

# Rust-eze

CMPT 331 - Spring 2023 | Dr. Labouseur

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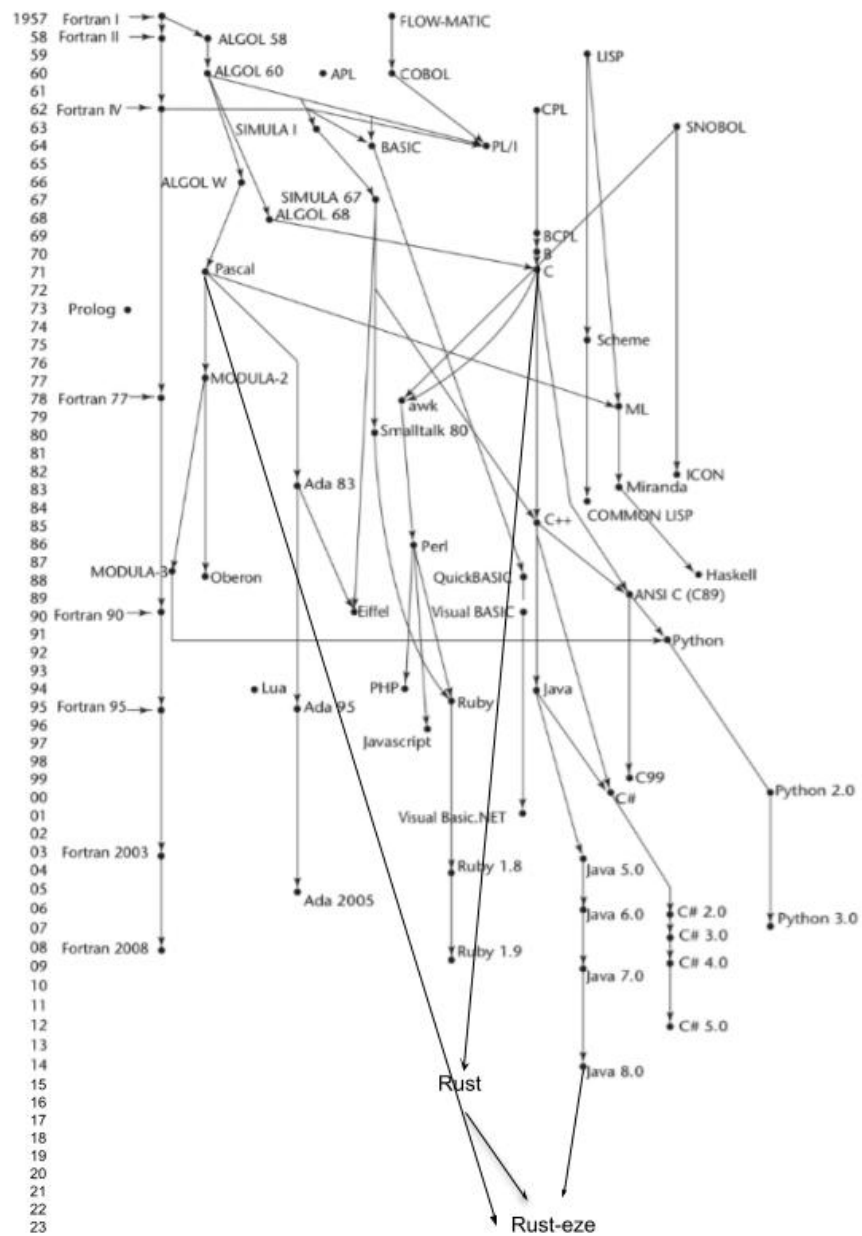


# 1 INTRODUCTION

Rust-eze is modern, object-oriented, type-safe programming language. It inherits the best parts of Rust and Java to provide a fast and memory-safe language for the object-oriented paradigm, while also bringing in some influence from Pascal. Rust-eze does, however, differ from its parent languages in the following ways:

1. Rust-eze is an object-oriented language, which means there are no structs and only classes/objects and enums.
2. Like Java, but unlike Rust, Rust-eze is statically typed, so all variables must be explicitly defined with their respective types.
3. Similar to Rust, but unlike Java, Rust-eze uses a system of borrowing and ownership so only one variable can point to a given place in memory at a time. This prevents the need for a garbage collector as variables are automatically dropped and the memory is freed when they go out of scope.
4. Unlike Java, but like Rust, Rust-eze is compiled into the native binary, so there is no need for a JVM or an intermediate bytecode representation of Rust-eze programs.
5. Similar to Rust, all instance variables must be initialized within the constructor.
6. Similar to both parent languages, all models (classes) belong to a garage (Java package). However, more similar to Rust, the garage is inferred based on the relative file location and does not have to be explicitly defined within the file.

## 1.1 GENEALOGY



## 1.2 HELLO WORLD

```
1 model HelloWorld
2 start
3     ext fn main(Vec<String> args) -> void
4         start
5             println("Hello_world!");
6         finish main
7 finish model
```

Listing 1: HelloWorld.rez

## 1.3 PROGRAM STRUCTURE

The key organizational concepts in Rust-eze are as follows:

1. Every file contains a single **model** (equivalent to a class), which should be the same name as the file minus the .rez file extension.
2. All instance members default to being in the interior (private) unless they are declared with the **ext** keyword to note their exterior (public) presence.
3. Instance variables are declared within the **specs** block and must be initialized within the constructor, which is a function that is the same name as the model.
4. Local variables are immutable by default unless they are declared with the **mut** keyword.
5. The entry point for all Rust-eze programs is the main method that is located in one of the models of the project.

The program below defines a new **model** called Lightning that contains 3 instance variables: an exterior String called *name*, an exterior integer called *age*, and an interior integer called *miles*. Each of these instance variables are initialized within the constructor. Each Lightning has 2 member functions: *drive* and *say\_it*. *drive* is an exterior method as it is defined with the **ext** keyword. Since it modifies an instance variable, it must take it a mutable reference to the object in addition to the number of miles being driven. Inside of the method, a new local variable called *new\_mileage* is declared without the **mut** keyword, meaning that it is immutable and is a constant with the value it is initialized with. The other instance method, *say\_it*, is also public and does not modify the instance variables, which is why it needs an immutable reference to **self**.

```
1 model Lightning
2 start
3     specs
4     start
5         ext String name;
6         ext i32 age;
7         i32 miles;
8     finish specs
9
10    ext fn Lightning(String my_name, i32 my_age)
11    start
12        self.name := my_name;
13        self.age := my_age;
14        self.miles := 0;
15    finish Lightning
16
17    ext fn drive(&mut self, i32 num_miles) -> void
18    start
19        i32 new_mileage := self.miles + num_miles;
20        self.miles := new_mileage;
21    finish drive
```

```

22
23     ext fn say_it(&self) -> void
24     start
25         println("Kachow!");
26     finish say_it
27 finish model

```

Listing 2: Lightning.rez

Next, the Lightning model is imported to a new file called *Main.rez* and is initialized within the main method. Since the **mut** keyword is used, we can use the mutable method of *drive* on the new object as well as directly modify its public instance variables. After *the\_lightning*'s name is printed, we call its *say\_it* method and then call the *drive* method with an input of 42 miles to increase the object's mileage.

```

1 import garage.Lightning;
2
3 model Main
4 start
5     ext fn main(Vec<String> args) -> void
6     start
7         mut Lightning the_lightning := new Lightning("McQueen", 17);
8         println(the_lightning.name);
9
10         the_lightning.say_it();
11         the_lightning.drive(42);
12     finish main
13 finish model

```

Listing 3: Main.rez

## 1.4 TYPES AND VARIABLES

There are two kinds of variables in Rust-eze: *value types* and *reference types*. Variables of value types directly contain their data, while variables of reference types store references to their data or objects in memory. Due to the ownership system, only one variable of a reference type can point to a particular place in memory at a given time. See Section 3 for details.

## 1.5 VISIBILITY

In Rust-eze, visibility of methods and instance variables is defined as either interior (private) or exterior (public). Everything is part of the interior unless explicitly stated to be in the exterior. Once a variable or method is public, it may be accessed outside of the model in which it is defined.

## 1.6 STATEMENTS DIFFERING FROM RUST AND JAVA

Statement	Example
Assignment statement	<pre> mut i32 x := 5; x = 3; i32 y := x + 2; </pre>

If statement	<pre> i32 x := 7; if x &gt; 3 &amp;&amp; x &lt; 9 start     println("Hello_there") else     println("Kachow") finish if </pre>
For loop	<pre> for mut i32 i in range(0, 10, 1) start     println(i) finish for </pre>
While loop	<pre> mut i32 i := 0; while i &lt; 10 start     println(i);     i := i + 1; finish while </pre>

## 2 LEXICAL STRUCTURE

### 2.1 PROGRAMS

A Rust-eze program consists of one or more source files. A source file is an ordered sequence of (probably) Unicode characters.

Conceptually speaking, a program is compiled using five steps:

1. Transformation, which converts a file from a particular character repertoire and encoding scheme into a sequence of Unicode characters.
2. Lexical analysis, which translates a stream of Unicode input characters into a stream of tokens.
3. Syntactic analysis (parsing), which translates the stream of tokens into a concrete syntax tree (CST).
4. Semantic analysis, which converts the CST into an abstract syntax tree (AST) and is passed to the semantic analyzer for type checking and the borrow checker to make sure all variables referenced are active owners of data.
5. Code generation, which converts the AST into executable code for the target platform and CPU architecture.

### 2.2 GRAMMARS

This specification presents the syntax of the Rust-eze programming language where it differs from Rust and Java.

<code>&lt;assignment operator&gt;</code>	$\rightarrow :=$
<code>&lt;block begin&gt;</code>	$\rightarrow \text{start}$
<code>&lt;block end&gt;</code>	$\rightarrow \text{finish}$
<code>&lt;print&gt;</code>	$\rightarrow \text{println}$
<code>&lt;visibility modifier&gt;</code>	$\rightarrow \text{ext} \mid \epsilon$
<code>&lt;mutability modifier&gt;</code>	$\rightarrow \text{mut} \mid \epsilon$

$\langle \text{model definition} \rangle \rightarrow \text{model } \langle \text{model name} \rangle \langle \text{parent declaration} \rangle \langle \text{block begin} \rangle \langle \text{statements} \rangle$   
 $\langle \text{block end} \rangle \text{ model}$   
 $\langle \text{parent declaration} \rangle \rightarrow \text{extends } \langle \text{parent model name} \rangle \mid \epsilon$   
 $\langle \text{specs definition} \rangle \rightarrow \text{specs } \langle \text{block begin} \rangle \langle \text{spec definition} \rangle \langle \text{block end} \rangle \text{ specs}$   
 $\langle \text{spec definition} \rangle \rightarrow \langle \text{visibility modifier} \rangle \langle \text{type} \rangle \langle \text{spec name} \rangle; \langle \text{spec definition} \rangle \mid \epsilon$   
 $\langle \text{variable declaration} \rangle \rightarrow \langle \text{mutability modifier} \rangle \langle \text{type} \rangle \langle \text{variable name} \rangle \langle \text{assignment operator} \rangle$   
 $\langle \text{expression} \rangle;$   
 $\langle \text{if statement} \rangle \rightarrow \text{if } \langle \text{condition} \rangle \langle \text{block begin} \rangle \langle \text{statements} \rangle \text{ else } \langle \text{statements} \rangle \langle \text{block end} \rangle \text{ if}$   
 $\langle \text{for loop} \rangle \rightarrow \text{for mut } \langle \text{type} \rangle \langle \text{var name} \rangle \text{ in } \langle \text{expr} \rangle \langle \text{block begin} \rangle \langle \text{statements} \rangle \langle \text{block end} \rangle \text{ for}$   
 $\langle \text{while loop} \rangle \rightarrow \text{while } \langle \text{condition} \rangle \langle \text{block begin} \rangle \langle \text{statements} \rangle \langle \text{block end} \rangle \text{ while}$   
 $\langle \text{function definition} \rangle \rightarrow \langle \text{visibility modifier} \rangle \text{ fn } \langle \text{function name} \rangle ( \langle \text{parameter list} \rangle ) \text{ -} \rangle \langle \text{return type} \rangle$   
 $\langle \text{block begin} \rangle \langle \text{statements} \rangle \langle \text{block end} \rangle \langle \text{function name} \rangle$   
 $\langle \text{parameter list} \rangle \rightarrow \langle \text{type} \rangle \langle \text{parameter name} \rangle, \langle \text{parameter list} \rangle \mid \epsilon$

### 2.3.1 COMMENTS

## 2.4 TOKENS

Tokens:

- identifier
- keyword
- integer literal
- real literal
- character literal
- string literal
- operator or punctuation

#### 2.4.1 KEYWORDS DIFFERENT FROM RUST AND JAVA

**New keywords:** range, model, specs, start, finish, ext, Tuple

**Removed keywords:** use, class, match, do, private, byte, short, str, boolean, static, public, double, long, float, int, as, pub, impl, struct

### 3 TYPE SYSTEM

Rust-eze uses a strong static type system. This means that the Rust-eze compiler will catch type mismatch errors at compile time through early binding compile-time type checking.

#### 3.1 TYPE RULES

The type rules for Rust-eze are as follows:

$$\begin{array}{l} S \vdash e1 : T \\ S \vdash e2 : T \\ T \text{ is a primitive type} \end{array}$$

---

$$S \vdash e1 := e2 : T$$
$$\begin{array}{l} S \vdash e1 : T \\ S \vdash e2 : T \\ T \text{ is a primitive type} \end{array}$$

---

$$S \vdash e1 == e2 : \text{bool}$$
$$\begin{array}{l} S \vdash e1 : T \\ S \vdash e2 : T \\ T \text{ is a primitive type} \end{array}$$

---

$$S \vdash e1 != e2 : \text{bool}$$
$$\begin{array}{l} S \vdash e1 : T \\ S \vdash e2 : T \\ T \text{ is a numeric primitive type} \end{array}$$

---

$$S \vdash e1 > e2 : \text{bool}$$
$$\begin{array}{l} S \vdash e1 : T \\ S \vdash e2 : T \\ T \text{ is a numeric primitive type} \end{array}$$

---

$$S \vdash e1 < e2 : \text{bool}$$
$$\begin{array}{l} S \vdash e1 : T \\ S \vdash e2 : T \\ T \text{ is a numeric primitive type} \end{array}$$

---

$$S \vdash e1 + e2 : T$$



$S \vdash e1 : \text{String}$   
 $S \vdash e2 : T$  with a String representation

---

$S \vdash e1 + e2 : \text{String}$

### 3.2 VALUE TYPES

Data Type	Description
i8, i16, i32, i64	Signed integers that store up to X bits, where X is the number after "i" in the data type.
u8, u16, u32, u64	Unsigned integers that store up to X bits, where X is the number after "u" in the data type.
f32, f64	Floating point numbers that store up to X bits, where X is the number after "f" in the data type.
bool	Boolean value that can be either <b>false</b> or <b>true</b> .
char	Character value that stores the data for a single character.

### 3.3 REFERENCE TYPES

Data Type	Description
String	<p>A sequence of characters.</p> <p>Example:</p> <pre>String x := "hello";</pre>
Vec<T>	<p>A dynamic, homogeneous array of values of type T, which can be any type.</p> <p>Example:</p> <pre>Vec&lt;i32&gt; nums1 := [0, 0, 7]; mut Vec&lt;i32&gt; nums2 := new Vec&lt;i32&gt;(2); nums2[0] := 42; nums2[1] := 99;</pre>
Tuple	<p>A collection of values of different types that is fixed in size.</p> <p>Example:</p> <pre>Tuple&lt;i32, bool, i32&gt; my_tuple := (7, false, 3); mut Tuple&lt;String, i32&gt; the_tuple := new Tuple&lt;String, i32&gt;(); the_tuple.0 := "jOSh"; the_tuple.1 := 2;</pre>

## 4 EXAMPLE PROGRAMS

### 4.1 CAESAR CIPHER ENCRYPT

```
1 // Model definition for the Caesar cipher
2 model CaesarCipher
3 start
4 // Encrypt a string based on the shift amount
5 ext fn encrypt(&self, &String in_str, i32 shift_amt) -> String
6 start
7 // Get the real shift amount and create a new vector of characters
8 i32 real_shift := shift_amt % 26;
9 Vec<char> out_vec := new Vec<char>();
10
11 // Loop through the entire string
12 for mut i32 i in range(0, in_str.len(), 1)
13 start
14
15 // Get the character at the given index as an integer
16 // (i8) casts the expression on the right of it to be an i8
17 mut i8 cur_char := (i8) in_str.char_at(i);
18
19 if cur_char >= 97 && cur_char <= 122
20 start
21 // Convert the lowercase letters to uppercase letters
22 cur_char := cur_char - 32;
23 finish if
24
25 // Only modify uppercase letters
26 if cur_char >= 65 && cur_char <= 90
27 start
28 // Perform the shift
29 cur_char := cur_char + real_shift;
30
31 // This is the difference for wraparound for Z
32 mut i32 diff := cur_char - 90;
33 if diff > 0
34 start
35 // Perform the Z wraparound
36 cur_char := 65 + diff - 1;
37 else
38 // Now compute the A wraparound if there was no Z wraparound
39 diff := 65 - cur_char;
40
41 if diff > 0
42 start
43 cur_char := 90 - diff + 1;
44 finish if
45 finish if
46 finish if
47
48 // Get the final character as the appropriate type
49 char final_char := (char) cur_char;
50
51 // Push it to the end of the vector (vector will resize as needed)
52 out_vec.push(final_char);
53 finish for
54
55 // Join the elements of the vector together to form a string
56 // by using the string representation of each of the elements
57 return out_vec.join("");
58 finish encrypt
59
60 ext fn main(Vec<String> args) -> void
```

```

61     start
62         CaesarCipher cipher := new CaesarCipher();
63
64         // Create a new string
65         String x := "Kachow";
66
67         // Perform encrypt and pass an immutable reference to x
68         String y := cipher.encrypt(&x, 95);
69
70         // Should print Kachow
71         println(x);
72         // Should print BRTYFN
73         println(y);
74     finish main
75 finish model

```

Listing 4: CaesarCipher.rez

## 4.2 CAESAR CIPHER DECRYPT

```

1 model CaesarCipher
2 start
3     // Returns a decrypted string based on the shift amount
4     ext fn decrypt(&self, &String in_str, i32 shift_amt) -> String
5     start
6         // Decrypt is the same as encrypt with negative shift amount
7         // Encrypt is defined in Section 4.1
8         return self.encrypt(in_str, -shift_amt);
9     finish encrypt
10
11 ext fn main(Vec<String> args) -> void
12 start
13     CaesarCipher cipher := new CaesarCipher();
14
15     String x := "Kachow";
16     String y := cipher.encrypt(&x, 95);
17     String z := cipher.decrypt(&y, 95);
18     // Kachow
19     println(x);
20     // BRTYFN
21     println(y);
22     // KACHOW
23     println(z);
24     finish main
25 finish model

```

Listing 5: CaesarCipher.rez (enhanced)

## 4.3 FACTORIAL

```

1 // Define a model for the factorial program
2 model FactorialProgram
3 start
4     // Return the result of factorial(num)
5     ext fn factorial(&self, i32 num) -> i32
6     start
7         if num <= 0
8         start
9             // factorial(0) = 1
10            // and anything < 0 is invalid, so return 1
11            return 1;

```

```

12         else
13             // factorial(n) = n * factorial(n - 1)
14             return num * self.factorial(num - 1);
15         finish if
16     finish factorial
17
18     ext fn main(Vec<String> args) -> void
19     start
20         FactorialProgram fp := new FactorialProgram();
21         // Should be 120
22         println(fp.factorial(5));
23
24         // Both should be 1
25         println(fp.factorial(0));
26         println(fp.factorial(-1));
27     finish main
28 finish model

```

Listing 6: FatorialProgram.rez

## 4.4 QUICKSORT

```

1 // Import the Random model for use later
2 import std.util.Random;
3
4 // Define a model for the classic SortsAndShuffles file from algorithms
5 model SortsAndShuffles
6 start
7     // This is the wrapper function for the quicksort implementation
8     ext fn quicksort(&self, &mut Vec<i32> data) -> void
9     start
10         // Call quicksort on the entire vector
11         self.quicksort_with_indices(data, 0, data.len() - 1);
12     finish quicksort
13
14     // Helper quicksort function
15     // Private because only accessible within the model
16     fn quicksort_with_indices(&self, &mut Vec<i32> data, i32 start_index, i32 end_index) ->
17         void
18     start
19         // Recursion base case to end if we have an array of size 0 or 1
20         if start_index >= end_index
21         start
22             return;
23         finish if
24
25         // Declare a pivot index that will be changed in a few lines
26         mut i32 pivot_index := 0;
27
28         if end_index - start_index < 3
29         start
30             // Pivot index is the start index because will need one more level
31             // of recursion regardless of the pivot
32             pivot_index := start_index;
33         else
34             // Otherwise declare a new random object
35             Random ran := new Random();
36
37             // Get the first pivot option
38             i32 pivot_choice_1 := ran.randint(start_index, end_index + 1);
39
40             // Get the second pivot option, but only use it if different from
41             // the first

```

```

41     mut i32 pivot_choice_2 := ran.randint(start_index, end_index + 1);
42     while pivot_choice_2 == pivot_choice_1
43     start
44         pivot_choice_2 := ran.randint(start_index, end_index + 1);
45     finish while
46
47     // Get the third pivot option but only use it if different from
48     // both of the other options
49     mut pivot_choice_3 := ran.randint(start_index, end_index + 1);
50     while pivot_choice_3 == pivot_choice_1 || pivot_choice_3 == pivot_choice_2
51     start
52         pivot_choice_3 := ran.randint(start_index, end_index + 1);
53     finish while
54
55     // Get the median of the pivots and set the appropriate pivot index
56     if *data[pivot_choice_1] <= *data[pivot_choice_2] && *data[pivot_choice_1] >= *
57         data[pivot_choice_3]
58     start
59         pivot_index := pivot_choice_1;
60     else if *data[pivot_choice_1] <= *data[pivot_choice_3] && *data[pivot_choice_1]
61         >= *data[pivot_choice_2]
62     start
63         pivot_index := pivot_choice_1;
64     else if *data[pivot_choice_2] <= *data[pivot_choice_1] && *data[pivot_choice_2]
65         >= *data[pivot_choice_3]
66     start
67         pivot_index := pivot_choice_2;
68     else if *data[pivot_choice_2] <= *data[pivot_choice_3] && *data[pivot_choice_2]
69         >= *data[pivot_choice_1]
70     start
71         pivot_index := pivot_choice_2;
72     else
73         pivot_index := pivot_choice_3;
74     finish if
75 finish if
76
77 // Perform the partition
78 i32 partition_out := self.partition(data, start_index, end_index, pivot_index);
79
80 // Perform quicksort on the 2 sides of the partition
81 self.quicksort_with_indices(data, start_index, partition_out - 1);
82 self.quicksort_with_indices(data, partition_out + 1, end_index);
83
84 finish quicksort_with_indices
85
86 // Declare a private function for sorting the array that returns the index
87 // for the partition
88 fn partition(&self, &mut Vec<i32> data, i32 start_index, i32 end_index, i32 pivot_index)
89     -> i32
90 start
91     // Move the pivot to the end of the array
92     i32 pivot := *data[pivot_index];
93     *data[pivot_index] := *data[end];
94     *data[end] := pivot;
95
96     // Keep track of where the low partition starts
97     mut i32 last_low_partition_index := start_index - 1;
98
99     // Go through the sub array, excluding the last index because the pivot
100    // value is in the end index
101    for mut i in range(start_index, end_index, 1)
102    start
103        if *data[i] < pivot
104        start
105            // Make space for the low value
106            last_low_partition_index := last_low_partition_index + 1;
107
108            // Move it to its new spot in the array

```

```

101         i32 temp := *data[i];
102         *data[i] := *data[last_low_partition_index];
103         *data[last_low_partition_index] := temp;
104     finish if
105 finish for
106
107 // Move the pivot to the appropriate location
108 *data[end] := *data[last_low_partition_index + 1];
109 *data[last_low_partition_index + 1] := pivot;
110
111 // Return the location of the pivot to distinguish the 2 partitions
112 return last_low_partition_index + 1;
113 finish partition
114
115 // Knuth shuffle
116 ext fn knuth_shuffle(&self, &mut Vec<i32> data) -> void
117 start
118     // Create the random object
119     Random ran := new Random();
120
121 // Iterate through the entire array
122 for mut i32 i in range(0, *data.len(), 1)
123 start
124     // Get a random index
125     i32 swap_index := ran.randint(0, *data.len());
126
127 // Swap the 2 elements
128     i32 temp := *data[i];
129     *data[i] := *data[swap_index];
130     *data[swap_index] := temp;
131 finish for
132
133 finish knuth_shuffle
134
135 ext fn main(Vec<String> args) -> void
136 start
137     // Initialize a vector with initial capacity for 10 elements
138     mut Vec<i32> my_arr := new Vec<i32>(10);
139     // Fill the vector with values 0 - 9
140     for mut i32 i in range(0, 10, 1)
141     start
142         my_arr[i] := i;
143     finish for
144
145     SortsAndShuffles sas := new SortsAndShuffles();
146
147 // Shuffly the vector
148 sas.knuth_shuffle(&mut my_arr);
149 println(my_arr.to_string());
150
151 // Sort the vector
152 sas.quicksort(&mut my_arr);
153 println(my_arr.to_string());
154 finish main
155
156 finish model

```

Listing 7: SortsAndShuffles.rez

## 4.5 SELECTION SORT

```

1 // Import random for the Knuth shuffle defined in Section 4.4
2 import std.util.Random;

```

```

3
4 model SortsAndShuffles
5 start
6     // Create a public function for doing a selection sort
7     ext fn selection_sort(&self, &mut Vec<i32> data) -> void
8         // Loop through all but the last element because an array of length 1
9         // is already sorted
10        for mut i32 i in range(0, *data.len() - 1, 1)
11            start
12                // Assume first element is smallest
13                // Can directly assign here because i32 is a value type, so the value
14                // gets stored rather than the actual reference
15                mut i32 smallest_index := i;
16
17                // Go through the rest of the array
18                for mut i32 j in range(i + 1, *data.len(), 1)
19                    start
20                        // If we have a smaller element, save the new lower index
21                        if *data[smallest_index] > *data[j]
22                            start
23                                smallest_index := j;
24                            finish if
25                        finish for
26
27                        // Move the smallest element in place
28                        i32 temp := *data[i];
29                        *data[i] := *data[smallest_index];
30                        *data[smallest_index] := temp;
31                    finish for
32            finish selection_sort
33
34    ext fn main(Vec<String> args) -> void
35    start
36        // From Section 4.4
37        mut Vec<i32> my_arr := new Vec<i32>(10);
38        for mut i32 i in range(0, 10, 1)
39            start
40                my_arr[i] := i;
41            finish for
42
43        SortsAndShuffles sas := new SortsAndShuffles();
44
45        // Shuffle (from Section 4.4)
46        sas.knuth_shuffle(&mut my_arr);
47        println(my_arr.to_string());
48
49        // Sort
50        sas.selection_sort(&mut my_arr);
51        println(my_arr.to_string());
52    finish main
53 finish model

```

Listing 8: SortsAndShuffles.rez (enhanced)

## 4.6 OBJECT-ORIENTED PROGRAMMING WITH TRANSFORMERS

```

1 model Owner
2 start
3     specs
4     start
5         // Every owner has a name
6         ext String name;
7     finish specs

```

```

8
9 // Define a new owner with the given name
10 ext fn Owner(String my_name)
11 start
12     self.name := my_name;
13 finish Owner
14 finish model

```

Listing 9: Owner.rez

```

1 import garage.Owner;
2
3 model Transformer
4 start
5     specs
6     start
7         ext String name;
8         ext String car_name;
9         i32 power;
10        &Transformer leader;
11        &Owner owner;
12    finish specs
13
14    // Define a constructor for the Transformer
15    ext fn Transformer(String my_name, String my_car_name, i32 power)
16    start
17        self.name := my_name;
18        self.car_name := my_car_name;
19        self.power := power;
20
21        // Leader and owner have to be set by setters, so null at first
22        // Also follow the rule that all specs are initialized in the constructor
23        self.leader := null;
24        self.owner := null;
25    finish Transformer
26
27    // Returns the difference in power when attacking another transformer
28    // > 0 means win
29    // < 0 means loss
30    // == 0 means draw
31    ext fn attack(&self, &Transformer opponent) -> i32
32    start
33        mut i32 power_diff := self.power - *opponent.get_power();
34
35        &Transformer opponent_leader := *opponent.get_leader();
36        if *opponent_leader != null
37        start
38            // We will say the leader helps out if their comrade is being attacked
39            power_diff := power_diff - *opponent_leader.get_power();
40        finish if
41
42        return power_diff;
43    finish attack
44
45    // Increases the power of the transformer by the factor
46    ext fn supercharge(&mut self, i32 factor)
47    start
48        self.power := self.power * factor;
49    finish supercharge
50
51    // Define a getter for the power spec
52    ext fn get_power(&self) -> i32
53    start
54        return self.power;
55    finish get_power

```



```

56
57 // Define a getter for the leader spec
58 ext fn get_leader(&self) -> &Transformer
59 start
60     return self.leader;
61 finish get_leader
62
63 // Define a setter for the leader
64 ext fn set_leader(&mut self, &Transformer new_leader)
65 start
66     self.leader := new_leader;
67 finish set_leader
68
69 // Define a setter for the owner
70 ext fn set_owner(&mut self, &Owner new_owner)
71 start
72     self.owner := new_owner;
73 finish set_owner
74 finish model

```

Listing 10: Transformer.rez

```

1 import garage.Transformer;
2
3 // Autobot is a subclass/model of Transformer
4 model Autobot extends Transformer
5 start
6     ext fn Autobot(String my_name, String my_car_name, i32 power)
7     start
8         // All specs are initialized in the super constructor, so nothing
9         // needs to be explicitly initialized here
10        self.super(my_name, my_car_name, power);
11    finish Autobot
12
13    // Function to "roll out"
14    ext fn roll_out(&self)
15    start
16        println("Roll_out:_ " + self.name);
17    finish roll_out
18 finish model

```

Listing 11: Autobot.rez

```

1 import garage.Owner;
2 import garage.Transformer;
3 import garage.Autobot;
4
5 model MainTransformers
6 start
7     ext fn main(Vec<String> args) -> void
8     start
9         // Create a new autobot for Bumblebee
10        mut Autobot bumblebee := new Autobot("Bumblebee", "Chevy_Camaro", 500);
11
12        // Give Bumblebee an owner
13        Owner sam := new Owner("Sam_Witwicky");
14        // This method is accessible because Autobot extends Transformer
15        bumblebee.set_owner(&sam);
16
17        Autobot optimus_prime := new Autobot("Optimus_Prime", "Truck", 1000);
18        // Give a reference to Optimus Prime for Bumblebee's leader
19        bumblebee.set_leader(&optimus_prime);
20
21        // Create Megatron

```

```

22 Transformer megatron := new Transformer("Megatron", "Tank", 2000);
23
24 // This will be 500 because Bumblebee gets assistance from Optimus Prime
25 // but their combined power is too low
26 println(megatron.attack(&bumblebee));
27
28 // Should be -1000 because the difference in their power is 1000 and
29 // Megatron has no leader
30 println(optimus_prime.attack(&megatron));
31
32 // Multiply Bumblebee's power by a factor of 3
33 bumblebee.supercharge(3);
34
35 // This will be -500 because Bumblebee is now at 1500 power
36 // plus Optimus Prime's 1000 power
37 println(megatron.attack(&bumblebee));
38
39 // Optimus Prime has the function because he is an Autobot
40 // Megatron does not because it is only defined in the Autobot model
41 optimus_prime.roll_out();
42 finish main
43 finish model

```

Listing 12: MainTransformers.rez