

# Functional Specifications | Team 6

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## 1. Document handling

### 1.1 Document information

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### 1.2 Document Approval

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## 2. Introduction

### 2.1 Glossary

Term used	Definition
"Team"	ALGOSUP team 6 (2023-2024 - Project 3)
"Language"	A set of symbols and rules for instructing computers.
"Assembly"	Low-level language for direct processor programming.
"C"	The C language is a high-level, efficient and portable programming language, originally developed for UNIX.
"Virtual Processor"	The term "virtual processor" refers to a simulated processing unit in a virtualized computing environment.
"IDE"	An IDE (Integrated Development Environment) combines code editing, compilation, and debugging tools in a single interface for efficient development.
"GCC"	GCC, or GNU Compiler Collection, is a set of open-source compilers for various languages, providing cross-platform compatibility and code optimization.
"Register"	A small, fast storage location in the CPU for temporary data and quick operations.
"Label"	A symbolic name in code used to mark positions, often the target of jumps or branches.
"Interpreter"	A program that directly executes code without prior compilation, translating and executing it line by line.
"IP"	Instruction Pointer, a register that holds the memory address of the next instruction to be executed.
"SP"	Stack Pointer, a register that holds the memory address of the top of the stack.
"LR"	Link Register, a register used to store the return address when calling subroutines or functions.
"PC"	Program Counter, a register that holds the memory address of the current instruction being executed.

### 2.2 Project Overview

Our team was tasked with creating a virtual processor and an interpreter for running and interpreting assembly code on that virtual processor. Additionally, we were tasked with creating a virtual system to observe the assembly program actually running, and displaying text in a virtual terminal that can be accessed from the assembly code.

### 2.3 Project Definition.

The project involves creating a virtual processor and an interpreter to run and interpret assembly code. The development will be in plain, portable C language, utilizing only C standard libraries and avoiding external libraries. The recommended tools include using GCC as a compiler and Visual Studio Code as the IDE.

#### 2.3.1 Goals of this Project

The primary goal of our team for this project is to conduct a meeting with team members to devise assembly instructions and discuss their implementation.

Secondly, we need to document all aspects, including the functional specification and technical specification. We also need to delve into the various phases of the project.

Thirdly, we will enter the implementation phase of the project.

Fourthly, we have to test all the different functions of the implemented code and compare the results with the desired outcomes.

Finally, we must ensure that the code works properly and deliver the project on time.

### 2.3.2 Our objectives

#### Assembly Language Support:

Develop a virtual processor that supports a simple assembly language, with a focus on essential instructions commonly used in low-level programming.

##### Interpreter:

The interpreter will return error messages discovered during execution. For example, if there is an error at the 'add: R1' level, we will receive an error message, indicating that there is an issue. In this case, the error message will specify the line where the error occurred, pointing out that there is an error since we only have a single register, which is the destination register.

##### Execution Accuracy:

Ensure that the virtual processor accurately interprets and executes assembly language instructions, maintaining compatibility with established conventions and standards.

##### User Interface:

Implement a virtual system to facilitate user interaction, enabling the loading and execution of assembly programs. The virtual system should provide relevant information about the assembly, ensuring a user-friendly and informative experience.

##### Architecture:

To implement our assembly code, we will draw inspiration from the ARM 16-bit architecture and the LC3 architecture, both of which are 16-bit and closely similar in their implementation.

##### Register and Memory Management:

Design the virtual processor to effectively manage registers for temporary data storage and intermediate results in 16 bits. Implement functionalities for storing and loading, jumping, calling, copying, computing operations, and comparing program instructions and data.

##### Interrupt Handling:

Implement a mechanism for handling interruptions, encompassing both software and hardware interruptions. The virtual processor should respond appropriately to interrupt signals.

##### Performance and Portability:

Achieve acceptable performance for the execution of moderate-sized assembly programs. Ensure the source code's portability to guarantee compatibility with various operating systems.

##### Security Measures:

Incorporate security measures to prevent buffer overflow attacks and ensure the secure execution of programs. Implement proper isolation between different executing processes to enhance system security.

## 2.4 Project Roles

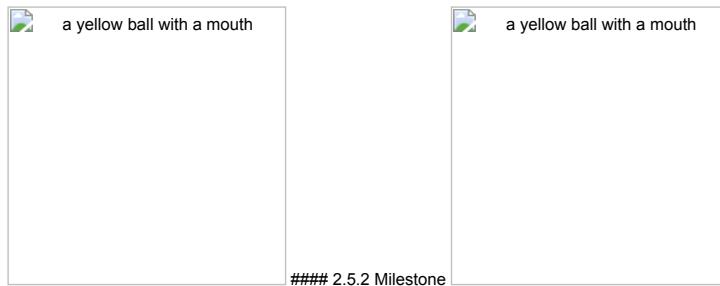
As defined by the project owner (ALGOSUP), the team is organized in the following way :

Role	Description	Name
Project Manager	Is in charge of organization, planning and budgeting. Keep the team motivated.	Michel Riff
Program Manager	Makes sure the project meets expectation. Is in charge of design.	Raphaël Descamps
Tech Lead	Is responsible for writing the Functional Specifications Makes the technical decision in the project. Translates the Functional Specification into Technical Specifications. Habi Cailleau Does code review.	Habi Cailleau
Software Engineer	Writes the code. Writes documentation Participate in the technical design.	Lucas Aubard

Role	Description	Name
Software Engineer	Writes the code. Writes documentation Participate in the technical	Vivien Bistrel Tsangue
Quality Assurance	Tests all the functionalities of a product to find bugs and issue. Document bugs and issues. Write the test plan. Check that issues have been fixed.	Loris De Mattia Segalata

## 2.5 Project Plan

### 2.5.1 Retro Planning



### 2.5.3 Project Constraints

#### Constraints

We have to code in C.

We can't use any external library beside C standard libraries.

We have to create an assembly with basic instructions.

Avoid using x86 architecture instruction

## 3. Functional Requirements

### 3.1 Virtual Processor and languages Overview

#### 3.1.2 Context

The concept of creating a virtual processor traces its origins back to the early days of computing when researchers and developers sought ways to simulate the behavior of a real processor in a controlled environment. Initial emulations of processors were developed to test software on various hardware architectures without requiring physical access to each type of processor.

The demand for virtual processors became more significant with the evolution of computer architectures and the emergence of distributed systems, virtual machines, and isolated execution environments.

#### 3.1.3 Assembly Language

Assembly language, often referred to as assembly code, is a low-level language specific to a particular hardware architecture. Each assembly language instruction typically corresponds to a machine instruction, facilitating direct programming of the processor. Programmers use assembly language to write more efficient programs by fully leveraging the hardware's capabilities.

However, learning and maintaining assembly language can be challenging due to its close connection to the underlying hardware architecture. Nevertheless, it provides precise control over the hardware, making it essential for developing embedded systems, device drivers, and other low-level software.

#### 3.1.4 C Language

The C language, created by Dennis Ritchie in the early 1970s, is a higher-level programming language compared to assembly language. It provides a higher level of abstraction from the hardware, allowing programmers to write portable and easily understandable code while maintaining efficiency close to that of assembly language.

C is an imperative and procedural language, offering features such as memory management through pointers, bit manipulation, and the ability to code critical portions in assembly language for fine optimization.

### 3.1.3 Our Assembly Language

Instruction	Objective
"ADD"	Takes two numbers, adds them together and stores the result in a register.
"SUB"	Subtracts the second number from the first and stores the result in a register.
"DIV"	Divides the first number by the second and stores the result in a register.
"MUL"	Multiplies two numbers and stores the result in a register.
"CPY"	Copies the value from one register to another.
"CMP"	Compares two numbers and sets flags in the status register based on the result.
"OR"	Performs a bitwise OR operation on two numbers and stores the result in a register.
"XOR"	Performs a bitwise XOR operation on two numbers and stores the result in a register.
"JMP"	Jumps to a specified memory address or label.
"NOT"	Performs a bitwise NOR operation on two numbers and stores the result in a register.
"LOAD"	Loads a value from memory into a register.
"STORE"	Stores the value from a register into memory.
"JE"	Jumps to a specified memory address or label if the result of the last comparison was equal.
"CALL"	Calls a subroutine or function at a specified memory address.
"RET"	Returns from a subroutine or function.
"AND"	Performs a bitwise AND operation on two numbers and stores the result.

Above are all the instructions that our assembly language will be composed of. These are the basic instructions of the normal assembler.

### 3.1.4 Characteristic Syntax

Here is an example of what should be entered in the command prompt of our virtual processor to execute one or more instructions:

**ADD: R1, 1 , 4**

"ADD" = Instruction

R1 = Register number 1

1 = value 1

2 = value 2

Instruction Objective = Add 1 to 2, then store the result in the register named R1.

## 3.2 Virtual processor

### 3.2.1 Instruction Set

As described in the table above in section 3.1.3, we have decided to select the basic instructions of the assembly language to avoid confusion. Furthermore, the chosen instructions are those that allow for arithmetic operations, logical maneuvers, and instructions to move data in and out of memory. Essentially, everything fundamental for a processor to perform its tasks.

### 3.2.2 Register

Our processor needs a set of internal registers to keep things organized during computation. Let's outline the purpose and limits of each register, like a choreography for our processor dance.

Our virtual processor will be based on 16 bits, so we'll have a total of 16 registers ranging from R1 to R12. Additionally, we will have specific registers such as R\_IP (Intra-Procedure-call scratch register), R\_SP (Stack Pointer), R\_LR (Link Register), and R\_PC (Program Counter).

### 3.2.3 Instruction Execution

Imagine each assembly instruction as a script. We need to decide how our virtual processor reads, understands, and acts upon these scripts. So, let's outline the steps for fetching, decoding, and executing each instruction. It's like teaching our processor a well-rehearsed routine.

### 3.2.4 Memory

Our processor needs a memory system – a mental space to store data and instructions. Let's sketch out how this memory works: the addressing method, its size, and the steps for loading and storing data. It's like building a mental filing cabinet for our processor's thoughts.

### 3.2.5 Interrupts

Sometimes our processor needs to take a break for important tasks – that's where interrupts come in. Let's design a system for managing these interruptions, deciding their types, priority, and how our processor responds when it gets a tap on the virtual shoulder.

### 3.3 Assembler Interpreter

The assembler interpreter is responsible for analyzing and executing programs written in assembly language intended for the virtual processor. It ensures that the program adheres to the syntax and semantics defined in Section 3.2.5 and provides an efficient execution mechanism.

#### 3.3.1 Syntax Analysis

The interpreter begins by analyzing the assembly language program provided by the user. It follows the defined syntactic rules and tokenizes the program by breaking it down into individual instructions, operands, and labels. The analysis process identifies the type of each instruction and validates the correct use of operands.

#### 3.3.2 Execution

Once the assembly language program is analyzed, the interpreter enters the execution phase. It iterates through each instruction, performs the specified operation, and updates the state of the virtual processor accordingly. The execution includes the following key steps:

- **Loading Immediate Values:**

- The interpreter handles instructions involving the loading of immediate values into registers.

```
LOAD: R1, 42      ; Loads the immediate value 42 into register R1
```

- **Operations on Registers:**

- Instructions to copy values between registers and perform arithmetic or logical operations are executed.

```
ADD: R2, R1, R3 ; Adds the values in registers R1 and R3 and stores the result in R2
```

- **Memory Access:**

- The interpreter reads from or writes to memory addresses based on the contents of registers.

```
LOAD: R4, [R2]    ; Loads the value at the memory address specified by R2 into register R4
STORE: R3, [R4]   ; Stores the value from register R3 at the memory address specified by R4
```

- **Conditional Jumps:**

- The interpreter handles jumps, whether unconditional or conditional based on comparison results.

```
CMP: R3, R4      ; Compares the values in registers R3 and R4
JMP: LABEL1       ; Jumps to LABEL1 if the comparison result is equal (JNEQ can be implemented by inverting the condition)
```

- **Subroutine Calls and Returns:**

- The interpreter manages subroutine calls and returns.

```
CALL: SUBROUTINE ; Calls a subroutine
RET:           ; Returns from a subroutine
```

- **Debugger Integration:**

- During execution, the interpreter can display debugging information, such as the current instruction, program counter, and register contents.

- **Handling Virtual System Calls:**

- If a virtual system call is encountered, the interpreter interacts with the virtual terminal or performs the specified action.

#### 3.3.3 Error Handling

The interpreter includes robust error-handling mechanisms to detect and report syntax errors, semantic errors, or runtime errors during program execution. Clear error messages and informative feedback assist users in identifying and resolving issues in their assembly language programs.

### 3.4 User Interface

The user interface for the virtual processor system consists of both the assembly language program input and the runtime display of information during program execution. The goal is to provide a seamless and informative experience for users interacting with the system.

### 3.4.1 Assembly Language Program Input

Users interact with the virtual processor system by providing assembly language programs through text files. The format of these files follows the specifications outlined in section 3.2, adhering to the defined assembly language syntax. To facilitate ease of use, consider providing a sample template or guidelines for creating assembly programs.

### 3.4.2 Runtime Display

During the execution of an assembly program, the virtual processor system provides real-time information to the user, aiding in debugging and understanding the program flow. The following elements are displayed:

- **Registers:** Display the contents of registers, updating after each instruction execution.

```
Registers:  
R1: 42  
R2: 0  
R3: 42  
...
```

- **Memory:** Optionally, display the state of memory, especially when reading or writing to memory addresses.

```
Memory:  
0x00: 42  
0x04: 0  
0x08: 0  
...
```

- **Virtual Terminal Output:** If a virtual system call is implemented for displaying text in a virtual terminal, show the output of the virtual terminal.

```
Virtual Terminal Output:  
Hello, World!
```

### 3.4.3 Error Handling

The user interface should also handle errors gracefully, providing meaningful messages for syntax errors, semantic errors, or runtime errors during program execution. Clear error messages will assist users in identifying and resolving issues in their assembly programs.

## 4. Non-Functional Requirement

#### Performance:

- Response Time: Define the maximum acceptable time for the virtual processor to respond to instructions.
- Throughput: Specify the number of instructions the virtual processor should be able to execute per unit of time.

#### Reliability:

- Availability: Specify the percentage of time the virtual processor should be available for executing instructions.
- Fault Tolerance: Define how the virtual processor should handle errors or unexpected situations during execution.

#### Scalability:

- Load Handling: Specify how the virtual processor should scale in terms of handling an increasing number of instructions or tasks.
- Concurrency: Define the maximum number of parallel instructions the virtual processor can handle.

#### Compatibility:

- Assembly Language Support: Specify which assembly language(s) the virtual processor should be compatible with.
- Binary Compatibility: Define compatibility requirements with existing binary formats or toolchains.

## 5. Conclusion

The development of the virtual processor and its assembly language interpreter constitutes the main stage in the realization of this project. In summary, we have defined a minimalist set of instructions for the assembly language, established the functionalities of the interpreter in C, and specified the functional and non-functional requirements of the system.

The interpreter will be capable of handling programs written in the specified assembly language from a text file, ensuring clear and precise error detection and reporting.

In conclusion, the project aims to create a reliable and efficient execution environment for programs using our version of the assembly language. Adherence to the requirements outlined in this document will ensure the success of the project, providing users with a practical learning, development, and testing platform for the field of processor architecture and low-level programming.