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1. Introduction

Many new programming languages are published every year. Many of them are initially developed as part of a scientific thesis. Often, private individuals as well as students work on their own languages in their free time in order to learn about topics in the field of implementing them. Sometimes it also happens that companies or organisations want to solve a certain problem, but the appropriate language does not yet exist. Most of them the average developer never has anything to do with, and yet they generally bring all programming languages forward together.

A new language has the advantage of not being hindered by special circumstances that have evolved over time, as is the case with many older predecessors. Since one can start from scratch in the implementation, but conceptually all knowledge from previous attempts is used, completely new ideas can be tried out much easier and faster. This process is more difficult with a language that is used by thousands of people and should remain as stable as possible.

Another advantage of small new projects is that there is less bureaucracy and coordination, which makes it possible to iteratively try out many concepts quickly. These processes are quite important in larger projects, as there are often many people working on them at the same time and otherwise there would be little progress.

If the resulting approaches of the „newcomers“ seem to make sense and are adapted on a large scale, this often results in an integration into older, larger languages. It is precisely such a language that is to be designed and implemented in the context of this work by analysing proven technologies and combining them with new ideas.

This thesis therefore deals with the analysis of past as well as current programming languages in order to find out in which direction they are currently developing. From the knowledge gained from this, a new language will then be designed, which is a possible answer to the question: *What would a next generation programming language look like?*

2. Analyzing existing programming languages

The first step in answering this question is to analyse currently used programming languages, especially those that were created more recently.

To keep the number of languages within a workable range, only the more popular programming languages of 2022 will be analysed. The primary source for this data is the *StackOverflow Developer Survey 2022*, a worldwide survey conducted by the StackOverflow

platform annually and aimed at all programmers. Below this paragraph, you can see a statistic in which programming languages are sorted according to how many votes they got. The participants gave their votes to all of the languages that they had used a lot in the last year and would continue using. Each person could choose as many languages as they wanted. [1]–[3]

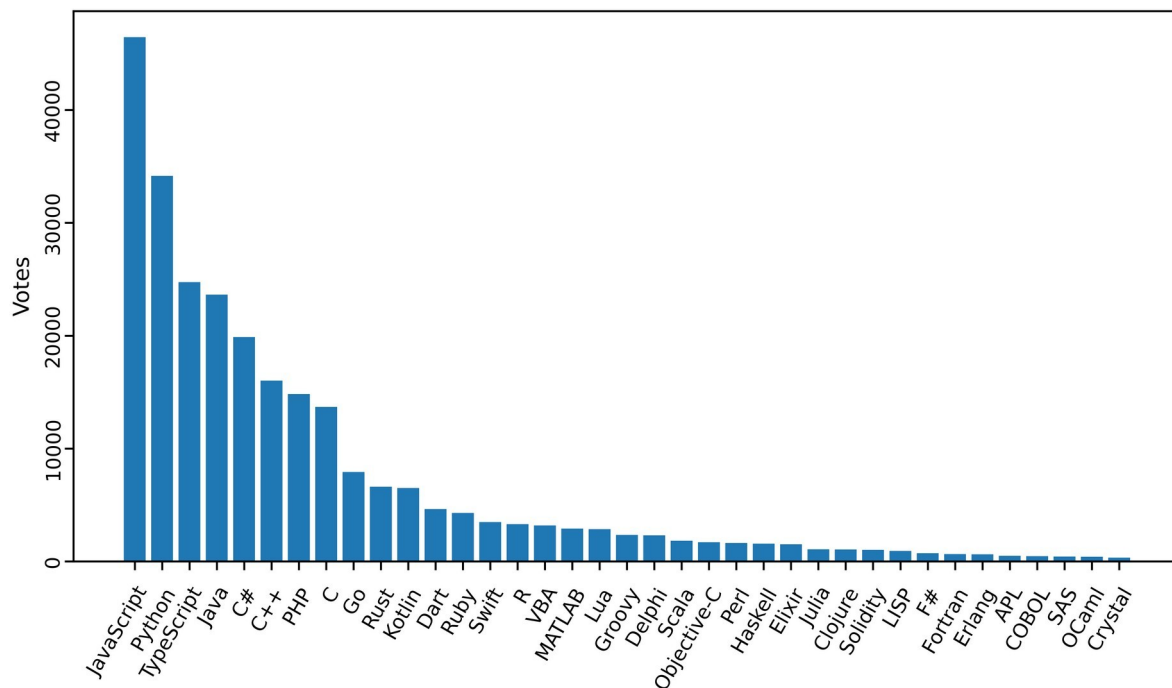


Abbildung 2.1: Popularity of programming languages in 2022

The original diagram also shows HTML, CSS, SQL, Bash/Shell and Powershell. All of them are excluded here because they are highly specialised and in part not Turing complete.

According to the StackOverflow Developer Survey 2022, JavaScript (1995), Python (1991), Typescript (2012), Java (1995), C# (2000), C++ (1985), PHP (1995), C (1978), Go (2009) and Rust (2010) are the ten most widely used programming languages. On average, these languages are therefore 25 years old. [4]

2.1 Popular Languages

The popular languages are popular for a variety of reasons, some of the most common reasons include:

Widespread use: Many popular languages have been around for a long time and have been adopted by many companies and organizations. This means that there is a large community

of developers who use the language, which makes it easier to find resources, tutorials, and support.

Versatility: Popular languages are often versatile and can be used for a wide range of projects. For example, Python is popular among data scientists, engineers, and web developers, while JavaScript is popular for both front-end and back-end web development.

Large ecosystem: Popular languages often have a large ecosystem of libraries and frameworks that make it easier to develop and deploy applications. This means that developers can use pre-built tools and libraries to speed up development and reduce the time it takes to get an application up and running.

High demand: Popular languages are often in high demand in the job market. This means that developers who know these languages are more likely to be able to find a job and have a higher earning potential.

Community support: Popular languages have a strong community support which helps in the development of the language, troubleshooting and learning new features.

Ease of use: Some popular languages are designed to be easy to learn and use, which makes them a good choice for beginners.

All these factors contribute to the popularity of a programming language. They make it easy for developers to start using the language, and they provide a large community of developers who can help with questions and issues. This makes it more likely that a language will continue to be popular over time.

2.2 Analyze

- The goal of this paper is the conception and implementation of a new programming language called Rym
- What exactly is a programming language
 - artificial language
 - turing complete
 - general
- 1. general pros of programming languages
- 2. flaws of currently used programming languages
- 3. specific features of Rym based on 2. and adhering to 1.

Many new programming languages that are continuations of older ones have gained popularity in the last years. These languages include Kotlin by JetBrains¹ as a successor to Java, which is trying to be more concise, safe and expressive while still running on the Java Virtual Machine and providing interoperability with Java. Groovy by Apache, Closure and

¹ JetBrains is a company that develops integrated development environments.

Scala are other JVM-based languages that can be used with Java and have been around for a while, but they have not gained as much popularity as Kotlin. Google's official support for Android development with Kotlin has possibly been the major factor in its success. [5]–[11] [12]–[15]

Another programming language that has gained popularity in recent years is Rust, which was started by Graydon Hoare at Mozilla and is now an independent community project. Rust is designed to be a systems programming language that is both safe and fast. It aims to eliminate risks like null or dangling pointer references, which can lead to memory safety issues often encountered when using C/C++. [16], [17]

Go and Dart are both programming languages developed by Google that have been gaining popularity in recent years. Both languages were created to address specific issues in the programming world and to provide a solution for developers. Go, often referred to as „Go“, was developed to address the need for a language that is simple, efficient and easy to learn, while still providing a high level of performance and scalability. Go is particularly well-suited for building networked services and large-scale web applications, it aims to make it easy to write concurrent and parallel systems. On the other hand, Dart was created to address the issue of building fast and high-performance apps on multiple platforms. Dart is designed to be a client-optimized language for building fast apps on any platform, it allows for a single codebase to run on different platforms and provides features such as Just-In-Time (JIT) and Ahead-of-Time (AOT) compilation. Both Go and Dart have been used to build a wide range of applications, from web and mobile to desktop and backend, and have strong and growing communities.

- Carbon?
- Swift: Developed by Apple, Swift is a general-purpose, compiled programming language that is designed to be easy to learn and use. It is particularly well-suited for developing iOS and macOS applications, and has been gaining popularity among developers for its modern syntax, strong type system, and improved performance over Objective-C.
- TypeScript: Developed by Microsoft, TypeScript is a typed superset of JavaScript that compiles to plain JavaScript. It was designed to make it easier to write and maintain large-scale JavaScript applications by adding features such as static typing, interfaces, and classes. It is widely used in Angular and React projects.
- Julia: Developed to be used in scientific, engineering, and technical computing, Julia is a high-performance, high-level dynamic programming language. It is designed to be easy to use and has a syntax similar to that of MATLAB or Python. Julia is

particularly well-suited for data science and numerical computing and it's been gaining popularity among researchers and data scientists.

- Scala: Developed by Martin Odersky, Scala is a general-purpose programming language that runs on the Java Virtual Machine (JVM). It is designed to be an object-oriented and functional language, and it's been gaining popularity among developers for its ability to write concurrent and parallel systems. It's also widely used for big data processing using Apache Spark.

3. General trends

Before we start to create the concept for Rym we first have to look at what other language have changed in recent years and if we should add these features. This analysis will extend the general **TODO** defined in **TODO: INSERT CHAPTER REF**.

-

4. Primitive Data Types

Data types that are not defined in terms of other types are called primitive data types. Nearly all programming languages provide a set of primitive data types. Some of the primitive types are merely reflections of the hardware for example, most integer types and others require only a little nonhardware support for their implementation. More complex types can be created by combining primitive types as we will see in Kapitel 5. [18, S. 400]

4.1 Boolean

Boolean types are perhaps the simplest of all types and have been included in most general-purpose languages designed since 1960. They only have two possible values one for true and one for false. Boolean types are often used to represent switches or flags in programs. Although other types, such as integers, can be used for these purposes, the use of boolean types is more readable. C and C++ still allow numeric expressions to be used as if they were boolean. This is not the case in the subsequent languages, Java and C# which is why Rym will disallow this as well. [19], [20]

A boolean value could be represented by a single bit, but because a single bit of memory cannot be accessed efficiently on many machines, they are often stored in the smallest efficiently addressable cell of memory, typically a byte. As this detail is trivial Rym does not specify how to store boolean values. [18, S. 404f]

The boolean type in Rym is called „bool” like in Python, PHP, C#, Go, Rust, Swift and many others. It is named after *George Boole* who pioneered the field of mathematical logic. [20]–[24]

4.2 Boolean Operations

A Boolean value may be created using the *true* or *false* literals

```
const var_1 = true
const var_2 = false
```

and is always the result for the comparison binary operators `==`, `<`, `<=`, `>=` and `>`. The comparison operations actually use the literals in their implementation as well, which can be seen in Kapitel 7. There is also the unary not prefix operator represented by `!` which allow one to invert a boolens value . The prefix already suggests that this operator must come before the expression it operates on, as the `!` can be used as a unary postfix operator to unwrap a value and **TODO: INSERT CHAPTER REF** explains why that is useful.

In Rym the control-flow expressions *if* and *while* use booleans to decide whether some code should be executed or not. How they work and why their syntax looks like this will be covered in **TODO: INSERT CHAPTER REF.**

```
const condition = true
if condition { /* do something once */ }
while condition { /* do something forever */ }
```

4.3 Numeric Types

4.3.1 Integer

Another very common primitive numeric data type is the integer. The hardware of many computers supports several sizes of integers. These sizes of integers, and often a few others, are supported by some programming languages. As seen in Tabelle 4.1, Java includes four signed integer sizes: byte, short, int, and long. Some languages, for example C, C++ and C# include unsigned integer types, which are types for integer values without signs. Unsigned types are often used for binary data. 8 bit large unsigned integers can for example represent exactly one byte. [18, S. 400]

The types for C and C++ that are represented in Tabelle 4.1 are using the „cstdint” header as the language standards do not specify the sizes for default integer types and leave them up to the implementation. Types from this standard header file are however required to that exact size. [25, S. 0], [26, S. 0]

- Python ²
 - size as large as needed
- PHP ³
 - int
 - size platform dependent, 32bit|64bit
- Java ⁴
- C, C++:
 - char, short, int, long are not always the same size
 - cstdint header: c++ standard S. 493f.
- Go ⁵
- Zig (special case) ⁶
 - arbitrary size
 - size 1–65535
 - i{Size} eg. i333

² <https://docs.python.org/3/library/stdtypes.html#numeric-types-int-float-complex>

³ <https://www.php.net/manual/en/language.types.integer.php>

⁴ <https://docs.oracle.com/javase/specs/jls/se19/html/jls-4.html#jls-4.2>

⁵ https://go.dev/ref/spec#Numeric_types

⁶ <https://ziglang.org/documentation/master/#Integers>

- u{Size} eg. u8
- Rust⁷

Tabelle 4.1: Supported integer formats

Size [Bits]	Java	C#	C, C++	Go	Rust
8	byte	sbyte, byte	int8_t, uint8_t	int8, uint8	i8, u8
16	short	short, ushort	int16_t, uint16_t	int16, uint16	i16, u16
32	int	int, uint	int32_t, uint32_t	int32, uint32	i32, u32
64	long	long, ulong	int64_t, uint64_t	int64, uint64	i64, u64
32 64	—	nint, nuint	—	int, uint	—
128	—	—	—	—	i128, u128
pointer	—	—	intptr_t, uintptr_t	uintptr, uintptr	isize, usize

4.3.2 Float

Generally languages provide floating point data types that adhere to the „IEEE 754 - Floating-Point“ arithmetic standard [27] or its ISO adoption „ISO/IEC 60559“ [28]. How wide that support is can be seen in Tabelle 4.2.

- IEEE 754
 - https://en.wikipedia.org/wiki/IEEE_754
 - active version is from 2019 [27]
 - <https://ieeexplore.ieee.org/document/8766229>
 - same as ISO/IEC 60559
- Accessed: 02.01.2023
 - Js: https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference/Global_Objects/Number
 - Python: <https://docs.python.org/3/library/stdtypes.html#typesnumeric>
 - PHP: <https://www.php.net/manual/en/language.types.float.php>
 - Java: <https://docs.oracle.com/javase/specs/jls/se19/html/jls-4.html#jls-4.2.3>
 - Go: https://go.dev/ref/spec#Numeric_types
 - Rust: <https://doc.rust-lang.org/reference/types/numeric.html#floating-point-types>
- Accessed: 09.01.2023
 - C#
 - <https://learn.microsoft.com/en-us/dotnet/csharp/language-reference/language-specification/types#837-floating-point-types>
 - <https://learn.microsoft.com/en-us/dotnet/csharp/language-reference/builtin-types/floating-point-numeric-types>
 - C, C++
 - C++ „The value representation of floating-point types is implementation-defined.“ S. 75
 - standards do not specific float format to use, they just mandate the minimum range and precision

⁷ <https://doc.rust-lang.org/reference/types/numeric.html#integer-types>

- <https://en.cppreference.com/w/cpp/language/types>

Tabelle 4.2: Supported IEEE-754 floating point formats

Size [Bits]	Js/Ts	Python	PHP	Java	C#	C, C++	Go	Rust
32	Number	—	—	float	float	?	float32	f32
64	—	—	—	double	double	?	float64	f64
32 64	—	float	float	—	—	—	—	—

4.3.3 Decimal

- Pythony 09.01.2023
 - decimal.Decimal
 - The decimal module provides support for fast correctly rounded decimal floating point arithmetic.
 - Once constructed, Decimal objects are immutable.
 - <https://docs.python.org/3/library/decimal.html>

4.4 Character

- Rym:
 - Name: char
 - valid utf-8 character
 - space: 1 byte?

Tabelle 4.3: Character data types

Language	Formats
Js/Ts	not supported
Python	not supported?
PHP	not supported?
Java	char: 16bit unsinged int
C#	?
C++	?
C	?
Go	?
Rust	char

- Java: 09.01.2023 <https://docs.oracle.com/javase/specs/jls/se19/html/jls-4.html#jls-4.2>

4.5 String

- Rym:
 - characters array: [char]
 - dynamic characters vector: String

5. Algebraic Data Types

Definition

5.1 Product Types

- explain product types
 - <https://jrsinclair.com/articles/2019/algebraic-data-types-what-i-wish-someone-had-explained-about-functional-programming>
- exist in:
 - Js/Ts (Arrays, Objects, Maps, WeakMaps)
 - Python (Lists, Records, ..)
 - PHP
 - Java
 - C#
 - C++ (Classes, Structs, ..)
 - C (Structs, ..)
 - Go
 - Rust (Structs, ..)

5.2 Sum Types

- explain sum types
 - <https://jrsinclair.com/articles/2019/algebraic-data-types-what-i-wish-someone-had-explained-about-functional-programming/>
- exist in: (https://en.wikipedia.org/wiki/Algebraic_data_type)
 - C++, Java 15, Rust, TypeScript
 - F#, Haskell, Idris, Kotlin, Nim, Swift

5.2.1 Enums

```
// Declare an enum.  
enum Type {  
    Ok,  
    NotOk,  
}  
  
// Declare a specific enum field.  
const c = Type.Ok
```

You can override the ordinal value for an enum.

```
enum Value2 {  
    Hundred = 100,  
    Thousand = 1_000,  
    Million = 1_000_000,  
}
```

```

}
test "set enum ordinal value" {
  // TODO: How to convert enum to int/uint?
  assert_eq(@enumToInt(Value2.Hundred), 100)
  assert_eq(@enumToInt(Value2.Thousand), 1000)
  assert_eq(@enumToInt(Value2.Million), 1000000)
}

```

You can also override only some values.

```

enum Value3 {
  A,
  B = 8,
  C,
  D = 4,
  E,
}
test "enum implicit ordinal values and overridden values" {
  assert_eq(@enumToInt(Value3.A), 0)
  assert_eq(@enumToInt(Value3.B), 8)
  assert_eq(@enumToInt(Value3.C), 9)
  assert_eq(@enumToInt(Value3.D), 4)
  assert_eq(@enumToInt(Value3.E), 5)
}

```

Enums can have methods, the same as structs. Enum methods are not special, they are only namespaced functions that you can call with dot syntax.

```

enum Suit {
  Clubs,
  Spades,
  Diamonds,
  Hearts,

  pub fn isClubs(self: Suit) bool {
    self == Suit.Clubs
  }
}
test "enum method" {
  const suit = Suit.Spades
  assert_eq(suit.isClubs(), false)
}

```

An enum can be matched upon.

```

enum Foo {
  String,
  Number,
}

```

```

    None,
}
test "enum match" {
    const foo = Foo.Number
    const what_is_it = match foo {
        Foo.String ⇒ "this is a string",
        Foo.Number ⇒ "this is a number",
        Foo.None ⇒ "this is a none",
    }
    assert_eq(what_is_it, "this is a number")
}

```

5.2.2 Non-exhaustive enum

A non-exhaustive enum can be created by adding an underscore as the last field. Non-exhaustive means the enum might gain additional variants in the future, so when unpacking the enum it is required to add a fall through case.

```

// TODO: Use #NonExhaustive Attribute insted?
#NonExhaustive
enum Number {
    One,
    Two,
    Three,
    _,
}

test "match on non-exhaustive enum" {
    const number = Number.One
    const result = match number {
        .One ⇒ true,
        .Two | .Three ⇒ false,
        _ ⇒ false,
    }
    assert(result)
    const is_one = match number {
        .One ⇒ true,
        else ⇒ false,
    }
    assert(is_one)
}

```

5.3 Optional Values

The *Option* type represents an optional value: every *Option* is either *Some* and contains a value, or *None*, and does not. *Option* types are very common in Rym code, as they have a number of uses:

- Initial values
- Return values for functions that are not defined over their entire input range (partial functions)
- Return value for otherwise reporting simple errors, where *None* is returned on error
- Optional struct fields
- Struct fields that can be loaned or „taken“
- Optional function arguments
- Nullable pointers
- Swapping things out of difficult situations

Options are commonly paired with pattern matching to query the presence of a value and take action, always accounting for the *None* case.

- null references, the billion dollar mistake
 - <https://www.lucidchart.com/techblog/2015/08/31/the-worst-mistake-of-computer-science/>
 - <https://www.infoq.com/presentations/Null-References-The-Billion-Dollar-Mistake-Tony-Hoare/>
 - https://en.wikipedia.org/wiki/Tony_Hoare
- Ts
 - `null`, `undefined`
 - can be detected by Ts compiler
- Java, C, C++, ..
- Rust
 - `Option` enum
 - must be unwrapped to use the value
- *Options* replace null references
 - is a sum type / enum

[29]

6. Functions

Functions are one of the most important building blocks of many programming languages, especially functional ones, TODO.

6.1 Basic functionality

In Rym it will be possible to define a function by using the *func* keyword followed by a name for the function, a comma separated list of parameters and their respective types as well as the return type of the function.

This means that a function with multiple parameters will generally look like this:

```
func name(parameter0: Type0, parameter1: Type1) → ReturnType {  
    // ..  
}
```

Just like in any *C-style* language this function may be called by specifying the name of the function followed by a list of arguments within parentheses separated by commas. The arguments must match the types of the parameters defined in the function definition. The previous example function would be called like this:

```
const result = name(argument0, argument1)
```

This would assign the return value to the variable `result`.

6.2 Scope

When a function is called, the variables and values in the current scope are temporarily suspended and a new scope is created for the function. This new scope contains the parameters of the function as variables, initialized with the values of the arguments passed to the function. The function body is then executed within this new scope, and any variables or values defined within the function are only accessible within this scope. When the function execution is complete, the function scope is destroyed and the original scope is restored. This can be seen in the following example:

```
const x = 5  
  
func changeX(x: Int) → Int {  
    const y = 10  
    return x + y  
}
```

```
const result = changeX(3) // result = 13
```

When the function `changeX` is called, a new scope is created containing the parameter `newX` initialized with the value 3. The variable `y` is also defined within this scope and initialized with the value 10. The function body is executed, and the value of `newX + y` (13) is returned. The function scope is then destroyed and the original scope is restored, resulting in the value 13 being assigned to the variable `result`. The variable `y` is not accessible outside of the function scope and therefore does not affect the value of `x`.

6.3 Returning

In the Rym programming language, a function may be defined with a return type, which specifies the type of value that will be returned by the function. The return type is specified after the arrow symbol (\rightarrow) in the function definition, followed by the function body in curly braces (`{}`). The function body may contain any number of statements and expressions, and the value of the final expression in the function body will be returned as the result of the function.

For example, consider the following function definition:

```
func multiply(x: Int, y: Int) → Int {  
    return x * y  
}
```

In this example, the function `multiply` takes two integer arguments, `x` and `y`, and returns the result of their multiplication as an integer. The function body contains a single statement that defines a local variable `result` and initializes it with the value of `x * y`. The return statement then specifies that the value of `result` should be returned as the result of the function.

However, it is not necessary to specify a return statement in every function. If the return type of the function is specified, the value of the final expression in the function body will be returned automatically. For example, the following function is equivalent to the one above:

```
func multiply(x: Int, y: Int) → Int {  
    x * y  
}
```

In this case, the value of the expression `x * y` is returned as the result of the function, without the need for a separate return statement. This allows for more concise and readable code, as the return statement is often unnecessary when the function body contains only a single expression.

7. Polymorphism

Some much older languages are based on the idea that functions, procedures and their respective parameters have unique types. These languages are said to be *monomorphic* (from Greek ,one shape'), in the sense that every value and variable can be interpreted to be of one and only one type. Monomorphic programming languages may be contrasted with *polymorphic* (from Greek ,many shapes') [30, S. 760] languages in which some values may have more than one type. [31, S. 4]

Polymorphic functions are functions whose parameters can have more than one type. Polymorphic types are types whose operations are applicable to values of multiple types.

Polymorphism is supported by

Most often, it is a good idea to give different functions different names, but when different functions conceptually perform the same task on objects of different types, it can be more convenient to give them the same name [30, S. 326]

- *polymorphic*
- compile-time vs run-time polymorphism
 - Rym will only support compile-time as it is simpler to design and implement
 - run-time polymorphism could be added later on

8. Tooling and Ecosystem

- no time to implement them for Rym

8.1 Package Manager

- examples:
 - Python: pip
 - Js/Ts: npm, yarn, deno
 - C: ?
 - C++: ?
 - Rust: cargo

=> rympkg?

8.2 Formatting and Styleguide

8.2.1 Naming Conventions

- checked by compiler => error that stops compilation
 - variable: `variable_name`
 - function: `function_name`
 - struct: `StructName`
 - enum: `EnumName`
 - trait: `TraitName`

8.2.2 Linters

- examples:
 - Python: pep8, ?
 - Js/Ts: not official?, eslint, prettier, ..
 - PHP: ?
 - ...: ?
 - Go: ?, gofmt
 - Rust: builtin, clippy, rustfmt

Precommit scripts can ensure that only correctly formatted code gets committed.

=> rymfmt, rym fmt

Appendix

Code Examples

```
func main() → @Io {
    const numbers = [-14, 1, 3, 6, 7, 7, 12]

    const sum = -13
    if const Some([left, right]) = summands(numbers, -13) {
        print(f"Sum of {left} and {right} = {sum}")
    }
    print("Pointers have crossed, no sum found")
}

/// array must be sorted
func summands(array: [i32], sum: i32) → Option<[usize; 2]> {
    mut low = 0
    mut high = array.len() - 1

    while low < high {
        const current_sum = array[low] + array[high]

        if current_sum == sum {
            return Some([array[low], array[high]])
        } else if current_sum < sum {
            low += 1
        } else {
            high -= 1
        }
    }

    None
}
```

Rym Parser Grammar

TODO

References

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