# Never

## Functional Programming Language

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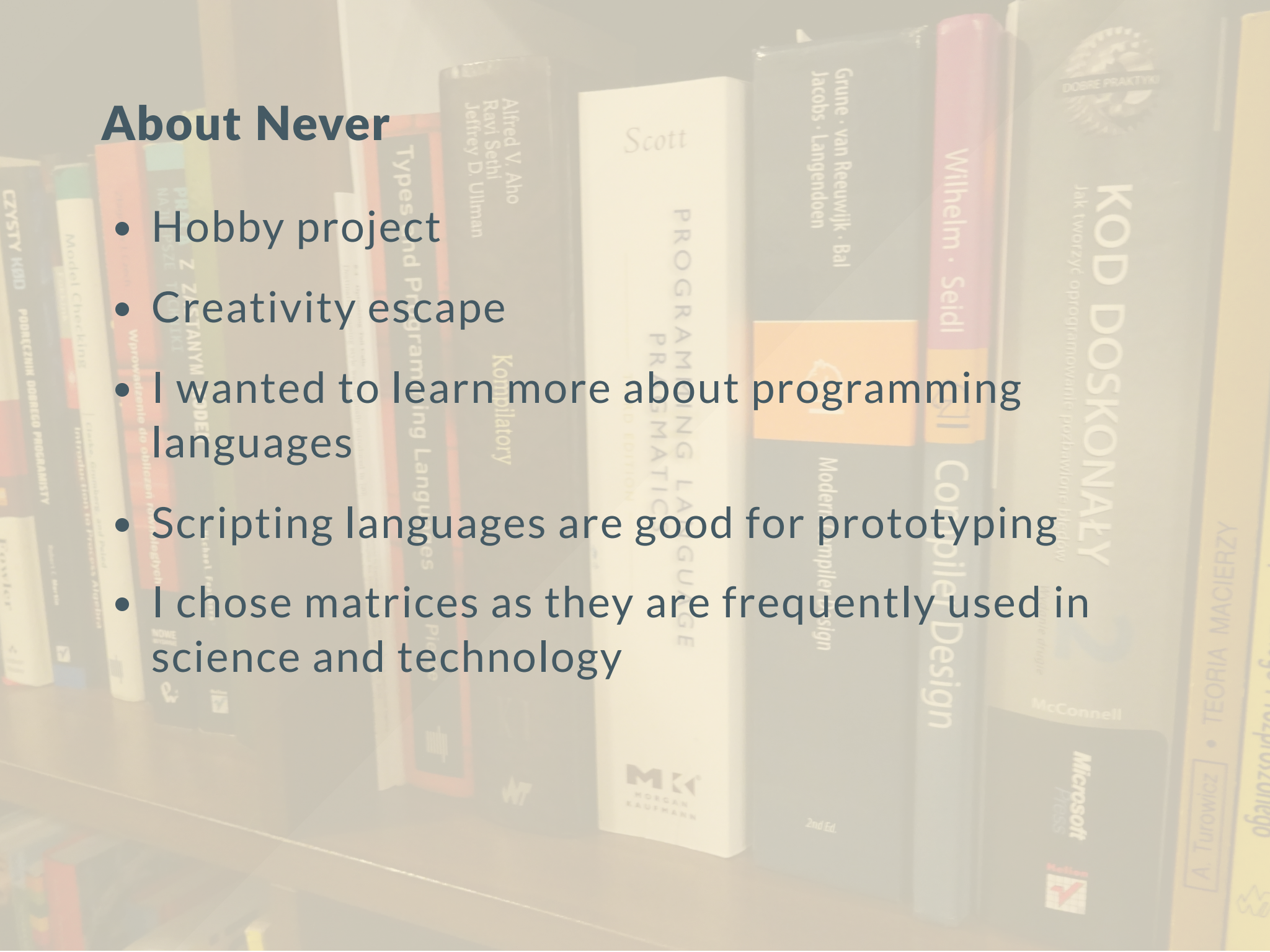
# Agenda

| | |
|---|---|
| Introduction | Motivation |
| Design | Design Decisions \| Under the Hood<br>Features |
| Demo | Neural Network \| Perceptron<br>Supervised Learning \| Results |

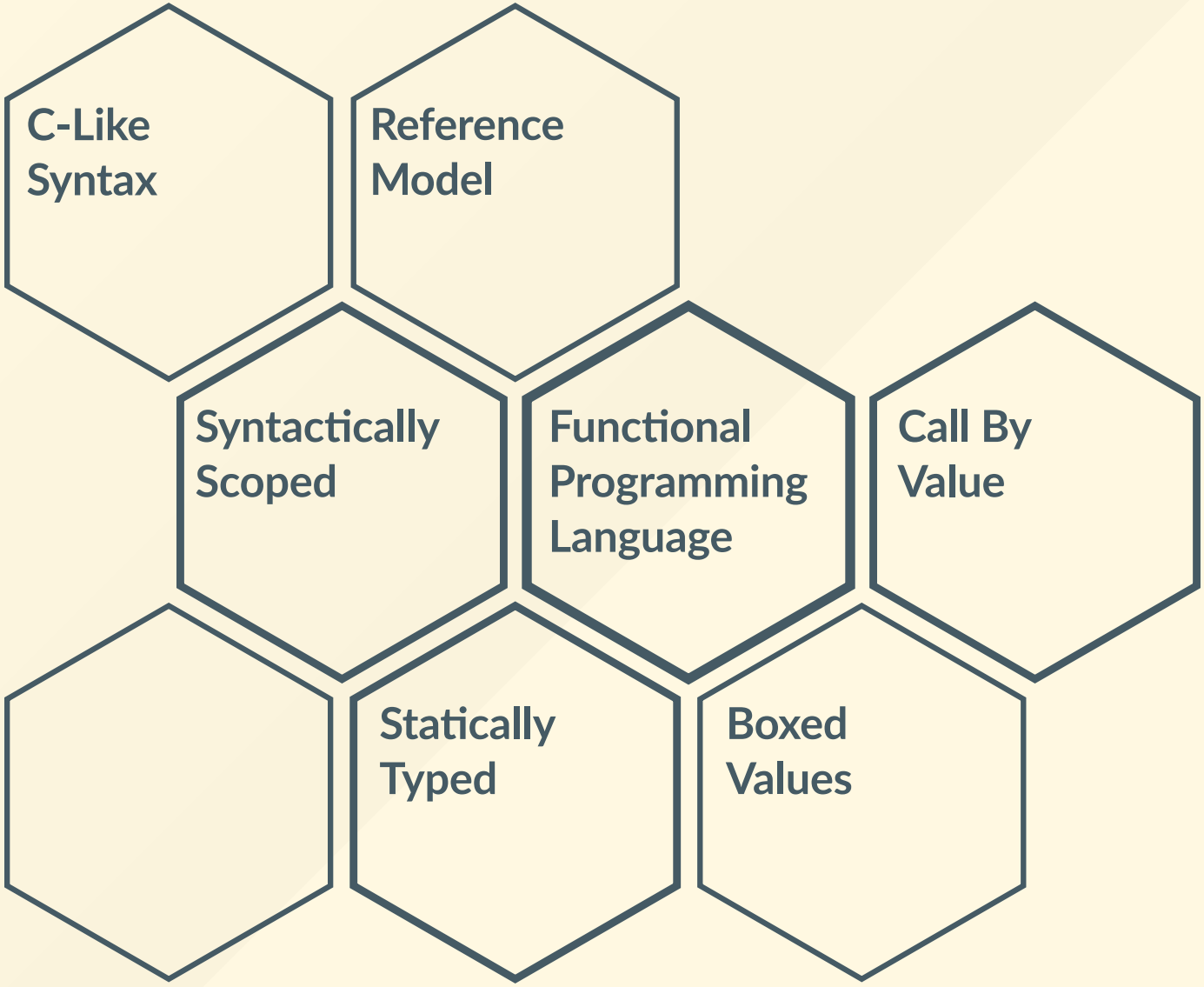

Mary
Pony
Agda
Hugo
M
Zebra
Euler
Ada
R
Clair
Orwell
Panda
Miranda
Mercury
Turing
Karel
D
Cranus
Cobra
P
Charity
Eve
Lisa
Gödel
Lily
Bertrand
Fjölnir
Julia
V
T
F
A
Dog
Squirrel
Pascal
Pike
Escher
Euphoria
Mouse
Alice
Esterel
Kitten
BS
G
Euclid
Crystal
Swift
C
Monkey
Falcon
Viper
Q
Lynx
Python
Hope
K
Cybil
Hermes
E
Reia
Mirah
Tom



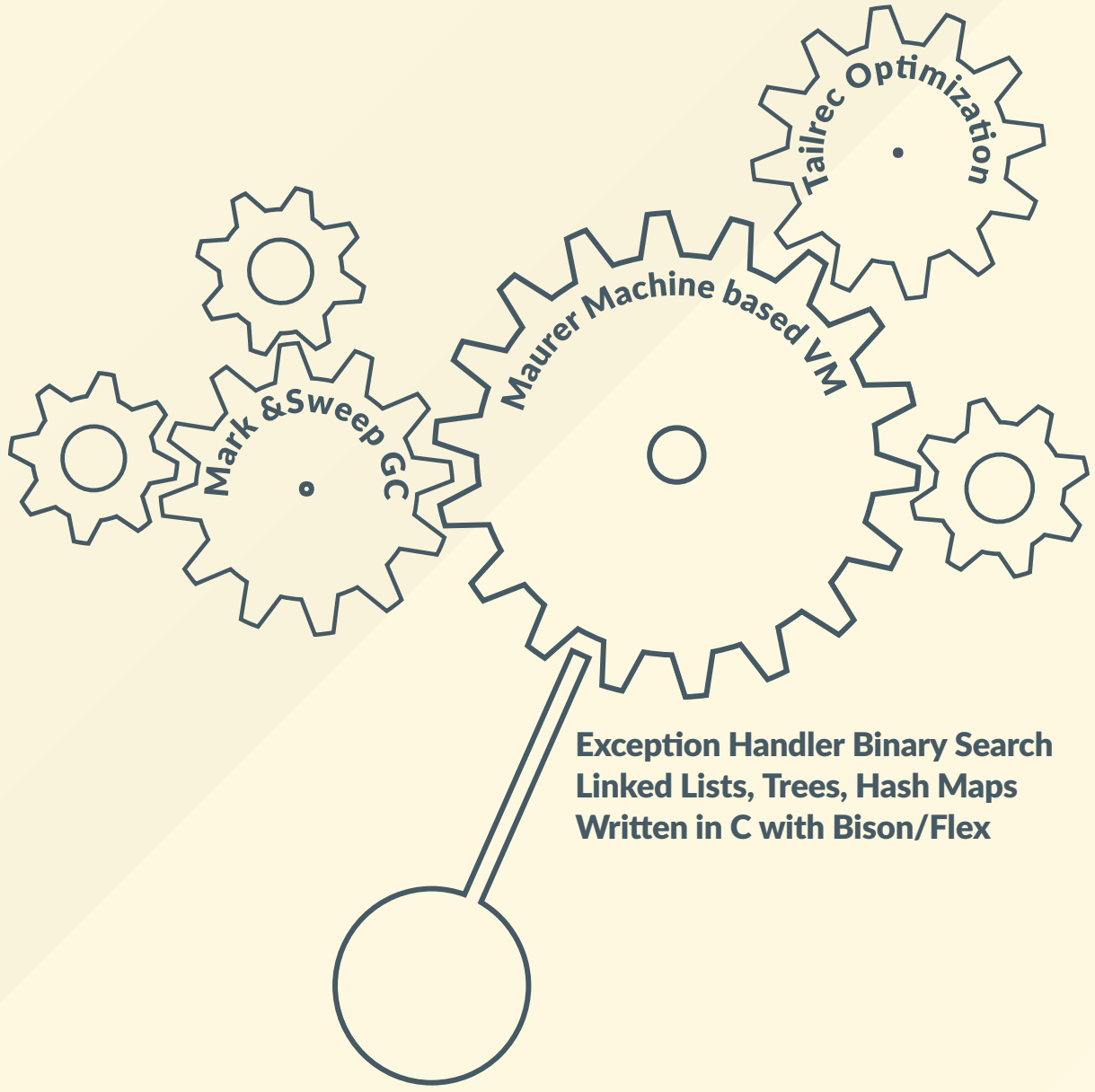
## About Never

- Hobby project
- Creativity escape
- I wanted to learn more about programming languages
- Scripting languages are good for prototyping
- I chose matrices as they are frequently used in science and technology

# Design Decisions



# Under the Hood



# Tick - Control - Functions & Expressions

```
func calc() -> (float) -> float {
    func fah2cel(float f) -> float { (f - 32.0) / 1.8 }
}

func main() -> float {
    calc()(212.0)
}
```

- First class functions
- Everything is an expression
- Operators + - * / ?:
- Float

# Tock - Types - Integer

```
func gcd(x -> int, y -> int) -> int {
    (y == 0) ? x : gcd(y, x % y)
}

func main() -> int {
    gcd(56, 12)
}
```

- Integer
- Operator %
- Operators and or not

# Tick - Control - Built-in

```
func deg2rad(deg -> float) -> float {
    deg * 3.14159 / 180
}

func get_func() -> (float) -> float {
    cos
}

func main() -> float {
    get_func()(deg2rad(60.0))
}
```

- Built-in functions:
  - sin, cos, tan, exp, log, sqrt, pow
  - print, printf, assert

# Tock - Types - Matrices

```
func rotate_matrix(alpha -> float) -> [_,_] -> float {
    [ [ cos(alpha), -sin(alpha) ],
      [ sin(alpha), cos(alpha)  ] ] -> float
}

func main() -> int {
    var vect = [[ 10.0, 0.0 ]] -> float;

    print_vect(vect * rotate_matrix(0.0));
}
```

- First class matrices
- Conformat arrays
- Overloaded operators + - *

# Tick - Control Flow

```
var i = 0; var j = 0;

for ({ i = 0; j = 0 }; i < 10;
     { i = i + 1; j = j + 2 }) {
    print(i + j)
}
```

- Bindings
- Control flow
- Side effects
- Operator =

# Tock - Types - String

```
func main() -> int {
    var s1 = "text equal";
    var s2 = "text equal";

    assert(if (s1 == s2) { 1 } else { 0 } == 1)
}
```

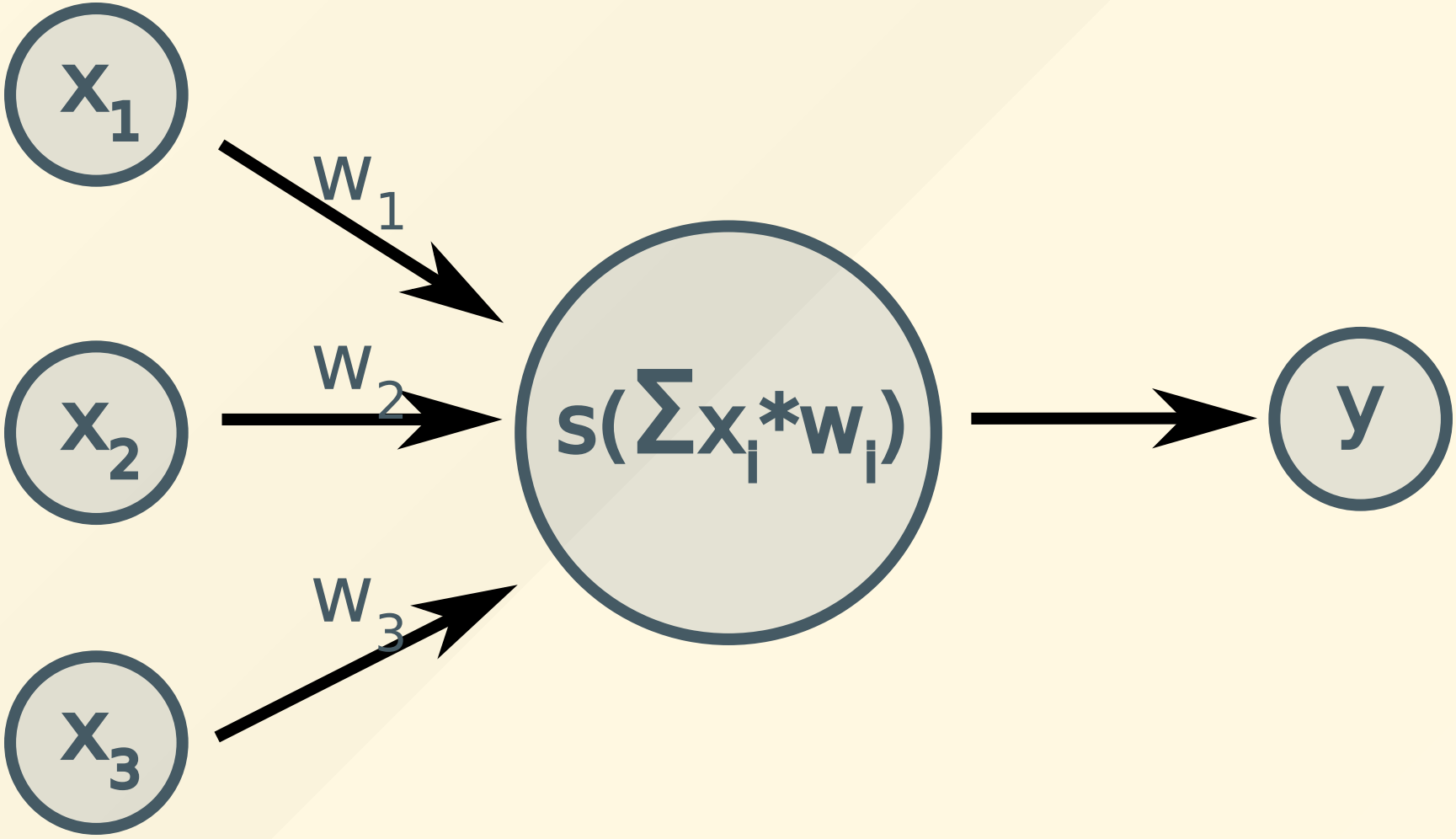
- Strings
- Operator == !=

# Tick - Control - Exceptions

```
func one(d -> int) -> int {
    var f = let func (d -> int) -> int {
                12 / d
            }
            catch (division_by_zero)
            {
                12
            };
    f(0)
}
```

- Exceptions

# Neural Network in Never



# Sigmoid

```
func sigmoid(x -> float) -> float
{
    1.0 / (1.0 + exp(-x))
}
```

- Function $\frac{1}{1+e^{-x}}$
- Statically typed
- Float type
- Returns expression

# Linear Congruential Generator

```
func randomize(seed -> int) -> () -> int
{
    var v = seed;
    func rand() -> int {
        v = (v * 1103515245 + 12345) % 2147483648
    }
    rand
}
```

- First class functions - `rand`
- Syntax scope - nested to any level
- `v` - closed within `randomize`

# Matrix Algebra

```
func Hadamard_matrix(W1[D1, D2] -> float,
     W2[D3, D4] -> float) -> [_,_] -> float
{
    var r = 0; var c = 0;
    var H = {[ D1, D2 ]} -> float;

    for (r = 0; r < D1; r = r + 1) {
        for (c = 0; c < D2; c = c + 1) {
            H[r, c] = W1[r, c] * W2[r, c]
        }
    };
    H
}
```

- Hadamard multiplication
- Conformant matrices (arrays)

# Forward Propagation - Input & Output

```
var x = [ [0, 1, 0],
          [1, 0, 0],
          [1, 1, 1],
          [0, 0, 1] ] -> float;

var y = [ [1, 0, 1, 0] ] -> float;
var yT = T_matrix(y);
```

- Input matrix `x`
- Output transposed matrix
  `y = [ [1], [0], [1], [0] ]`
- Middle value as output

# Forward Propagation - Initialization

```
var W = {[ 3, 1 ]} -> float;
var rand = randomize(165);

rand_matrix(W, rand);
```

- `W` initialized to random values

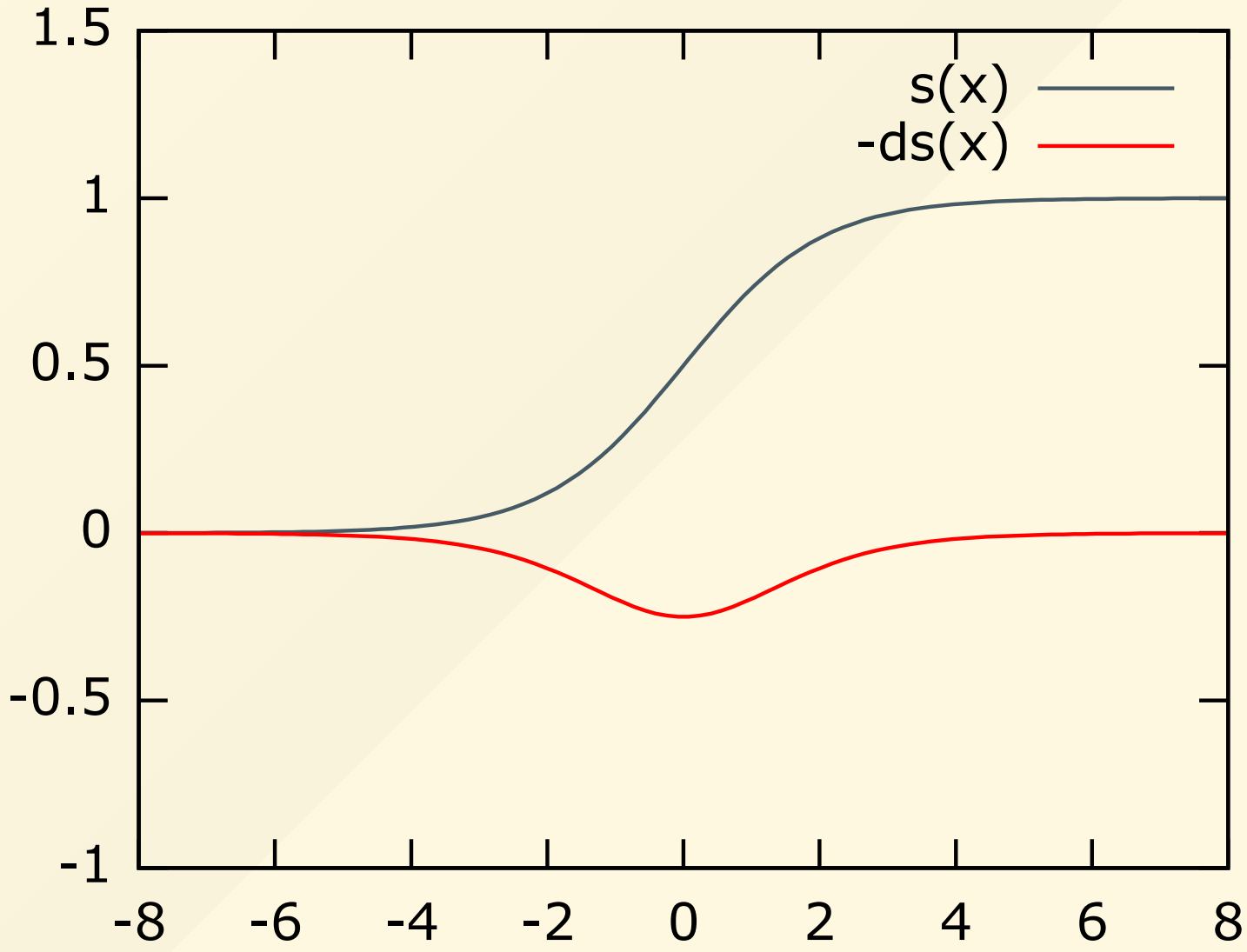
# Forward Propagation - Output Calculation

```
var s = {[ 4, 1 ]} -> float;

s = sigmoid_matrix(x * W);
```

- Operators `+, -, *` are overloaded for matrices
- Output calculated to all inputs
- Sigmoid function used to get 0/1 results

# Backpropagation - Error Reduction



# Backpropagation - Error Calculation

```
var err = {[ 4, 1 ]} -> float;

err = yT - s;
```

- Calculate error for each input sample
- `err` used to correct `W` weights

# Backpropagation - Gradient Descent

```
    var sD = {[ 4, 1 ]} -> float;
    var one = {[ 4, 1 ]} -> float;

    sD = Hadamard_matrix(s, one - s);
    W = W + xT * Hadamard_matrix(err, sD)
```

- `sD = s * (1 - s)`
- `W = W + xT * err * sD`
- First derivative (or gradient) multiplied by error lets to move towards function minimum
- Calculations for all input values `x` at once

# Forward and Backpropagation Learning Cycles

```
func main() -> int {
    var i = 0;
    for (i = 0; i < 1000; i = i + 1) {
        ...
    }
}
```

- Forward and backpropagation need to be repeated until error is low
- Function `main` as program entry point

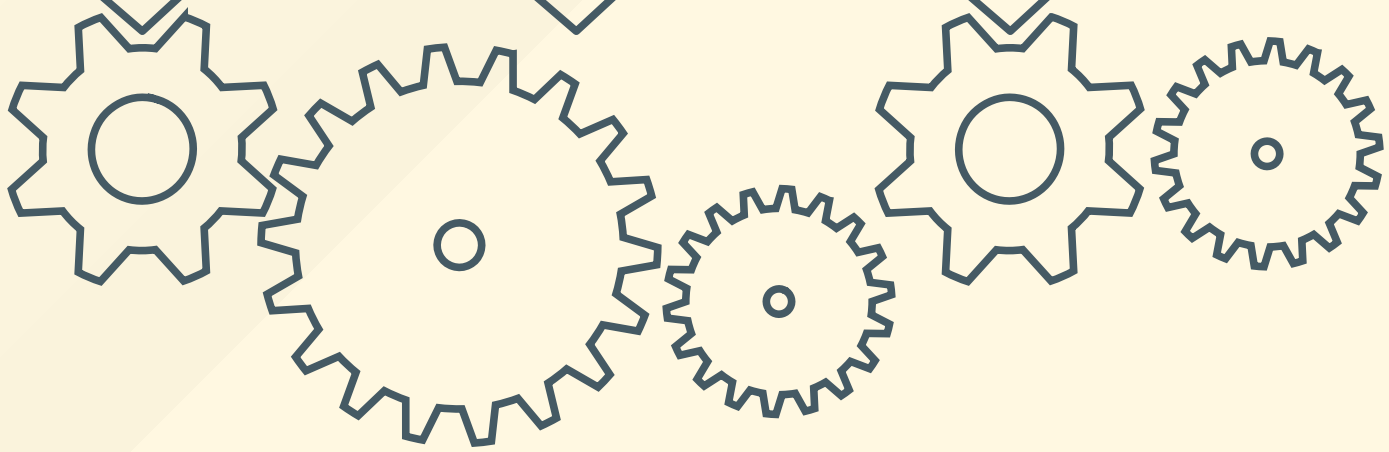
## Results

| X | s(X * W) | y |
|---|---|---|
| [[ 1, 1, 1 ]] | 0.96 | 1.00 |
| **[[ 1, 1, 0 ]]** | **1.00** | **1.00** |
| **[[ 1, 0, 1 ]]** | **0.00** | **0.00** |
| [[ 1, 0, 0 ]] | 0.05 | 0.00 |
| **[[ 0, 1, 1 ]]** | **1.00** | **1.00** |
| [[ 0, 1, 0 ]] | 1.00 | 1.00 |
| [[ 0, 0, 1 ]] | 0.05 | 0.00 |
| **[[ 0, 0, 0 ]]** | **0.50** | **0.00** |

- 7 correct results, 1 undecided

# Future

| Types | Lists | Externals | Runtime |
| --- | --- | --- | --- |
| record | join | I/O | libraries |
| polynomial functions | slice | modules | VM optimizations |
| type inference | comprehension | foreign function interface | |



# Summary

- Creating programming languages...
  - is fun 😄
  - can teach you a lot 😓
  - is satisfactory 😎

# Thank You!

# never-lang.github.io/never