Diploma Thesis

Höhere Technische Bundeslehranstalt Leonding
Abteilung für Informatik

Visulation of the NoBeard Virtual Machine

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Date: **April 4, 2018**

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Declaration of Academic Honesty

Hereby, I declare that I have composed the presented paper independently on my own and without any other resources than the ones indicated. All thoughts taken directly or indirectly from external sources are properly denoted as such.

This paper has neither been previously submitted to another authority nor has it been published yet.

Leonding, April 4, 2018

Egon Manya

Eidesstattliche Erklärung

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Abstract

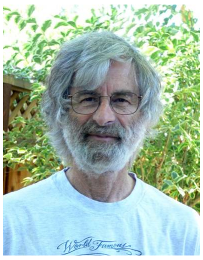
Here it is described what the thesis is all about. The abstract shall be brief and concise and its size shall not go beyond one page. Furthermore it has no chapters, sections etc. Paragraphs can be used to structure the abstract. If necessary one can also use bullet point lists but care must be taken that also in this part of the text full sentences and a clearly readable structure are required.

Concerning the content the following points shall be covered.

- *Definition of the project:* What do we currently know about the topic or on which results can the work be based? What is the goal of the project? Who can use the results of the project?
- *Implementation:* What are the tools and methods used to implement the project?
- *Results:* What is the final result of the project?

This list does not mean that the abstract must strictly follow this structure. Rather it should be understood in that way that these points shall be described such that the reader is animated to dig further into the thesis.

Finally it is required to add a representative image which describes your project best. The image here shows Leslie Lamport the inventor of LaTeX.



Zusammenfassung

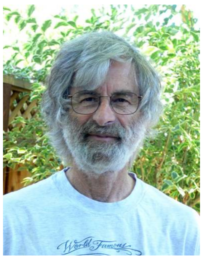
An dieser Stelle wird beschrieben, worum es in der Diplomarbeit geht. Die Zusammenfassung soll kurz und prägnant sein und den Umfang einer Seite nicht übersteigen. Weiters ist zu beachten, dass hier keine Kapitel oder Abschnitte zur Strukturierung verwendet werden. Die Verwendung von Absätzen ist zulässig. Wenn notwendig, können auch Aufzählungslisten verwendet werden. Dabei ist aber zu beachten, dass auch in der Zusammenfassung vollständige Sätze gefordert sind.

Bezüglich des Inhalts sollen folgende Punkte in der Zusammenfassung vorkommen:

- *Aufgabenstellung:* Von welchem Wissenstand kann man im Umfeld der Aufgabenstellung ausgehen? Was ist das Ziel des Projekts? Wer kann die Ergebnisse der Arbeit benutzen?
- *Umsetzung:* Welche fachtheoretischen oder -praktischen Methoden wurden bei der Umsetzung verwendet?
- *Ergebnisse:* Was ist das endgültige Ergebnis der Arbeit?

Diese Liste soll als Sammlung von inhaltlichen Punkten für die Zusammenfassung verstanden werden. Die konkrete Gliederung und Reihung der Punkte ist den Autoren überlassen. Zu beachten ist, dass der/die LeserIn beim Lesen dieses Teils Lust bekommt, diese Arbeit weiter zu lesen.

Abschließend soll die Zusammenfassung noch ein Foto zeigen, das das beschriebene Projekt am besten repräsentiert. Das folgende Bild zeigt Leslie Lamport, den Erfinder von LaTeX.



Acknowledgments

If you feel like saying thanks to your grandma and/or other relatives.

Contents

Chapter 1

Introduction

1.1 Initial Situation

Common word processors do not prepare print-like documents in so far as these programs do not reflect the rules of professional printing which have been grown over centuries. These rules contain clear requirements for balancing page layouts, the amount of white space on pages, font-handling, etc. Donald Knuth's TeX package (see [?]) is a word processor which conforms to these printing rules. This package was enhanced by Leslie Lamport by providing more text structuring commands. He called his package LaTeX [?].

When preparing a thesis, we want not only to have our content on a top level, we also want to commit to a high level of formal criteria. Therefore, we request our students to use one of these professional printing production environments like TeX or LaTeX.

Furthermore students should train their scientific writing skills. This includes a clear and structured break-down of their ideas, a high-level and clear wording, and the training of transparent citations of ideas from other sources than from theirs. A good source for more information concerning technical and scientific writing can be found in [?].

1.2 Goals

The general goals and objectives of the project are described here. Care must be taken that the goals documented here are purely project goals and have nothing to do with individual goals of the team members. If individual goals should be part of the thesis they are listed in appendix B.

1.3 Overview

Details of the diploma thesis have to be aligned between student and supervisor. This should be a basic structure to facilitate the first steps when students start to write their theses.

Figure 1.1: Don Knuth, the inventor of TEX

Never forget to add some illustrative images. Images must not be messed up with your normal text. They are encapsulated in floating bodies and referenced in your text. An example can be seen in figure 1.1. As you can see, figures are placed by default on top of the page nearby the place where they are referenced the first time. Furthermore you can see that a list of figures is maintained automatically which can be included easily by typing the command `\listoffigures` into your document.

1.4 Basic Terminology

As usual the very basic terminology is briefly explained here. Most probably the explanations here only scratch a surface level. More detailed explanations of terminology goes into chapter **??**.

1.5 Related Work and Projects

Here a survey of other work in and around the area of the thesis is given. The reader shall see that the authors of the thesis know their field well and understand the developments there. Furthermore here is a good place to show what relevance the thesis in its field has.

1.6 Structure of the Thesis

Finally the reader is given a brief description what (s)he can expect in the thesis. Each chapter is introduced with a paragraph roughly describing its content.

Chapter 2

Formal languages

Chapter 3

Compiler construction

Chapter 4

The NoBeard Machine Architecture

4.1 The NoBeard Machine

It is a virtual machine with an instruction set of 31 instructions which is pretty easy to understand compared to the instruction set sizes of real life machines. The machine is purely stack based such that the structure of each instruction is easy to grasp and to follow. The machine has a word width of four bytes and is being target for NoBeard programs. The NoBeard Machine consists of the following components.

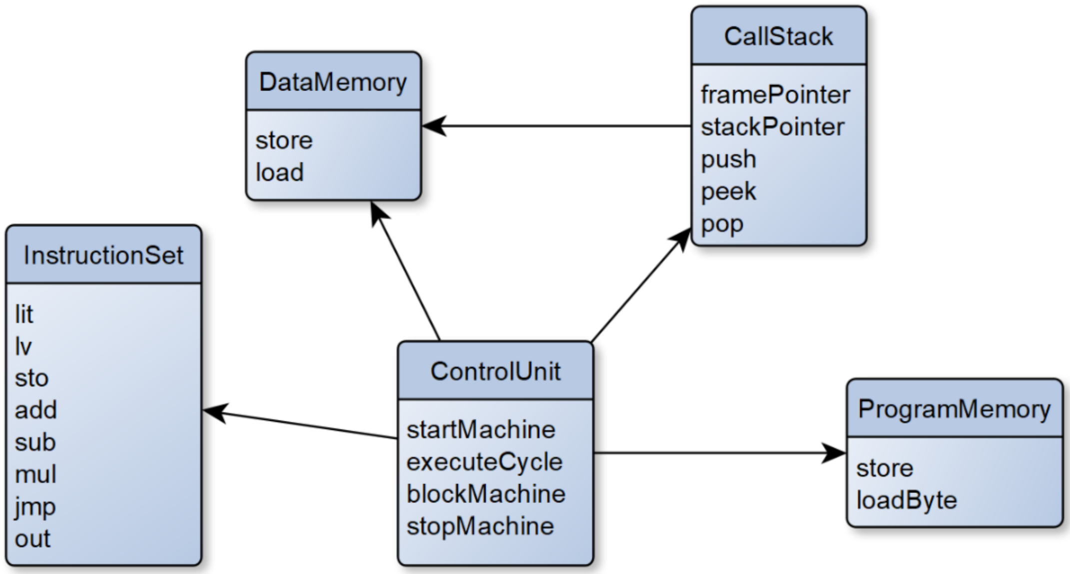


Figure 4.1: Components of the NoBeardMachine Architecture

4.1.1 Program Memory

The program memory stores instructions with belonging opcode and operands. It is byte addressed memory with a specified maximum size. Addresses access outside the range of 0 to the maximum size -1 lead to a “ProgramAddressError”.

4.1.2 Data Memory

The Data memory is a storage which is byte addressed and stores variables in the following way:

- **Characters** are one-byte values are stored byte wise into the data memory.
- **Integers** are four-byte values and are stored in little endian order. Negative integer values are stored as Two’s Complement (see [wik18]).
- **Booleans** are four-bytes values and are stored as the integer 0 for false and the integer 1 for true.

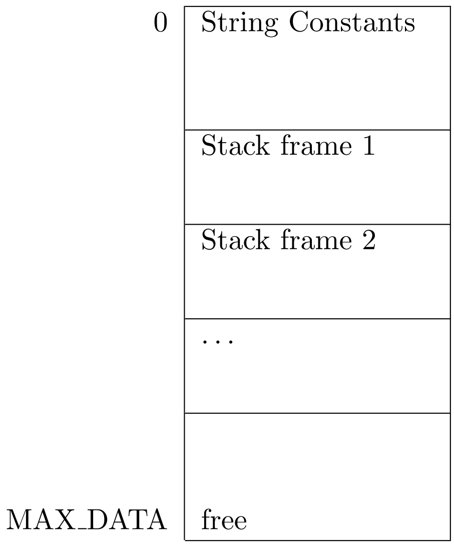


Figure 4.2: Data Memory of the NoBeard Machine

As figure 4.2 shows, the data memory is separated into two parts, string constants and to stack frames of the currently running functions.

String Constants

String constants in NoBeard assembler programs are written at the beginning of the source code under quotation marks. It includes all strings that has to be printed out on the console. Before starting a program on the virtual machine string constants are stored in the constant memory.

Stack Frames

After the constant memory the stack frames are maintained in a certain way. For every execution of a function a new frame is added. It holds data for the functions arguments, local variables and its expression stack. As soon as functions ends, its frame is removed.

Address	Content	Remark
0	0	frame pointer of frame 0
	...	
32	13	local int in frame 0
36	0	static link to frame 0 (start of frame 1)
	...	
68	17	local int in frame 1
72	42	local int in frame 1
76	36	static link to frame 1 (start of frame 2)
	...	
108	'D'	
109	61	
MAX_DATA	free	

Figure 4.3: Snapshot of a call stack with three frames

Figure 4.3 shows a pretty good example from [Bau17]. Here we can see that the memory is working with three frames. Frame 0 starts at address 0. The first 32 bytes of each frame are reserved for administrative data like the static link and the dynamic link to the surrounding frame, the return value, etc. Address 32 holds the value of a local variable in frame 0.

At address 36 frame 1 starts with the address to its statically surrounding frame, i.e, the function (or unit or block) represented by frame 0 is defining the function (or block) represented by frame 1. Frame 1 defines two local values at addresses 68 and 72. Now it can be easily verified that an assembler instruction `la 0 32` (see section 4.4) loads the value of the local (i.e., relative to the closest frame pointer) address 32. In the concrete example this is address $36 + 32 = 68$.

4.1.3 Call Stack

By structuring the data memory as a stack the call stack is needed as an abstraction to the data memory. With the help of different functions the call stack is able to add and remove frames from the stack and to maintain the expression stack. Data that are needed for each statement get stored in the expression stack. It grows and shrinks as needed and is empty at the end of each statement. The stack is addressed word-wise only. The call stack has the two major components:

- **Stack Pointer:** Address of the start of the last used word on the stack.
- **Frame Pointer:** Address of the first byte of the currently running function's stack frame.

4.1.4 Control Unit

It is responsible for the program work flow. It executes one machine cycle in three steps, it fetches, decodes and operates the current instruction. Depending on some instruction, the control unit also affect the state of the machine. To achieve these steps it has to work with the following components:

- **Program Counter:** Start address of the next instruction to be executed.
- **Machine State:** The NoBeard machine has four different states and is always in one of them.
  - `running`: The machine runs
  - `stopped`: The machine stops. Usually when the end of program is reached.
  - `blocked`: The machine pauses. Mostly when a breakpoint is placed by the user.
  - `error`: Error state

4.2 Binary File Format

The virtual machine runs only NoBeard object files with extension `.no` which can be generated by an NoBeard Assembler or NoBeard Compiler. From the first byte onwards the machine instructions are stored in a continuous flow. After a final `halt` instruction the stream of string constants is stored. This is also shown in figure 4.4.

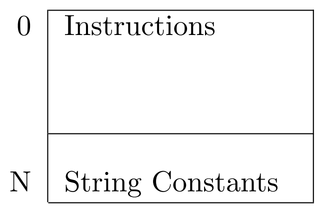


Figure 4.4: NoBeard Binary File Format

4.3 Runtime Structure of NoBeard Program

The machine has a firmly defined execution cycle:

1. Fetch instruction
2. Decode instruction
3. Execute instruction

The very first instruction is fetched from a specified starting program counter which is provided as an argument when starting the program. From this point of time forwards the program is running until the machine state changes from run. There are two options to interrupt the machine from running state. It get interrupted mostly by the debugger with a breakpoint. Or otherwise when the `halt` instruction get executed.

4.4 Instructions

NoBeard instructions are of a different length and each has an opcode and operands of an amount between 0 and 2. The first byte of all instructions is reserved for the op code, which is the identifier used to identify the instruction on machine language level. The remaining bytes, if any, are assigned to the operand of the instruction. Each of the following subsections explains these instructions in four categories. The underlined title is the shorthand that identifies the instruction on assembler level. Then follows a table showing the size of the instruction and which bytes carry which information. Finally, each one has also a short explanation in human language and in some cases also an example. All the examples here are taken from [Bau17].

4.4.1 Load and Store Instructions

nop

Byte 0
0x00

Operation: Empty instruction. Does nothing

```
nop
```

lit

Byte 0	Byte 1	Byte 2
0x01	Literal	

Operation: Pushes a value on the expression stack.

```
lit Literal
push(Literal);
```

la

Byte 0	Byte 1	Byte 2	Byte 3
0x02	Displacement	DataAddress	

Operation: Loads an address on the stack.

```
la Displacement DataAddress
base = fp;
for (i= 0; i < Displacement; i++) {
    base = dat[base ... base + 3];
}
push(base + DataAddress);
```

lv

Byte 0	Byte 1	Byte 2	Byte 3
0x03	Displacement	DataAddress	

Operation: Loads a value on the stack.

```
lv Displacement DataAddress
base = fp;
for (i = 0; i < Displacement; i++) {
    base = dat[base ... base + 3];
}
adr = base + DataAddress;
push(dat[addr ... addr + 3]);
```

lc

Byte 0	Byte 1	Byte 2	Byte 3
0x04	Displacement	DataAddress	

Operation: Loads a character on the stack.

```
lc Displacement DataAddress
base = fp;
for (i = 0; i < Displacement; i++) {
   base = dat[base ... base + 3];
}
// fill 3 bytes of zeros to get a full word
lw = 000dat[base + Address];
push(lw);
```

lvi

Byte 0	Byte 1	Byte 2	Byte 3
0x03	Displacement	DataAddress	

Operation: Loads a value indirectly on the stack.

```
lvi Displacement DataAddress
base = fp;
for (i = 0; i < Displacement; i++) {
   base = dat[base ... base + 3];
}
adr = base + DataAddress;
ra = dat[addr ... addr + 3];
push(ra);
```

lci

Byte 0	Byte 1	Byte 2	Byte 3
0x05	Displacement	DataAddress	

Operation: Loads a character indirectly on the stack.

```
lci Displacement DataAddress
base = fp;
for (i = 0; i < Displacement; i++) {
   base = dat[base ... base + 3];
}
ra = dat[base + Address];
// fill 3 bytes of zeros to get a full word
lw = 000dat[ra];
push(lw);
```

inc

Byte 0	Byte 1	Byte 2
0x1D	Size	

Operation: Increases the size of the stack frame by `Size`.

```
inc Size
top += Size;
```

sto

Byte 0
0x07

Operation: Stores a value on an address.

```
sto
x = pop();
a = pop();
dat[a ... a + 3] = x;
```

stc

Byte 0
0x08

Operation: Stores a character on an address.

```
stc
x = pop();
a = pop();
// Only take the rightmost byte
dat[a] = 000x;
```

4.4.2 Integer Instructions

neg

Byte 0
0x0B

Operation: Negates the top of the stack.

```
neg
x = pop();
push(-x);
```

add

Byte 0
0x0C

Operation: Adds the top two values of the stack.

```
add
push(pop() + pop());
```

sub

Byte 0
0x0D

Operation: Subtracts the top two values of the stack.

```
sub
y = pop();
x = pop();
push(x - y);
```

mul

Byte 0
0x0E

Operation: Multiplies the top two values of the stack.

```
mul
push(pop() * pop());
```

div

Byte 0
0x0F

Operation: Divides the top two values of the stack.

```
div
y = pop();
x = pop();
if (y != 0)
    push(x / y);
else
    throwDivByZero();
```

mod

Byte 0
0x10

Operation: Calculates the remainder of the division of the top values of the stack.

```
mod
y = pop();
x = pop();
push(x % y);
```

not

Byte 0
0x11

Operation: Calculates the remainder of the division of the top values of the stack.

```
not
x = pop();
if (x == 0)
    push(1);
else
    push(0);
```

4.4.3 Control Flow Instructions

fjmp

Byte 0	Byte 1	Byte 2
0x16	NewPc	

Operation: Sets `pc` to `newPc` if stack top value is false.

```
fjmp newPc
x = pop();
if (x == 0)
    pc = NewPc;
```

tjmp

Byte 0	Byte 1	Byte 2
0x17	NewPc	

Operation: Sets `pc` to `newPc` if stack top value is true.

```
tjmp newPc
x = pop();
if (x == 1)
    pc = NewPc;
```

jmp

Byte 0	Byte 1	Byte 2
0x18	NewPc	

Operation: Unconditional jump: Sets `pc` to `newPc`.

```
jmp newPc
pc = NewPc;
```

break

Byte 0
0x1F

Operation: Breaks the machine. Especially used for the debugging function.

```
break
ms = blocked;
```

halt

Byte 0
0x1F

Operation: Halts the machine.

```
halt
ms = stopped;
```

4.4.4 IO-Instructions

in

Byte 0	Byte 1
0x19	Type

Operation: Reads data from the terminal. Depending on `Type` different data types are read:

- 0: An `int` is read and stored at the address on top of the stack. After execution the value 1 is pushed if an integer was read successfully, otherwise 0 is pushed.
- 1: A `char` is read and stored at the address on top of the stack. After execution the value 1 is pushed
- 2: a `string` with a specific length is read

```
in Type
switch(Type) {
   case 0:
      a = pop();
      n = readInt();
      dat[a ... a + 3] = n;
      break;
   case 1:
      a= pop();
      ch = readChar();
      dat[a] = ch;
      break;
   case 2:
      a = pop();
      strLen = pop();

      break;
}
```

out

Byte 0	Byte 1
0x1A	Type

Operation: Writes data to the terminal. Depending on `Type` different data types are printed:

- 0: An `int` with a specific column width is printed
- 1: A `char` with a specific column width is printed
- 2: a `string` with a specific column width is printed
- 3: a new line is printed

```
out Type
switch(Type) {
    case 0:
        width = pop();
        x = pop();
        // + means string concatenation in the next line
        formatString = "%" + width + "d";
        printf(formatString, x);
        break;
    case 1:
        width= pop();
        x = pop();
        printf("%c", x);
        for (i = 0; i < width - 1; i++)
            printf(" ");
        break;
    case 2:
        width = pop();
        strLen = pop();
        strAddr = pop();
        printf("%s", dat[strAddr ... strAddr + strLen - 1]);
        for (i = n; i < width - 1; i++)
            printf(" ");
        break;
    case 3:
        printf("\n");
        break;
}
```

4.5 NoBeard Assembler

To write programs for the NoBeard machine an Assembler is provided. NoBeard Assembler files are separated in two blocks, which is called the string constants and the assembler program. The files have the extensions `.na` for NoBeard Assembler. The string constants are stored between two double quotes and has to be located at the beginning of the file. There is no way to address a single constant. So, if we use a string constant in the assembler program, we have to specify the starting address of the string constant and the length needed in the program. Assembler programs contain a sequence of assembler instructions like `lit` for load or `out` for print. After the opcode of the instruction follows the operands, if they are needed as already described in section 4.4.

4.5.1 Example

Chapter 5

User Manual

This chapter describes how to use the graphical user interface of the NoBeard virtual machine and serves at the same time as a user manual. With the NoBeardMachine users are able to load and run NoBeard object files with just a view clicks. The integrated debugger of the virtual machine gives them also the possibility to debug these programs by setting breakpoints. Another big feature is the data visualization which gives users a whole view of the data memory.

5.1 The UI Components

As shown in figure 5.1 the NoBeardMachine contains the following five windows:

- **Control Window:**
- **Output Window:**
- **Program Window:**
- **Data Memory Window:**
- **Input Window:**

5.1.1 Control Window

This window consists of five buttons that gives the possibility to open, run, step, stop or jump in programs.

- **Open file:** Opens up a file chooser dialog where the target object file can be selected.
- **Run:** Executes the program from the first byte.
- **Step:** Gives the opportunity to step one single line further in the program flow. This button is only in a "blocked" state available.

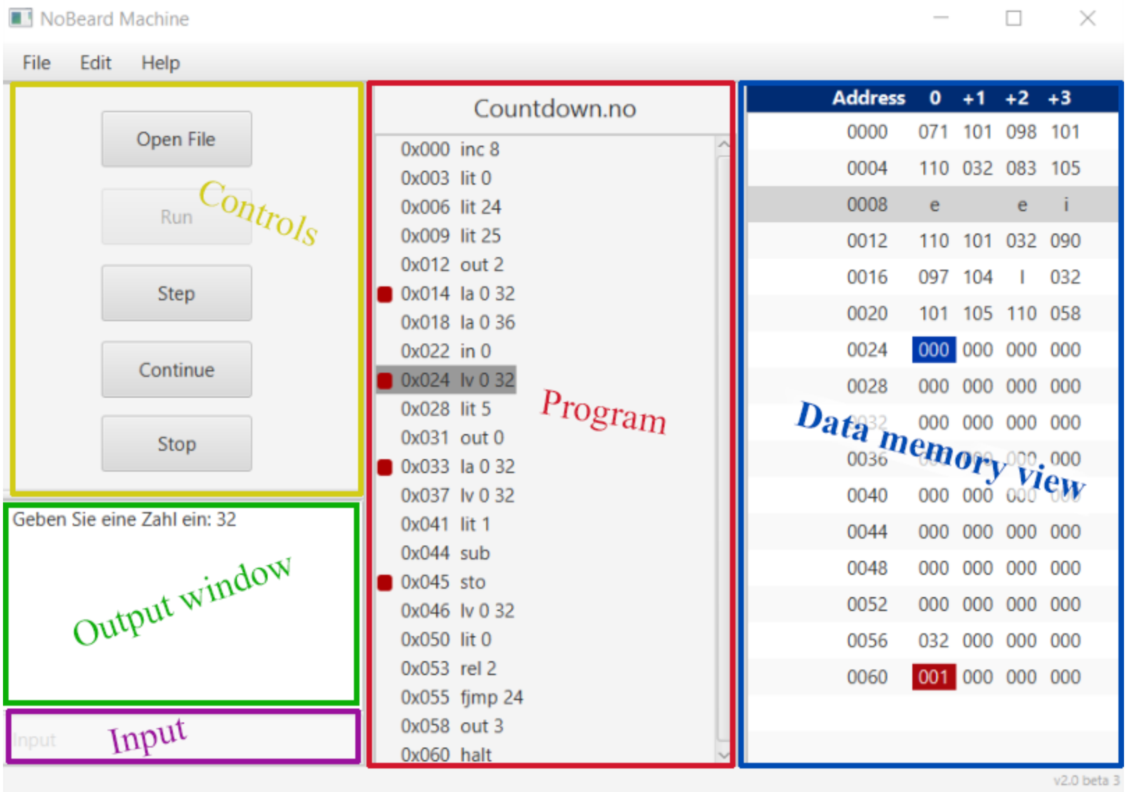


Figure 5.1: Components of the NoBeardMachine

- **Continue:** When the program execution gets interrupted by a breakpoint this button enables users to jump to the next breakpoint. If there is no breakpoints left it continues the process until the end.
- **Stop:** Stops the execution and sets the machine into the "stopped" state.

5.1.2 Output Window

It is a non-editable TextArea which simulates a terminal. Program outputs that are coming from an "OUT" instruction are shown here. Submitted inputs are also visible here after a successfully submit.

5.1.3 Program Window

This window shows assembler instructions with the belonging addresses in a VBox. Every line also gets a checkbox that is responsible for setting and removing breakpoints.

5.1.4 Data Memory Window

A ListView filled with raw data from the data memory. Every line of the ListView contains four byte data with the belonging addresses. Each byte can be converted to a character. Even a whole line can be translated to four characters or to a single four byte integer. Data with blue background color highlights the frame pointer. Red background color stands for the stack pointer.

5.1.5 Input Window

The Input window is a TextField where inputs from users can be handled. It is only enabled when the machine is executing an "IN" instruction. To submit an input, the "ENTER" key has to be pressed and then the entered text will be attached to the Output window.

5.2 Loading and Running a Program

After starting the NoBeardMachine, a NoBeard object file has to be loaded by a click on the "Open File" button. Than a file chooser dialog should appear where the user can choose the desired file. Afterward, the window shows the assembler code and the title of the opened program which is now executable.

The Program window lists the assembler instructions with the belonging addresses and operators. By hitting the "Run" button, the machine executes the loaded program. Output results can be seen in the Output window. If the program runs against an input instruction, the machine stops and requests the user for an input which can be done at the Input window. To submit an input, the Enter key has to be pressed.

5.3 Debugging

To debug a program the user has to set breakpoints which interrupts the program flow and allows the user to inspect the current state of the running program. These breakpoints can be placed by clicking on the address with the instruction where the program flow has to be interrupted.

After an interruption of a breakpoint, the user is able to step one line further or jump to the next breakpoint. Stepping is handled by the "Step" button as shown in figure 5.3. By clicking the "Continue" button, the program runs from the current line until the next breakpoint. If there is not any breakpoint left from the current line, it runs until the end of the program. Optionally, the user is able to stop the program during the execution. This could be achieved by clicking the "Stop" button.

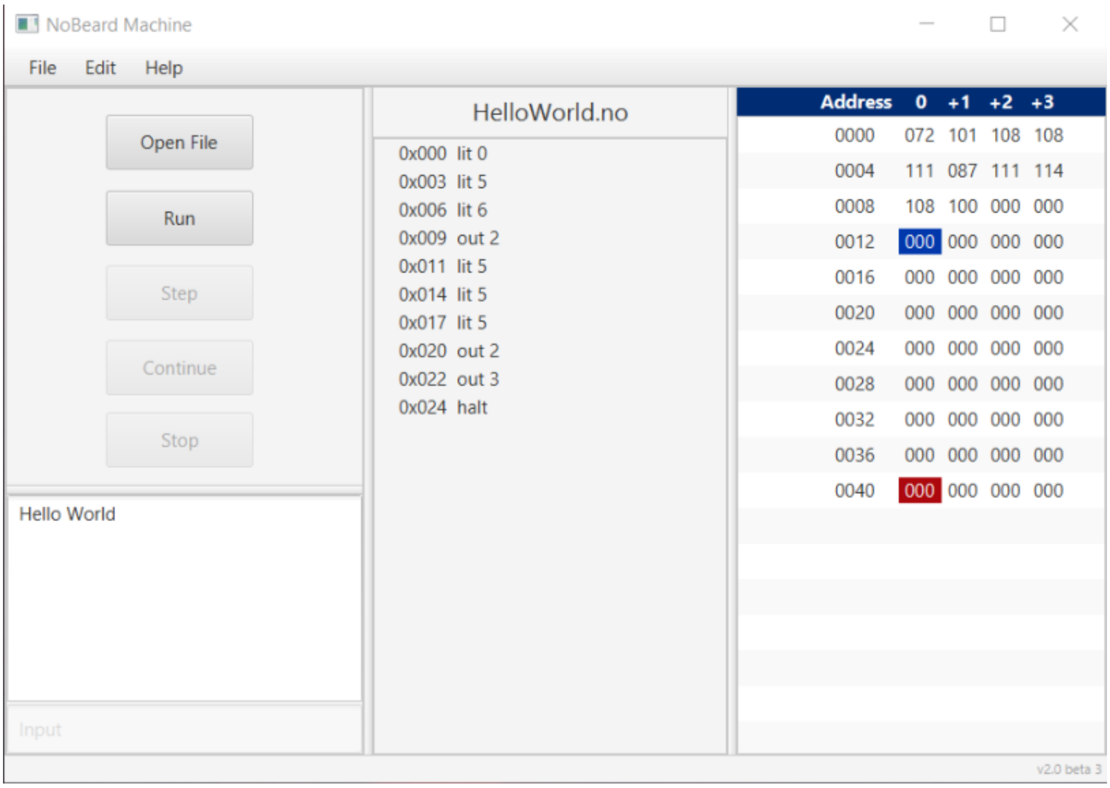


Figure 5.2: Executed "Hello World" program

5.4 Data Visualization

On the right side of the window is the visualisation of the data memory in a ListView form. This window lists data byte wise from the data memory of the machine. Each line of the ListView has a content of an address given in decimal notation following by four bytes raw data. The memory is separated in two parts. The list starts on the top with the string constants followed by stack frames of the currently running functions. While the frame pointer is highlighted with a blue background, the stack pointer is signed with a red background. The user has also the possibility to convert raw data to characters or integers. With a right click on the selected line of the list, a context menu could be opened. This menu includes following functions:

- showing integer,
- characters of the whole line,
- a single character
- or converting back the line to raw data.

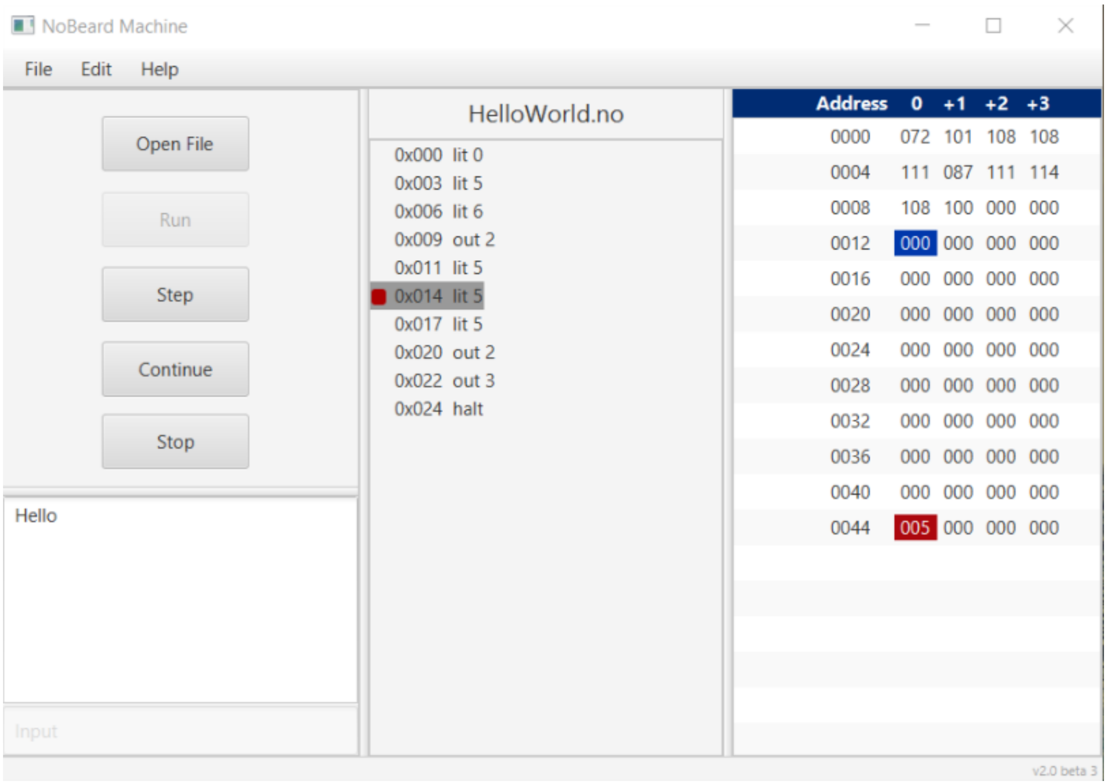


Figure 5.3: Debugging the "Hello World" program

5.4.1 Converting Data to Character

To view a character of a one-byte data as shown in figure 5.4, the following steps has to be done:

1. Select the line where the one-byte value is located
2. Right click on the value to be converted
3. Click on "View Char"

Now the value at the given address is translated to an alphanumeric character.

5.4.2 Converting Data to Integer

The translation of an integer takes four bytes that means, it takes all values of a whole row and translates them to a single integer.

1. Select the row with the four-byte value
2. Right click on the line

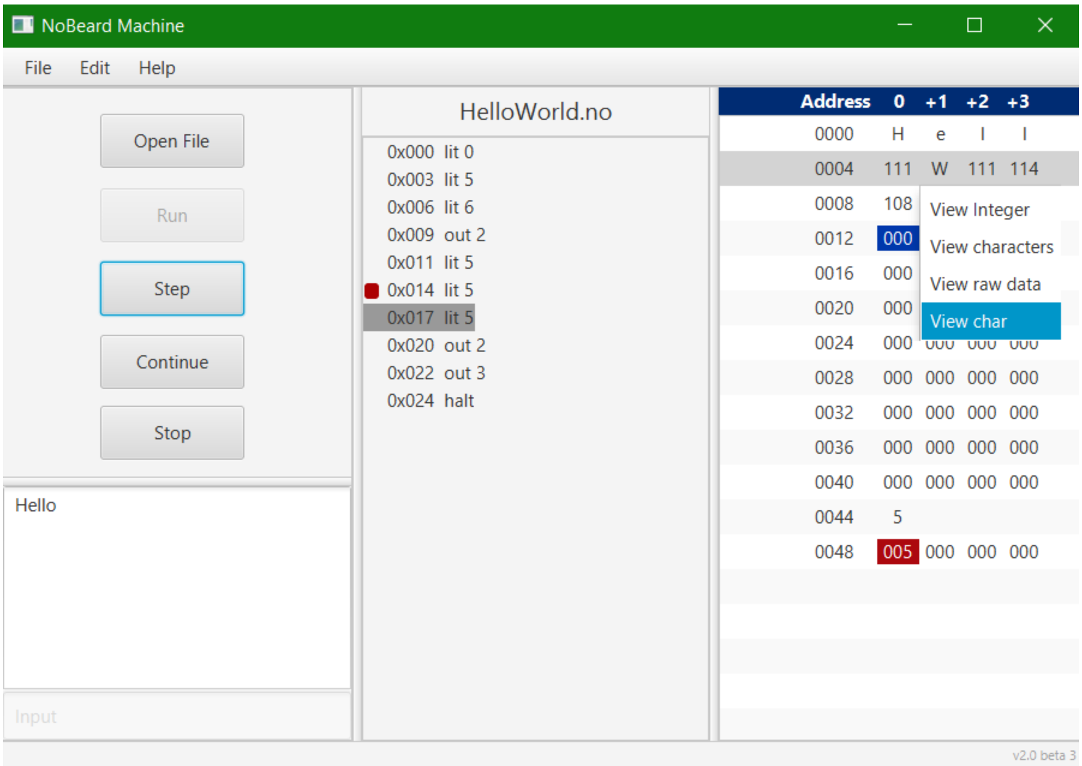


Figure 5.4: Converting data to a character

3. Click on "View Integer"

Figure 5.5 shows an example of a translated integer which is on the same place as the stack pointer, precisely at the address 64. A detailed description of the implementation can be found in chapter 6.7.

5.4.3 Multiple Conversion

To make the conversion from raw data to alphanumeric characters or integers more easy and fast, a multi selection function is available for the list of the data memory. To convert multiple data rows, the user has to hold the "Ctrl" key and select the specified rows with the left mouse click. Chosen lines will get highlighted with a light grey background color. As figure 5.6 shows, the selected rows with grey background are successfully concerted to some characters.

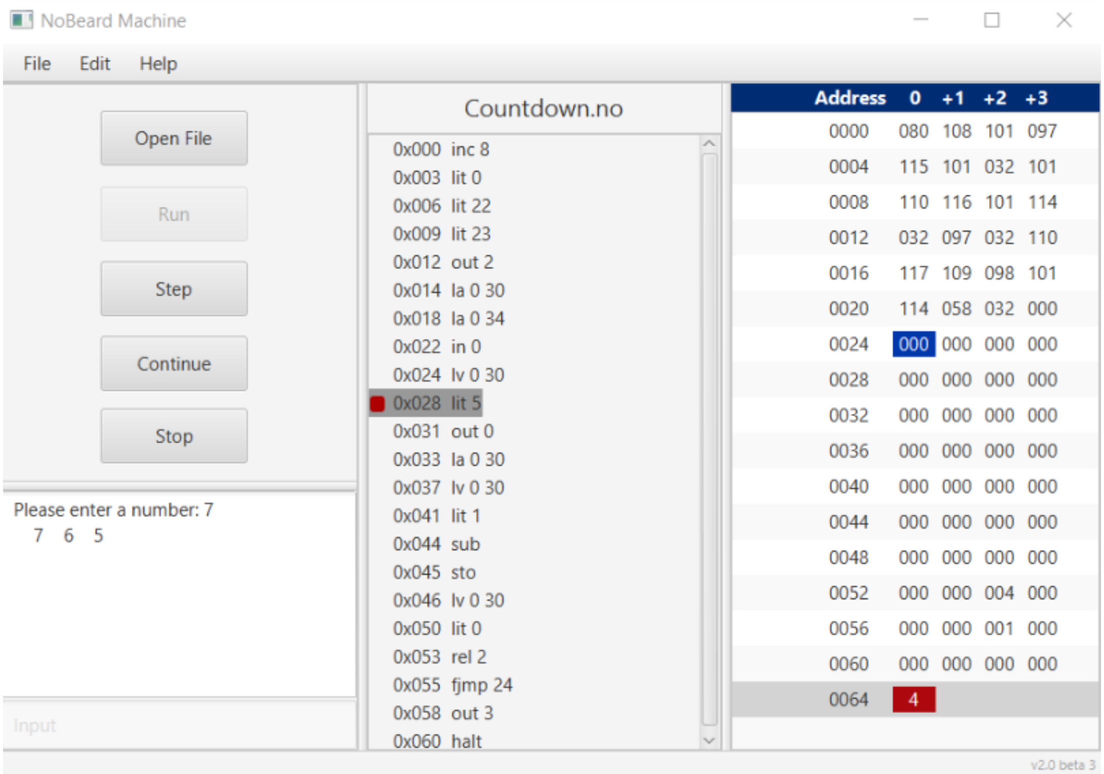


Figure 5.5: Converting data to a single integer

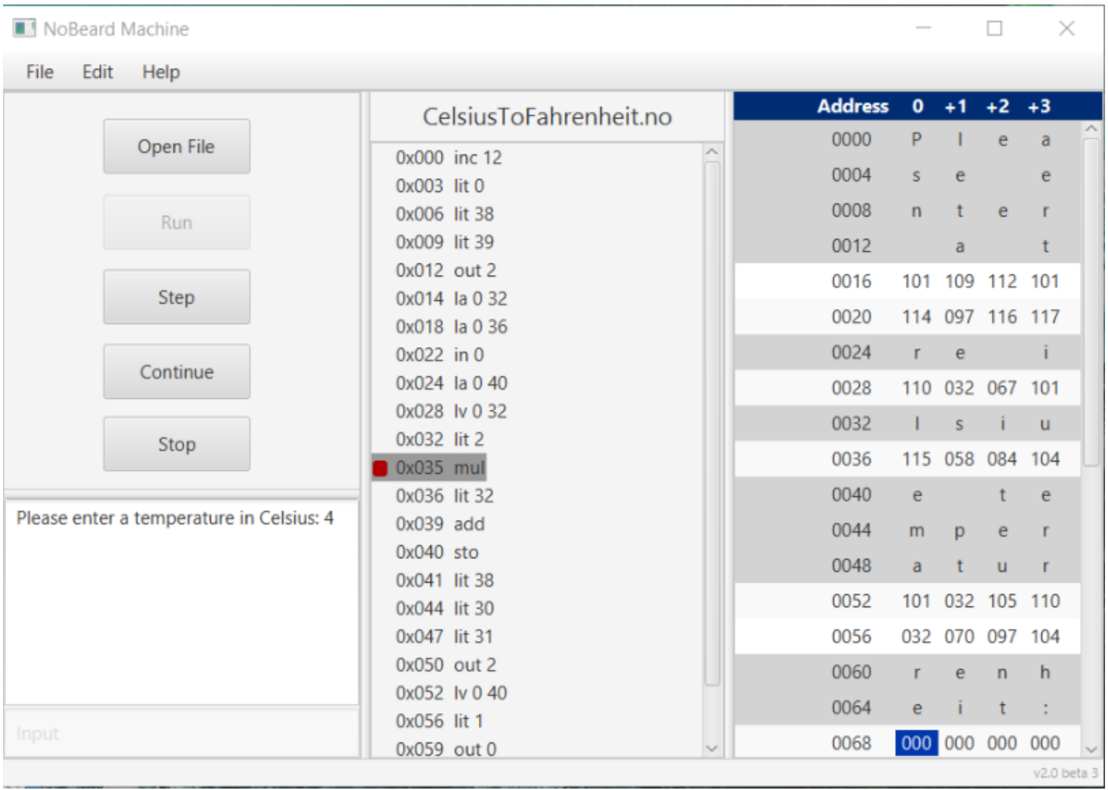


Figure 5.6: Multiple conversion of data

Chapter 6

Implementation

6.1 Used Technologies

6.1.1 IntelliJ IDEA

The Implementation of the project is written in Java on the integrated development environment IntelliJ. It is an integrated development environment for developing Java based software. Nevertheless, it supports other programming languages too like Scala, Groovy and Kotlin. The IDE is also often used for mobile development in Android or Cordova. It could be very practicable for web development because of the following different frameworks: JavaScript, AngularJs, Node.js, TypeScript etc... This IDE support a huge variety of benefits like:

- Different build systems (maven, gradle, ant, grunt, bower etc ...)
- Version control systems (Git, Mercurial, Perforce, and SVN)
- Plugin ecosystem
- Test runner and coverage

6.1.2 Maven

This is a software management and build automation tool which is based on the concept of a project object modem (POM). One of the biggest feature in Maven is the dependency management. Maven automatically downloads in POM file declared libraries and plugins from a repository and stores them local. The local repository is a folder structure that is used as a centralized storage place for locally built artifacts and as a cache for downloaded dependencies. The Maven command mvn install builds a project and places its binaries in the local repository. Then other projects can utilize this project by specifying its coordinates in their POMs.

6.1.3 SceneBuilder

JavaFX Scene Builder is a visual layout tool that generates FXML, an XML-based markup language that lets developers to quickly design user interfaces, without any coding. Users just have to drag and drop UI components to the work area. By selecting components users can easily modify their properties or apply style sheets. The code for the layout is generated automatically in the background by the tool. The resulting FXML file can be combined with a Java project by binding the UI to the application's logic. Every item of the layout view can be assigned with an fx:id to give the controller an easy access of components by the "@FXML" annotation. SceneBuilder is an external tool so it has to be downloaded from the official Oracle website and has to be integrated to a Java supportive IDE.

6.1.4 JavaFX

JavaFX enables developers to design rich client applications that is able to run constantly on different platforms. It offers a wide range of APIs for web rendering, user interface styling and media streaming. The newest JavaFX releases are fully integrated with the Java SE 7 Runtime Environment, which is available for all main desktop platforms. and the Java development Kit. So JavaFX application compiled to JDK 7 or later also run on all major desktop.

6.2 Surrounding packages

The NoBeardMachine is part of the existing NoBeard project. This project already consists of the following packages:

- **asm:** NoBeard Assembler to assemble .na files
- **compiler:** NoBeard Compiler to compile .nb source code files
- **config:** Returns the version of the NoBeard project
- **error:** To handle errors that are acquiring during compilation or assembly
- **io:** Responsible for reading source files and handling binary files
- **machine:** Implements a virtual machine with components like DataMemory, ProgramMemory, Instructions etc...
- **parser:** Converts source code files to binary files
- **scanner:** To analyze NoBeard source code files for keywords, operands or arguments
- **symbolTable:** Looks up for matching words based on the symbol table entry

However, one of the most important package is the “machine”. This is defined as the core of the whole project because it has the most significantly roles such as running a NoBeard program.

6.3 Architecture of the User Interface

The GUI is designed very similar to the Model-View-Controller pattern. However, this project is not depending on any database so it comes without any Model. The GUI project is build up of three main components as shown in figure 6.1. The Controller and the Virtual Machine both of them is running on different threads and are accordingly synchronized. This will be described in detail in section 6.4. The relationship between the controller and view is for event actions and updating of view-components like data memory, output or program flow. The View allows users to call functions from the Controller by clicking on control buttons or by entering inputs.

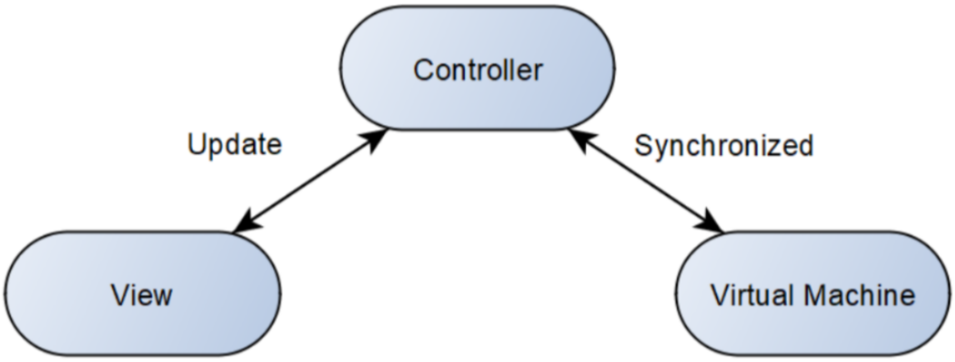


Figure 6.1: Main parts of the GUI implementation

6.3.1 The View

The view is a single fxml file which holds the view components of the layout. It was created with an external tool called SceneBuilder which is already described in section 6.1.3. Each window is made up of an AnchorPane and is separated by SplitPanes. AnchorPane enables developers to construct high rated dynamic user interfaces for desktops. It is a highly specialized layout that can be used for edge alignment. This benefit gives the possibility to fill the whole pane to the parent, which is a SplitPane, by setting anchor offsets to zero. So, it becomes very comfortable and easy to size every window as the user wants. Then each of these AnchorPanes holds the needed view-components like Button, TextArea, TextField, ListView or ScrollPane.

6.3.2 The Controller

The controller is primarily responsible for the coordination and operation of the view and its components. As already described in section 6.1.3 the controller can have easy access to the view components via the binding of an fx id. But firstly, they have to be connected with each other by setting the "fx:controller" attribute of the root view element to the currently used controller. Through this advantage it does not need to now the resource file of the layout or to call any "get" functions to get the target items. Even event actions, like mouse click or key pressing, can be bound between the controller and the view. This could be achieved by setting a name for the "On Action" property in SceneBuilder and then creating the related function in the controller. The function has to be declared with the "@FXML" annotation and the same name as it was set on the action property of the item. Even functions like this comes only with a single argument which an ActionEvent. This parameter could be very helpful for getting some further information of the fired event like which mouse button was pressed.

6.4 Synchronization of NoBeard Machine and GUI

Initially, it gets an instance of the NoBeard machine where simple program can be executed. The opening of a NoBeard object file is operated with the help of a Binary-FileHandler. After a successful opening of the object file, it has to be disassemble. This function converts binary files to primary program data where addresses, instructions and operands become visible on the UI. By finishing the translation, the machine has to load the string storage and the program from the object file. Program data is filled in a VBox with a CheckBox and text of the data for every line. All of the CheckBoxes gets an OnAction event which add and remove breakpoints from the machine. On starting a program, a new external thread has to be started where the machine runs separate from the UI. Its executes step by step every instruction of the program until any interruptions. It can be interrupted by a breakpoint, input request or by a halt instruction.

6.5 Handling of Breakpoints (Break instruction)

Machine internal handling of breakpoints is done as described in [Ben].

The implementation for the maintaining of breakpoints is coded with a simple observer pattern design to achieve the best performance of the virtual machine. The machine is completely separated from the breakpoint stuff. It runs only until its state equals to “running”. So, a new instruction is introduced, called “BREAK”, which sets the machine in to a “blocked” state. The ControlUnit which is responsible for execution cycles in the virtual machine is going to be an Observable. Then a new Observer class is implemented which is called debugger that is holding all breakpoints in a HashMap. This HashMap stores the address and the instruction of a breakpoint. The debugger class contains in all three major functions. Adding, removing breakpoints to the HashMap and replacing an instruction at a specified address from the program memory to a new one. The selection of a breakpoint on the UI calls the set or remove function from the debugger, as the case may be. As soon as a breakpoint is selected, it will be stored to the HashMap with its original instruction and at same time replaces the original instruction by the newly added break instruction. This break instruction set the machine to a blocked state and notify the observer to change the break instruction back to the original one which is stored in the HashMap. Now the machine is blocked at a specified breakpoint and the user can take a look to the current stack frames and go one step further in the program or continue the execution cycle to a next breakpoint. However, when the user wants to step further to execute the current instruction where the breakpoint is, a switch back to the break instruction is needed again after the original instruction completed.

6.6 Interruption by input request (Threading)

As already mentioned, the virtual machine runs on a separate thread so every time the user has to operate an input, a switch to the UI thread is needed. Otherwise it would cause a critical section between the threads. The synchronization of these two threads is implemented with the semaphore construction. The NoBeardMachine contains two interfaces to optimize outputs and inputs on the used device. As soon as the machine executes an input instruction (IN), it calls firstly a function from the input interface either hasNextInt() or hasNext(). Both do the same thing, checks whether there is an input by the user or not. The only different is that the one of them also checks if the string is numeric. These functions are overridden in the FxInputDevice class where also an instance of the controller is loaded by the constructor. So, by calling one of these hasNext function the machine thread should be paused. To avoid the deadlock, the semaphore from the controller is acquired at this position. Now the user can make an input on the FX thread and submit it. To get back to the machine thread, the semaphore hast to be released after the user fires the submit event by pressing the ENTER key. Then the machine continues at the same position where the semaphore was acquired, at one of the has Next function and can analyse the provided input string.

6.7 Visualisation of DataMemory

To visualize data like string constants or local variables of the current frame from the data memory a listView is defined on the view. Firstly a function iterates through the dataMemory until the current stack pointer and groups all data into four bytes and finally stores them into an observable collection of strings. Of course, after each break this list view has to be updated to the current stack. Each row of the list view contains a line of string, for example by calling the getItem() function it should return a collection of strings for every row. So the translation for one byte is impossible because one row contains for byte data. Now one row of the list view will be separated in four labels with one byte. These labels get a click event to open up a context menu where four functions are available. For the implementation of these functions a separated

DataMemoryConverter class is introduced. The conversion of a single byte to character is handled by translating the ASCII value which is the current byte to a char.

As already mentioned in section 4.1.2 integers are stored in little endian order, that means the lowest significant byte is stored first.

Chapter 7

Summary

Here you give a summary of your results and experiences. You can add also some design alternatives you considered, but kicked out later. Furthermore you might have some ideas how to drive the work you accomplished in further directions.

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List of Figures

List of Tables

Project Log Book

Date	Participants	Todos	Due

Appendix A

Additional Information

If needed the appendix is the place where additional information concerning your thesis goes. Examples could be:

- Source Code
- Test Protocols
- Project Proposal
- Project Plan
- Individual Goals
- ...

Again this has to be aligned with the supervisor.

Appendix B

Individual Goals

This is just another example to show what content could go into the appendix.