

Befunge-93 interpreter in Haskell

A project for the course Program Design and Data Structures (1DL201)

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Abstract

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1 Introduction

We introduce the programming language Befunge-93 and its fundamental principles.

1.1 What is Befunge-93?

Befunge is a two-dimensional esoteric programming language developed by Chris Pressey in 1993 [1]. The program to be executed is stored in a 80 by 25 grid (in this document also referred to as the “program space” or “memory”) where each cell can hold 1 byte of data.

There are no variables available but data can be stored in either a LIFO-stack (last-in-first-out) or – using the `p` instruction – the program space itself. This allows for the program to modify itself while running.

1.1.1 Program flow and the Program Counter

Program flow is determined by the position and direction of a unique Program Counter (“PC”). The position is usually represented as a pair (x, y) of coordinates and the direction is always one of either East, South, West or North. Traveling East or West increases or decreases the x -component of the PC’s position respectively, and traveling North or South increases or decreases the y -component similarly.

The PC starts at position $(0, 0)$ – the upper-left corner of the program space – and has an initial direction of East. Execution of any Befunge program then consists of three simple steps:

1. Read the character at the PC’s position in the program memory.
2. Execute the instruction corresponding to the character that was read, if possible.
3. Step the PC one step in its direction.

These three steps are repeated until an `@`-character is read in step 1 at which point the program immediately terminates. See section 2.3 for more information on instructions.

1.1.2 The stack

The stack has the property that it is never truly empty. Instead, if an attempt to pop a value of the stack is made when the stack is thought to be empty, a value of 0 is returned. The stack is in all but this one regard a regular LIFO-stack.

1.1.3 The program space

The program space consists of 2,000 cells arranged in a 80 by 25 grid. The upper left corner of this grid is given the coordinate position $(0, 0)$ and the lower right corner is identified as $(79, 24)$, see Figure 1.

The grid can topologically be thought of as a torus (the surface of a dough-nut); should the PC at any point try to move outside the bounds of the program space, it “wraps around” to the other side. For example, assuming that indexing starts at 0, if the PC is at position $(6, 24)$ and attempts to move South, its new position would be $(6, 0)$, still facing South.

(0, 0)	(1, 0)	...	(79, 0)
(0, 1)	(1, 1)	...	(79, 1)
⋮	⋮	⋱	⋮
(0, 24)	(1, 24)	...	(79, 24)

Figure 1: A visualization of the program space in Befunge where each cell is labeled with its coordinates.

1.2 Funge-98

Befunge-93 was the first iteration of several Befunge-specifications which eventually lead to Funge-98, a generalization of in which program spaces can be either one-, two-, or three-dimensional. Funge-98 also provides a paradigm for program spaces in an arbitrary number of dimensions [2]. Besides new dimensions, Funge-98 also specifies several new instructions as well as concurrent program flow and a stack of stacks.

2 Running the interpreter

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2.1 Linux

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2.2 Windows

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2.3 Befunge instruction characters

Befunge-93 specifies a total of 35 actions, 9 of which simply push the numeric values 0 – 9 to the stack, each represented by an ASCII character. Arithmetic is executed using Reverse Polish Notation (RPN)

Table 1 contains a complete list of all characters that the interpreter recognizes. If the PC encounters an unrecognized character, it ignores it completely – as if it were a space (`_`).

2.4 Example Befunge-93 programs

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2.4.1 Basic arithmetic

Addition (+), subtraction (-), multiplication (*), division (/) and modulo (%) execute using Reverse Polish Notation (RPN). That is, the program `65-.` prints 1 (and not -1). Division by 0 pushes 0 back to the stack regardless of the value of the numerator.

An example that utilizes all of these instructions is `329**2*7/4%.@`. It first pushes 3, 2 and 9 to the stack followed by a multiplication of the top two values making the stack look like `18 3`, where the left-most value is the top of the stack. The `+` instruction adds the top two values on the stack; the stack now contains a single value 21. This is then multiplied by 2 and divided by 7 resulting in the stack 6. Finally, a 4 is pushed and the modulo operation `%` calculates $6 \bmod 4 = 2$ and pushes it. The top value on the stack, 2, is printed by `.` and the program stops after reading the `@`-character.

2.4.2 Moving around

There are 7 instructions that can change the direction of the Program Counter: `>`, `v`, `<`, `^`, `?`, `_` and `|`. The first four should be thought of as arrows; they change the direction of the PC so that it moves in the direction indicated by these “arrows”. The questionmark symbol `?` randomizes the direction of the PC to one of four cardinal directions. The characters `_` and `|` are conditionals; one value is popped off the stack the PC changes

Character	Action
<code>0 - 9</code>	Push the desired value onto the stack.
<code>+</code>	Pop <code>b</code> and <code>a</code> off the stack, then push <code>a + b</code> .
<code>-</code>	Pop <code>b</code> , <code>a</code> . Push <code>a - b</code> .
<code>*</code>	Pop <code>b</code> , <code>a</code> . Push <code>a · b</code> .
<code>/</code>	Pop <code>b</code> , <code>a</code> . Push 0 if <code>b = 0</code> , otherwise the integer part of <code>a/b</code> .
<code>%</code>	Pop <code>b</code> , <code>a</code> . Push <code>a mod b</code> .
<code>`</code>	Pop <code>b</code> and <code>a</code> . If <code>a > b</code> then push 1, otherwise push 0.
<code>!</code>	Pop <code>a</code> and if <code>a</code> is non-zero then push 0, otherwise push 1.
<code>></code>	Instruct the PC to move East.
<code>v</code>	Instruct the PC to move South.
<code><</code>	Instruct the PC to move West.
<code>^</code>	Instruct the PC to move North.
<code>?</code>	Instruct the PC to move in a random cardinal direction.
<code>#</code>	Skip the next instruction; the PC moves twice.
<code>_</code>	Pop <code>a</code> and instruct the PC to move West if <code>a ≠ 0</code> , otherwise East.
<code> </code>	Pop <code>a</code> and instruct the PC to move North if <code>a ≠ 0</code> , otherwise South.
<code>:</code>	Duplicate the top value of the stack.
<code>\</code>	Swap the top two values of the stack.
<code>\$</code>	Pop a value off the stack and discard it.
<code>g</code>	Pop <code>y</code> and <code>x</code> , then push the value of the character at position <code>(x,y)</code> .
<code>p</code>	Pop <code>y</code> , <code>x</code> and <code>v</code> , then insert <code>v</code> at position <code>(x,y)</code> .
<code>&</code>	Wait for user value input and push it.
<code>~</code>	Wait for user character input and push its ASCII value.
<code>.</code>	Pop a value and print it, followed by a space (<code>_</code>).
<code>,</code>	Pop a value and print its ASCII character.
<code>␣</code>	Spaces are ignored, the PC continues and no other modifications are made.
<code>@</code>	Terminate the program.

Table 1: All instructions available in Befunge-93.

direction to West and North respectively if the value is non-zero, otherwise East and South, respectively.

An example of the four basic move-instructions is shown in Figure 2. It makes use of the wrap-around property of the program space and never terminates, despite having a termination symbol in the center.

```

< ^
@
v >

```

Figure 2: A never-ending Befunge program.

Infinite loops are indeed easy to create; you simply force the PC in a path that loops back to where it started. A simple example is the program `><`, or, in fact, the empty Befunge program.

2.4.3 Input and output

Input can be asked for by `&` for numerical values and `~` for single-character inputs. Output is given by `.` and `,` for numeric and ASCII-characters respectively. The program `~.@` asks for a character input and prints its numerical value before terminating.

The program `&: !#@_.` asks for numerical inputs and echoes whatever the user entered until the user enters 0.

2.4.4 If-statements

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2.4.5 putting and getting values

3 Implementation

In which we discuss how the interpreter is implemented, including the data structures and algorithms used.

3.1 Data structures

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3.1.1 Stack

The Befunge stack, defined in `BStack.hs`, is implemented using a list of integers. It exports one identifier (`empty`) and three functions (`push`, `pop`, `top`). The type `BStack` is defined as a list of integers: `newtype BStack = BStack [Int] deriving (Show)`. The identifier `empty` (of type `BStack`) is identified simply as `BStack []`.

`push (BStack -> Int -> Bstack)` takes a (possibly empty) stack `s` and an integer `n`, and returns `s` with `n` on top.

`pop (BStack -> (BStack, Int))` takes a stack `s` and returns a tuple `(s', t)` where `t` is the top element of `s` and `s'` is `s` with `t` removed. Should `s` be empty, a tuple `(BStack [], 0)` is returned.

`top (BStack -> Int)` takes a stack and returns its top element without modifying the stack.

All three functions have precondition `True`.

3.1.2 Program space

The Befunge program space, the “memory”, is constructed using an array. `BMemory.hs` is a wrapper for an `IOArray` (from `Data.Array.IO`) and the type `BMemory` is synonymous to `IOArray Position Char`. It exports three functions:

`buildArray (BMemory -> [String] -> IO ())` allocates an array and populates it with the characters in a list of strings. Any characters outside the bounds (defaults to 80×25) are ignored.

`getValue (BMemory -> Position -> IO Char)` takes an array and returns the character at the given position.

`putValue (BMemory -> Position -> Char -> IO ())` takes an array, a position and a value. It inserts the value at the given position and returns nothing.

Both `getValue` and `putValue` wraps array indices using modulus.

3.2 Algorithms

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3.3 Major functions

empty (remember specifications!)

3.3.1 Program flow

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4 Shortcomings and caveats

References

- [1] “Befunge.” <http://esolangs.org/wiki/Befunge>. Online; retrieved 2017-02-17.
- [2] C. Pressey, “Funge-98 final specification.” <https://github.com/catseye/Funge-98/blob/master/doc/funge98.markdown>. Online; retrieved 2017-02-17.