Democritus Language Reference Manual

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Chapter 1

Introduction

Democritus is a programming language with a static type system and native support for concurrent programming via its atomic keyword, with facilities for both imperative and functional programming. Democritus is compiled to the LLVM (Low Level Virtual Machine) intermediate form, which can then be optimized to machine-specific assembly code. Democritus’ syntax draws inspiration from contemporary languages, aspiring to emulate Go and Python in terms of focusing on use cases familiar to the modern software engineer, emphasizing readability, and having “one – and preferably only one – obvious way to do it”\(^1\).

\(^1\)http://c2.com/cgi/wiki?PythonPhilosophy
Chapter 2

Data types

2.1 Primitive Types

int
A standard 32-bit two’s-complement signed integer. It can take any value in the inclusive range (-2147483648, 2147483647).

float
A 64-bit floating precision number, represented in the IEEE 754 format.

char
An 8-bit ASCII character. We include the extended ASCII set, so we use all 256 possible values.

boolean
A 1-bit true or false value.

pointer
A 64-bit pointer that holds the value to a location in memory; very similar to those found in C.

2.2 Complex Types

Array
A fixed-size array, allocated on the stack and containing other primitive types. The size must be defined at
declaration. An array object can be accessed by C array notation, such as list1[0].

string
An immutable array of characters, implemented as a native data type in Democritus.

struct
A struct is a simple user-defined data structure that holds various primitives, similar to the ones found in C.
Chapter 3

Lexical Conventions

In this section, we will cover the standard lexical conventions for Democritus. As with languages such as C, Algol, or Pascal, Democritus is a free-format language. The parser will discard whitespace characters such as ‘ ’, \t, and \n.

3.1 Identifiers

Identifiers for Democritus will be defined in the same way as they are in most other languages; any sequence of letters and numbers without whitespaces and is not a keyword will be parsed as an identifier. Note that, as in other languages, identifiers cannot begin with a number. Somewhat different, however, is the order of variable declarations; in Democritus, declarations are made following the varname vartype structure. The regular expression defining identifiers is as follows:

\['a'-'z' 'A'-'Z' '0'-'9' '_']*

An example of declarations with identifiers:

2wrongID int; /* not a valid identifier declaration */
mySecond float; /* valid */
my_Second char; /* valid */

3.2 Literals

Literals, simply a sequence of numbers, may be identified with the regular expression

\['0'-'9']+ (* Int *)
\['0'-'9']\.'\['0'-'9']+ (* Float *)

3.3 Tokens

The list of tokens used in Democritus are as follows:

| \('\) | \{' | \}' | \',' | \';' | \':' |
|---|---|---|---|---|
| LPAREN | RPARAREN | LBRACE | RBRACE | SEMI | COLON |
3.4 Punctuation

Semicolon

As in C, the semicolon ‘;’ is required to terminate any statement in Democritus.
Curly Brackets
In order to keep the language free-format, curly braces are used to delineate separate and nested blocks. These braces are required even for single-statement conditional and iteration loops.

LBRACE statements RBRACE

Parentheses
To assert precedence, expressions may be encapsulated within parentheses to guarantee order of operations.

LPAREN expression RPAREN

Comments
For now, comments are initiated with `/*` and closed with `*/`. They cannot be nested.
Chapter 4

Expressions and Operators

An expression consists of a combination of any of the following:

- a literal value
- a variable name
- a binary operation
- a unary operation
- a C-style array access operation

4.1 Assignment

Assignment is done with =. As mentioned above, variables and declared with the varname vartype syntax. Variables can be assigned to a single value or to the result of an expression.

```plaintext
x float = 4.0;
y int = 5/2 + 1; /* y = 3 */
```

Array assignment is done with Java-like syntax. Note that the size of the array must be specified in the declaration.

```plaintext
x int[5] = {0,1,2,3,4};
```

Pointer types are denoted with a * which must be attached to the primitive type that they reference.

```plaintext
x int = 4; /* x = 4 */
y int* = &x; /* y = 4 */
```

4.2 Arithmetic Operations

Democritus supports all the arithmetic operations standard to most general-purpose languages like C and Java. Note that casting is not built into the language; this functionality will instead be implemented through the standard library.
Addition and Subtraction
Addition works with the + character, behaving as expected.

```c
int x = 4;
int y = 2;
x = x + y;  /* x = 6 */
y = y - x  /* y = -4 */
```

Multiplication
Multiplication follows the same rules as well.

```c
int x = 4;
int y = 2;
x = x * y + y;  /* x = 10 */
```

Division
Democritus will default to integer division, unless both types provided are floats.

```c
int x = 5;
int y = 2;
x = x / y;  /* x = 2 */
float a = 4.0;
float b = 2.0;
a = b / a;  /* a = 2.0 approximately */
```

Modulus
The remainder of an integer division operation can be computed via the modulo % operator.

```c
int x = 8;
int y = 5;
x = x % y;  /* x = 3 */
```

Bit Shifting
Integers can be bit-shifted with >> and <<.

```c
int x = 9;
int y = x >> 1;  /* y = 4 */
x = y << 2;  /* x = 16 */
```

4.3 Boolean Expressions
Democritus features all of the standard logical operators, following Java-style syntax. Each expression will return a boolean value of true or false.
Equality

Equality is tested with the == operator. Inequality is tested with !=.

```java
x int = 8;
y int = 8;
z boolean = (x == y);  /* z = true */
z = (x == (y + 1));  /* z = false */
z = (x != (y + 1));  /* z = true */
```

Negation

Negation is done with !, a unary operation.

Comparison

Democritus also features the <, <=, >, and >= operators.

```java
x int = 9;
y int = 8;
z int = 8;
x>y;  /* true */
y>=z;  /* true */
z<x;  /* true */
```

Chained Expressions

Boolean expressions can be chained with && and ||, representing and and or, respectively. These operators have lower precedence than any of the other boolean operators described above. The and operator has a higher precedence than or.

```java
x int = 9;
y int = 8;
z int = 8;
(x>y && y<x);  /* false */
(x>y || y<x);  /* true */
(x>y && y<x || z==y)  /* true */
```

4.4 Pointers and References

Pointers and dereferencing operations utilize the same syntax as C. The unary operator & gives a variables address in memory, and the operator * dereferences a pointer. See the assignment section for usage.

4.5 Array access

Array access is done with [i] where i is the index being accessed.

```java
x int[5] = {0,1,2,3,4};
y int = x[2];  /* y = 2 */
```
### 4.6 Operator Precedence and Associativity

<table>
<thead>
<tr>
<th>Precedence</th>
<th>Operator</th>
<th>Description</th>
<th>Associativity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>()</td>
<td>Parenthesis</td>
<td>Left-to-right</td>
</tr>
<tr>
<td>2</td>
<td>()</td>
<td>Function call</td>
<td>Left-to-right</td>
</tr>
<tr>
<td></td>
<td>{}</td>
<td>Array creation s</td>
<td>Left-to-right</td>
</tr>
<tr>
<td></td>
<td>[]</td>
<td>Array subscript</td>
<td>Left-to-right</td>
</tr>
<tr>
<td>3</td>
<td>*</td>
<td>Dereference</td>
<td>Right-to-left</td>
</tr>
<tr>
<td></td>
<td>&amp;</td>
<td>Address-of</td>
<td>Left-to-right</td>
</tr>
<tr>
<td></td>
<td>!</td>
<td>Negation</td>
<td>Left-to-right</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Unary minus</td>
<td>Left-to-right</td>
</tr>
<tr>
<td>4</td>
<td>*</td>
<td>Multiplication</td>
<td>Left-to-right</td>
</tr>
<tr>
<td></td>
<td>/</td>
<td>Division</td>
<td>Left-to-right</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>Modulo</td>
<td>Left-to-right</td>
</tr>
<tr>
<td>5</td>
<td>+</td>
<td>Addition</td>
<td>Left-to-right</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Subtraction</td>
<td>Left-to-right</td>
</tr>
<tr>
<td>6</td>
<td>&gt;&gt;</td>
<td>Bitwise shift shift right</td>
<td>Left-to-right</td>
</tr>
<tr>
<td></td>
<td>&lt;&lt;</td>
<td>Bitwise shift left</td>
<td>Left-to-right</td>
</tr>
<tr>
<td>7</td>
<td>&gt;&gt; =</td>
<td>For relational &gt; and ≥ respectively</td>
<td>Left-to-right</td>
</tr>
<tr>
<td></td>
<td>&lt;=</td>
<td>For relational &lt; and ≤ respectively</td>
<td>Left-to-right</td>
</tr>
<tr>
<td>8</td>
<td>== !≠</td>
<td>For relational = and ≠ respectively</td>
<td>Left-to-right</td>
</tr>
<tr>
<td>9</td>
<td>&amp;&amp;</td>
<td>Logical and</td>
<td>Left-to-right</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>=</td>
<td>Assignment</td>
<td>Right-to-left</td>
</tr>
</tbody>
</table>
Chapter 5

Statements

5.1 Expressions

An expression statement consists of an expression followed by a semicolon. Expressions in expression statements will be evaluated, and its value calculated.

```java
a int = 500;
s char = 'a';
2 + 4 - 3; /* Not used, thrown away */
```

5.2 Declarations

A declaration specifies a variable’s name and type, in that order. Values may also be initialized in the declaration.

```java
x int;
y char = '4';
```

5.3 Control Flow

if, elif, else

An if statement causes a block (encapsulated by { and }) to be entered if the specified condition evaluates to true.

An elif allows an alternate condition to be specified.

An else is entered if the ‘if’ and ‘elif’s are not entered.

A boolean expression encapsulated within parentheses is required for every if and elif. Elif and else belong to the first preceeding if statement.

```java
x int = 1;
if (x == 1)
{
    print("x==1");
}
```
elif (x == 2)
{
    print("x==2!");
}
else
{
    print("fail");
}

Looping with for

Democritus eliminates the while structure, replacing it instead with a modified for loop. For can be used to iterate by providing an initialization, termination condition, and update:

```plaintext
for(i int = 0; i < 10; i++)
{
    /* Some code here */
}
```

It can also be used as a while loop providing only one condition:

```plaintext
for(x < 10)
{
    /* Some code here */
}
```
Chapter 6

Functions

6.1 Overview

Functions can be defined in Democritus to return one or no data type. Functions are evaluated via eager evaluation and the function implementation must directly follow the function header. The syntax is reminiscent of Scala, although Democritus doesn’t support implied returns. A function appears in the form:

```
function [function name]([formal_arg type, ...]) type {
    [function implementation]
    return [variable of return type]
}
```

**Note:** all functions need `return` statements at the end (no falling off the end). A void `return` is simply a return with nothing following it.

Functions may be recursive and call themselves:

```
function recursive_func(i int) void {
    if (i < 0) {
        return;
    } else {
        print hi ;
        recursive_func(i-1);
    }
}
```

Functions may be called within other functions:

```
function main() void{
    recursive_func(3);
    return;
}
```

6.2 Built-in Functions

A handful of functions are natively built into Democritus for user flexibility and ease of usage. There are:
• print(s string) takes in a string (standard library functions will convert from other data types to strings)
• thread(f function, [arg1 type, arg2 type, ...]) takes in function and function args
Chapter 7

Concurrency

7.1 Overview

Democritus intends to cater to modern software engineering use cases. Developments in the field are steering us more and more towards highly concurrent programming as the scale at which software is used trends upward.

With this in mind, Democritus adds support for the atomic keyword, used as a modifier at the declaration step. The keyword can be used both in an inline declaration and when declaring a function’s types. We also wrap the pthread datatype and related functions.

7.2 Atomic Inline Declarations

Under the hood, declaring a variable with the atomic keyword embeds a locking structure into the type, as well as exposing the lock() and unlock() functions. If the keyword is used with a standard data type, the compiler replaces the normal version of that type with a version that includes the lock and the functions described above.

```c
x int;
x.lock(); x.unlock(); /* undefined! */

y atomic int;
y.lock(); y.unlock(); /* defined! */
```

7.3 Atomic Parameter Declarations

A function whose formal parameters are atomic will throw a compile-time error if a non-atomic type is passed in. The idea is to force the programmer to document which functions are safe to use in a multi-threaded context and which are not.

```c
function [function name]([formal_arg atomic type]) atomic type {
    formal_arg.lock();
    /* do something */
}
```
formal_arg.unlock();
return formal_arg
}

Naturally, rather than calling lock() and unlock() manually, the programmer can implement atomic operations.

### 7.4 Spawning Threads

To spawn threads, Democritus uses a wrapper around the C-language pthread family of functions. The thread data type wraps pthread.

To spawn a thread, the thread function takes a variable number of arguments where the first argument is a function and the remaining optional arguments are the arguments for that function. It returns an error code.

The detach boolean determines whether or not the parent thread will be able to join on the thread or not.

```c
{ thread(f function, boolean detach, [arg1 type, arg2 type, ...]) int;
}
```