & interpreters** * **JavaScript rewriting** * **Instrumentation** * **Program Analyzers** * **IDEs** | **Formal Semantics**   * Used to **share information *unambiguously*** * **Can formally prove a language supports a given property** * ***Crisply define* *how a language works*** | **Types of Formal Semantics**   * **Operational**   + Big Step “***natural***”   + Small Step “***structural***” * **Axiomatic** * **Denotational** |

**Haskell**

|  |  |  |
| --- | --- | --- |
| * **Purely functional** – Define “*what stuff is*” * **No side effects** * **Referential transparency** – **A function with the same input parameters will always have the same result**.   + **An expression can be replaced with its value and nothing will change.** * **Supports type inference.** | **Duck Typing** – Suitability of an object for some function is determined not by its type but by presence of certain methods and properties.   * + **More flexible** but **less safe**.   + **Supported by Haskell**   + **Common in scripting languages** (e.g. Python, Ruby) | **Side Effects in Haskell**   * Generally not supported. * **Example of Support Side Effects**: File IO * Functions that do have side effects must be separated from other functions. |
| **Lazy Evaluation**   * **Results are not calculated until they are needed** * **Allows for the representation of infinite data structures** |

**Lecture #02 – Introduction to Haskell**

|  |  |  |  |
| --- | --- | --- | --- |
| **Key Traits of Haskell**   1. **Purely functional** 2. **Lazy evaluation** 3. **Statically typed** 4. **Type Inference** 5. **Fully curried functions** | **ghci** – Interactive Haskell.  **let** – Keyword required in ghci to set a variable value. **Example**:  **> let f x = x + 1**  **> f 3**  **4** | **Run Haskell from Command Line**  Use **runhaskell** keyword. Example:  **> runhaskell <*FileName*>.hs** | **Hello World in Haskell**  **main :: IO ()**  **main = do**  **putStrLn “Hello World”** |

|  |  |  |  |
| --- | --- | --- | --- |
| **Primitive Classes in Haskell**   1. **Int** – **Bounded** Integers 2. **Integer** – **Unbounded** 3. **Float** 4. **Double** 5. **Bool** 6. **Char** | **Lists** | | **Ranges** |
| * **Base 0** * Comma separated in square brackets * **Operators**   + **:**  Prepend   + **++** Concatenate   + **!!** Get element a specific index   + **head** First element in list   + **tail** All elements after head | * + **last** Last element in the list   + **init** All elements except the last   + **take n** Take first n elements from a list   + **replicate l m** Create a list of length l containing only m   + **repeat m Create an in** | * Can be infinite or bounded * Use the “**..**” notation. **Examples**:   **> [1..4]**  **[1, 2, 3, 4]**  **> [1,2..6]**  **[1, 2, 3, 4, 5, 6]**  **> [1,3..10]**  **[1, 3, 5, 7, 9]** |
| **Hello World in Haskell**  **main :: IO ()**  **main = do**  **putStrLn “Hello World”** | **List Examples**  **> putStrLn $ “Hello “ ++ “World”**  **“Hello World”**  **> let s = bra in s !! 2 : s ++ ‘c’ : last s : ‘d’ : s**  **“abracadabra”** | | **Infinite List Example**  **> let even = [2,4..]**  **> take 5 even**  **[2, 4, 6, 8, 10]** |

|  |  |  |
| --- | --- | --- |
| **List Comprehension**   * **Based off set notation.** * **Supports filtering** as shown in second example * If **multiple variables** (e.g. a, b, c) are specified, **iterates through them like nested for loops**. * Uses the **pipe** (**|**) operator. **Examples:**   **> [ 2\*x | x <- [1..5]]**  **[2, 4, 6, 8, 10]** | **A Simple Function**  **> let inc x = x + 1**  **> inc 3**  **4**  **> inc 4.5**  **5.5**  **> inc (-5) -- Negative**  **-4** | **Pattern Matching**   * Used to handle different input data * Guard uses the pipe (|) operator * Example:   **inc :: Int -> Int**  **inc x**  **| x < 0 = error “invalid x”**  **inc x = x + 1** |
| **> [(a, b, c) | a <- [1..10], b <-[1..10],**  **c <- [1..10], a^2 + b ^2 == c^2]**  **[(3, 4, 5), (4, 3, 5), (6, 8, 10), (8, 6, 10)]** | **Type Signature**   * Uses symbols “**::**” and “**->**” * **Example**:   **inc :: Int -> Int**  **inc x = x + 1** |

|  |  |  |
| --- | --- | --- |
| **Recursion**   * **Base Case** – Says when recursion should stop. * **Recursive Step** – Calls the function with a ***smaller version*** of the problem   **Example:**  **addNum :: [Int] -> Int**  **addNum [] = 0**  **addNum (x:xs) = x + addNum xs** | **Lab #01 – Max** Number  **> maxNum :: [Int] -> Int**  **> maxNum [] = error "Invalid Input"**  **> maxNum [x] = x**  **> maxNum (x:xs) = if x > maxXs then x else maxXs**  **> where maxXs = maxNum xs** |  |

**Lecture #03 – Operational Semantics**

|  |  |  |  |
| --- | --- | --- | --- |
| **Formal Semantics**  ***Crisply define*** **how the language features work**. | | **Formal Semantic Styles**   * **Operational**   + Big-Step (“Natural”)   + Small-Step (“structural”) * **Axiomatic** * **Denotational** |  |
| **Abstract Syntax Tree**  Tree representation of the abstract syntactic structure of a program’s source code. **Example is Bool\* language below**. | |
| **Big Step Operational Semantics**   * **Evaluates every expression to a value** * : “***Evaluates to***” symbol in Big-Step operational semantics. * **Example Formatting:** * **Read as:** “Expression e ***evaluates*** to the value v” |
| **Bool \* Language** | |
| **e ::=**  **true**  **| false**  **| if e**  **then e**  **else e** | ***Expressions*:**  **constant true**  **constant false**  **conditional** |
| **v ::=**  **true**  **| false** | ***Values*:**  **constant true**  **constant false** |

|  |  |  |
| --- | --- | --- |
| **Small-Step Operational Semantics**   * Evaluate an expression until it is in ***normal form*** * **Normal Form** – Any form that cannot be evaluated further. * : “***Evaluates to***” symbol in small step operational semantics. **Example:** * : Many evaluation steps required. **Example:** | **Bool\* Small-Step Operational Semantics Rules** | **Example:** Reduce the expression  **Step #1:** Use rule E-IfTrue  **Step #2:** Use rule E-IfFalse (Now in normal form) |
| **E-IfTrue:** |
| **E-IfFalse:** |
| **E-If:** |

|  |  |  |  |
| --- | --- | --- | --- |
| **Bool\* Extension: Numbers**   * **0** : The Number “0” * **succ 0** : Represents “1” * **succ succ 0** : Represents “2” * **pred n** : Gets the predecessor of “*n*” | **Extended Bool \* Language** | **Literate Haskell**   * **File Extension:** “.lhs” * **Code lines begin with “>”** * **All other lines are comments**. |  |
| **e ::=**  **true**  **| false**  **| if e then e else e**  **| 0**  **| succ e**  **| pred e** |
| **v ::= true | false**  **| IntV**  **IntV ::= 0 | succ IntV** |

**Lab #02 Review**

|  |  |  |
| --- | --- | --- |
| **Bool Expression Type**  **> data BoolExp = BTrue**  **> | BFalse**  **> | Bif BoolExp BoolExp BoolExp**  **> | B0**  **> | Bsucc BoolExp**  **> | Bpred BoolExp**  **> deriving Show** | **BoolVal Type**  **> data BoolVal = BVTrue**  **> | BVFalse**  **> | BVNum BVInt**  **> deriving Show**  **> data BVInt = BV0**  **> | BVSucc BVInt**  **> deriving Show** | **Type Constructors:** BoolExp, BoolVal, BVInt  ***Non-nullary* Value Constructors:** BIf, Bsucc, Bpred, BVSucc, BVNum  **Note:** Even constants like B0, BTrue, BFalse, BVTrue, and BVFalse are nullary value constructors (since they take no arguments) |