ENG1467 - OTIMIZAÇÃO - PUC-Rio, 2022.1

Lista 3: Simplex Parte 2

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Professor: Alexandre Street *Aluno: Thiago Novaes*

O código completo desenvolvido durante essa atividade pode ser encontrado em `https://github.com/Thiago-NovaesB/MestradoPuc.jl/tree/main/Programa%C3%A7%C3%A3o%20Linear/Lista%203/Simplex`

1 Implementação

Para a implementação do algoritmo, foi criado o pacote *Simplex.jl*:

```
module Simplex

include("types.jl")
include("utils.jl")
include("log.jl")
include("solver.jl")

export create, solve

end # module
```

O arquivo *types.jl* contém estruturas em julia para guardar as entradas e saídas:

```
struct Input
    A::Matrix{}
    b::Vector{}
    c::Vector{}
    base::Vector{Int}
    nbase::Vector{Int}
    tol::Float64
    max_iter::Int
    verbose::Int
end

struct Output
    x::Vector{Float64}
    z::Float64
    termination_status::Int
    base::Vector{Int}
    nbase::Vector{Int}
end
```

O arquivo *utils.jl* contém funções para tratar entradas e saídas:

```
function create(A::Matrix{}, b::Vector{}, c::Vector{}, base::Vector{Int},
                nbase::Vector{Int}; tol::Float64 = 1E-6,
                max_iter::Int = 1000, verbose::Int = 1)
        input = Simplex.Input(A,b,c,base,nbase,tol,max_iter,verbose)
    return input
end

function write_output(input::Input, termination_status::Int, d::Vector{})

    A = input.A
    b = input.b
    c = input.c
    base = input.base
    nbase = input.nbase
    B = view(A,:,base)
    x = B \ b
    z = c[base]'x

    x_opt = zeros(length(c))
    x_opt[base] = x
    if termination_status == 2
        output = Simplex.Output(d, Inf, termination_status, base, nbase)
        last_log(input, termination_status, base, nbase, z, d)
    else
        output = Simplex.Output(x_opt, z, termination_status, base, nbase)
        last_log(input, termination_status, base, nbase, z, x_opt)
    end
    return output
end
```

O arquivo *log.jl* contém as funções para escrita de log:

```
function init_log(input::Simplex.Input)
    if input.verbose == 1
        var = length(input.c)
        con = length(input.b)
        println("----------------Inicio do algoritmo Simplex-----------------"
    )
        println("O problema possui $var variaveis e $con restrições")
    end
end

function iteration_log(input::Simplex.Input, iter::Int, base::Vector{Int},
    nbase::Vector{Int}, i::Int, j::Int, z::Float64, x::Vector{Float64},
    red_cost::Vector{Float64})
    if input.verbose == 1
        println("------------------------Iteração $iter
    ------------------------")
        println("Base: $base")
        println("Não-Base: $nbase")
        println("Deixa a base: $i")
        println("Entra na base: $j")
```

```
        println("Função objetivo: $z")
        println("Variaveis: $x")
        println("Custo reduzido: $red_cost")
    end
end

function last_log(input::Simplex.Input, termination_status::Int, base::Vector{
    Int}, nbase::Vector{Int}, z::Float64, x::Vector{Float64})
    if input.verbose == 1
        println("----------------------Fim do algoritmo----------------------"
    )
        if termination_status == 1
            println("Status: Optimal")
            println("Base: $base")
            println("Não-Base: $nbase")
            println("Função objetivo: $z")
            println("Variaveis: $x")
        else
            println("Status: Unbound")
            println("Base: $base")
            println("Não-Base: $nbase")
            println("Função objetivo: Inf")
            println("Direção extrema: $x")
        end
    end
end
```

O arquivo *solver.jl* contém o algortimo simplex:

```
function solve(input::Simplex.Input)

    termination_status = 0
    iter = 0
    max_iter = input.max_iter
    d = []
    init_log(input)
    while termination_status == 0 && iter < max_iter
        termination_status, iter, d = Simplex.iterate(input, iter)
    end
    output = write_output(input, termination_status, d)
    return output
end

function iterate(input::Simplex.Input, iter::Int)

    iter += 1
    A = input.A
    b = input.b
    c = input.c
    base = input.base
    nbase = input.nbase
    tol = input.tol
```

```
    B = view(A,:,base)
    N = view(A,:,nbase)
    xB = B \ b
    y = B' \ c[base]
    red_cost = c[nbase] - N'*y
    val, j = findmax(red_cost)
    if val <= tol
        return 1, iter, [] #optimal
    end
    d = zeros(length(c))
    d_base = B \ N[:,j]
    d[base] = - d_base
    d[nbase[j]] = 1
    d_base = max.(d_base, 0)
    r = xB ./ d_base
    val, i = findmin(r)
    if val == Inf
        return 2, iter, d #unbounded
    end
    z = c[base]'xB
    x_opt = zeros(length(c))
    x_opt[base] = xB
    iteration_log(input, iter, base, nbase, base[i], nbase[j], z, x_opt,
    red_cost)
    base[i], nbase[j] = nbase[j], base[i]
    return 0, iter, d #max iteration
end
```

2 Testes

2.1 Caso com solução ótima

Este caso foi mostrado em aula como sendo um exemplo pequeno de um problema de maximização com solução.

```
A = [2 1 1 0; 1 2 0 1]
b = [4, 4]
c = [4, 3, 0, 0]
base = [3, 4]
nbase = [1, 2]
input = Simplex.create(A, b, c, base, nbase)
output = Simplex.solve(input)
```

2.2 Caso ilimitado

Este caso foi mostrado em aula como sendo um exemplo pequeno de um problema de maximização ilimitado.

```
A = [-2 1 1 0; 1 -1 0 1]
b = [2, 2]
c = [1, 1, 0, 0]
base = [3, 4]
nbase = [1, 2]
input = Simplex.create(A, b, c, base, nbase)
output = Simplex.solve(input)
```

2.3 Caso 10 variáveis originais e 10 restrições

Este caso foi criado de forma aleatória usando seed=123.

```
Random.seed!(123)
A_prime = rand(1:20,10,10)
A = hcat(A_prime,Matrix(I,10,10))
c = zeros(20)
c[1:10] = rand(1:10,10)
b = rand(1:30,10)
nbase = collect(1:10)
base = collect(11:20)
input = Simplex.create(A, b, c, base, nbase)
output = Simplex.solve(input)
```

2.4 Caso 100 variáveis originais e 100 restrições

Este caso foi criado de forma aleatória usando seed=123.

```
Random.seed!(123)
A_prime = rand(1:200,100,100)
A = hcat(A_prime,Matrix(I,100,100))
c = zeros(200)
c[1:100] = rand(1:10,100)
b = rand(1:30,100)
nbase = collect(1:100)
base = collect(101:200)
input = Simplex.create(A, b, c, base, nbase)
output = Simplex.solve(input)
```

3 Resultados

3.1 Caso com solução ótima

```
----------------Inicio do algoritmo Simplex-----------------
O problema possui 4 variaveis e 2 restrições
------------------------Iteração 1------------------------
Base: [3, 4]
Não-Base: [1, 2]
```

```
Deixa a base: 3
Entra na base: 1
Função objetivo: 0.0
Variaveis: [0.0, 0.0, 4.0, 4.0]
Custo reduzido: [4.0, 3.0]
------------------------Iteração 2------------------------
Base: [1, 4]
Não-Base: [3, 2]
Deixa a base: 4
Entra na base: 2
Função objetivo: 8.0
Variaveis: [2.0, 0.0, 0.0, 2.0]
Custo reduzido: [-2.0, 1.0]
---------------------Fim do algoritmo---------------------
Status: Optimal
Base: [1, 2]
Não-Base: [3, 4]
Função objetivo: 9.333333333333334
Variaveis: [1.3333333333333335, 1.3333333333333333, 0.0, 0.0]
```

3.2 Caso ilimitado

```
----------------Inicio do algoritmo Simplex----------------
O problema possui 4 variaveis e 2 restrições
------------------------Iteração 1------------------------
Base: [3, 4]
Não-Base: [1, 2]
Deixa a base: 4
Entra na base: 1
Função objetivo: 0.0
Variaveis: [0.0, 0.0, 2.0, 2.0]
Custo reduzido: [1.0, 1.0]
---------------------Fim do algoritmo---------------------
Status: Unbound
Base: [3, 1]
Não-Base: [4, 2]
Função objetivo: Inf
Direção extrema: [1.0, 1.0, 1.0, 0.0]
```

3.3 Caso 10 variáveis originais e 10 restrições

```
----------------Inicio do algoritmo Simplex----------------
O problema possui 20 variaveis e 10 restrições
------------------------Iteração 1------------------------
Base: [11, 12, 13, 14, 15, 16, 17, 18, 19, 20]
Não-Base: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
Deixa a base: 16
Entra na base: 6
```

```
Função objetivo: 0.0
Variaveis: [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 9.0, 9.0, 24.0,
    21.0, 22.0, 1.0, 14.0, 1.0, 2.0, 2.0]
Custo reduzido: [6.0, 1.0, 6.0, 2.0, 7.0, 10.0, 3.0, 10.0, 7.0, 6.0]
------------------------Iteração 2------------------------
Base: [11, 12, 13, 14, 15, 6, 17, 18, 19, 20]
Não-Base: [1, 2, 3, 4, 5, 16, 7, 8, 9, 10]
Deixa a base: 18
Entra na base: 3
Função objetivo: 0.5263157894736842
Variaveis: [0.0, 0.0, 0.0, 0.0, 0.0, 0.05263157894736842, 0.0, 0.0, 0.0, 0.0,
    8.105263157894736, 8.736842105263158, 23.05263157894737,
    20.57894736842105, 21.263157894736842, 0.0, 13.210526315789474,
    0.26315789473684215, 1.0526315789473686, 1.5263157894736843]
Custo reduzido: [1.7894736842105257, -0.5789473684210527, 4.421052631578947,
    -0.6315789473684212, -3.0, -0.5263157894736842, -5.947368421052632,
    3.1578947368421044, 0.1578947368421053, 3.894736842105263]
------------------------Iteração 3------------------------
Base: [11, 12, 13, 14, 15, 6, 17, 3, 19, 20]
Não-Base: [1, 2, 18, 4, 5, 16, 7, 8, 9, 10]
Deixa a base: 20
Entra na base: 8
Função objetivo: 0.7692307692307693
Variaveis: [0.0, 0.0, 0.05494505494505496, 0.0, 0.0, 0.04395604395604395, 0.0,
     0.0, 0.0, 0.0, 7.9230769230769225, 7.681318681318681, 22.21978021978022,
    20.373626373626376, 20.945054945054945, 0.0, 13.230769230769232, 0.0,
    0.6593406593406594, 0.7802197802197801]
Custo reduzido: [-10.307692307692307, -9.615384615384615, -0.923076923076923,
    1.8461538461538463, -3.9230769230769234, 0.15384615384615372,
    -10.076923076923077, 11.076923076923075, 3.461538461538462,
    -9.999999999999996]
------------------------Iteração 4------------------------
Base: [11, 12, 13, 14, 15, 6, 17, 3, 19, 8]
Não-Base: [1, 2, 18, 4, 5, 16, 7, 20, 9, 10]
Deixa a base: 6
Entra na base: 1
Função objetivo: 1.0298210735586482
Variaveis: [0.0, 0.0, 0.09708416169648774, 0.0, 0.0, 0.02120609675281644, 0.0,
     0.02352551358515573, 0.0, 0.0, 8.009940357852884, 6.505301524188205,
    21.470841616964876, 19.96852220013254, 20.550033134526174, 0.0,
    13.276010603048377, 0.0, 0.3416169648774024, 0.0]
Custo reduzido: [1.0298210735586508, -1.874751491053675, 0.02385685884691868,
    -6.250497017892645, -3.978131212723653, -0.3856858846918489,
    -8.495029821073558, -0.33399602385685884, -0.20874751491053622,
    -0.45725646123260155]
----------------------Fim do algoritmo----------------------
Status: Optimal
Base: [11, 12, 13, 14, 15, 1, 17, 3, 19, 8]
Não-Base: [6, 2, 18, 4, 5, 16, 7, 20, 9, 10]
Função objetivo: 1.052132701421801
```

```
Variaveis: [0.021665538253215984, 0.0, 0.0775220040622884, 0.0, 0.0, 0.0, 0.0,
    0.04570074475287746, 0.0, 0.0, 8.205145565335139, 6.321259309410968,
    21.437711577522006, 19.794515910629656, 20.410291130670277, 0.0,
    13.41198375084631, 0.0, 0.3706838185511171, 0.0]
```

3.4 Caso 100 variáveis originais e 100 restrições

Este caso foi criado de forma aleatória usando seed=123.

```
----------------Inicio do algoritmo Simplex-----------------
O problema possui 200 variaveis e 100 restrições
-------------------------Iteração 1-------------------------
Base: [101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114,
    115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129,
    130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143,
    144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158,
    159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172,
    173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187,
    188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200]
Não-Base: [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19,
    20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37,
    38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55,
    56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73,
    74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91,
    92, 93, 94, 95, 96, 97, 98, 99, 100]
Deixa a base: 124
Entra na base: 3
Função objetivo: 0.0
Variaveis: [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
    0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
    0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
    0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
    0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
    0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
    0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
    20.0, 12.0, 7.0, 20.0, 16.0, 13.0, 9.0, 26.0, 6.0, 20.0, 10.0, 24.0, 10.0,
    20.0, 17.0, 8.0, 11.0, 15.0, 30.0, 3.0, 5.0, 10.0, 7.0, 1.0, 19.0, 3.0,
    7.0, 18.0, 25.0, 15.0, 26.0, 28.0, 26.0, 20.0, 30.0, 17.0, 23.0, 13.0,
    5.0, 23.0, 4.0, 4.0, 23.0, 6.0, 16.0, 6.0, 3.0, 7.0, 8.0, 11.0, 23.0,
    27.0, 27.0, 9.0, 24.0, 22.0, 17.0, 24.0, 1.0, 4.0, 7.0, 9.0, 7.0, 30.0,
    16.0, 21.0, 21.0, 25.0, 9.0, 23.0, 21.0, 9.0, 25.0, 15.0, 3.0, 19.0, 10.0,
    7.0, 19.0, 2.0, 28.0, 30.0, 30.0, 29.0, 29.0, 21.0, 8.0, 26.0, 26.0,
    14.0, 24.0, 18.0, 3.0, 13.0, 17.0, 23.0, 22.0, 5.0, 12.0, 26.0]
```

```
Custo reduzido: [1.0, 6.0, 10.0, 7.0, 6.0, 7.0, 6.0, 4.0, 1.0, 8.0, 4.0, 7.0,
    1.0, 4.0, 4.0, 2.0, 6.0, 6.0, 5.0, 3.0, 6.0, 10.0, 7.0, 6.0, 6.0, 8.0,
    10.0, 6.0, 10.0, 6.0, 1.0, 9.0, 4.0, 6.0, 3.0, 3.0, 10.0, 6.0, 5.0, 6.0,
    2.0, 2.0, 8.0, 8.0, 1.0, 7.0, 3.0, 7.0, 7.0, 5.0, 8.0, 4.0, 2.0, 7.0, 8.0,
     3.0, 7.0, 8.0, 3.0, 1.0, 1.0, 7.0, 3.0, 10.0, 7.0, 10.0, 10.0, 8.0, 5.0,
    2.0, 5.0, 5.0, 10.0, 9.0, 9.0, 5.0, 1.0, 9.0, 3.0, 3.0, 1.0, 2.0, 1.0,
    7.0, 10.0, 8.0, 3.0, 6.0, 4.0, 2.0, 10.0, 7.0, 5.0, 4.0, 4.0, 4.0, 5.0,
    7.0, 3.0, 6.0]
------------------------Iteração 2------------------------
Base: [101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114,
    115, 116, 117, 118, 119, 120, 121, 122, 123, 3, 125, 126, 127, 128, 129,
    130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144,
     145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158,
    159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173,
     174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187,
    188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200]
Não-Base: [1, 2, 124, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18,
    19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36,
    37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54,
    55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72,
    73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90,
    91, 92, 93, 94, 95, 96, 97, 98, 99, 100]
Deixa a base: 159
Entra na base: 64
Função objetivo: 0.05319148936170218
```

```
Variaveis: [0.0, 0.0, 0.005319148936170218, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
  0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
  0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
  0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
  0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
  0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
  0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
  0.0, 0.0, 0.0, 19.164893617021274, 11.154255319148936, 6.223404255319148,
  19.54255319148936, 15.25, 12.909574468085106, 8.803191489361701,
  25.93617021276596, 5.50531914893617, 19.329787234042552, 9.97340425531915,
  23.670212765957448, 9.223404255319148, 19.48404255319149,
  16.78191489361702, 7.079787234042552, 10.49468085106383,
  14.090425531914892, 29.170212765957444, 2.101063829787233,
  4.792553191489361, 9.053191489361701, 6.914893617021277, 0.0,
  18.47872340425532, 2.9627659574468086, 6.8936170212765955,
  17.835106382978726, 24.090425531914892, 14.085106382978722,
  25.101063829787233, 27.29255319148936, 25.111702127659576,
  19.27127659574468, 29.50531914893617, 16.654255319148938,
  22.601063829787233, 12.851063829787234, 4.835106382978723,
  22.78191489361702, 3.856382978723404, 3.4734042553191484,
  22.601063829787233, 5.861702127659574, 15.76063829787234,
  5.069148936170212, 2.99468085106383, 6.914893617021277, 7.579787234042553,
  10.053191489361701, 22.409574468085108, 26.664893617021278,
  26.50531914893617, 8.893617021276595, 23.3031914893617,
  21.196808510638295, 16.02659574468085, 23.28191489361702,
  0.015957446808509287, 3.1808510638297864, 6.297872340425531,
  8.12234042553191 5, 6.728723404255319, 29.095744680851066,
  15.712765957446809, 20.425531914893618, 20.03191489361702,
  24.81382978723404, 8.72872340425531 8, 22.819148936170212,
  20.12234042553191 3, 8.244680851063828, 24.27659574468085,
  14.909574468085106, 2.212765957446808, 18.840425531914892,
  9.78191489361702, 6.718085106382978, 18.882978723404253,
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  25.367021276595747]
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    -7.882978723404255, 7.095744680851064, 3.521276595744679,
    3.8085106382978724, -8.202127659574469, -0.9999999999999991,
    -3.7659574468085104, -1.244680851063829, 2.436170212765957,
    0.20212765957446877, -0.957446808510638, -0.5106382978723403,
    1.4787234042553186, 1.5957446808510642, 1.5212765957446805,
    0.202127659574467, 5.680851063829788, -0.13829787234042534,
    -0.47872340425531945, 1.3191489361702136, 8.244680851063832,
    0.6808510638297873, -7.670212765957446, -0.6276595744680868,
    -0.787234042553191, -2.031914893617021, -4.765957446808511,
    -6.414893617021276, 9.095744680851064, -1.819148936170211,
    2.97872340425532, 0.255319148936171, -0.07446808510638059,
    1.3085106382978724, 6.882978723404255, -1.5212765957446788,
    -8.361702127659575, -3.4787234042553195, 0.2340425531914887,
    0.5638297872340434, 6.308510638297874, 3.404255319148936,
    -1.3085106382978733, -4.98936170212766, -8.106382978723405,
    -3.372340425531913, -0.7765957446808489, 2.1489361702127656,
    3.3297872340425534, 4.4361702127659575, -1.414893617021277,
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    -6.680851063829786, 9.893617021276595, 3.3829787234042548,
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    -3.319148936170212, 7.127659574468083, 3.595744680851064,
    -2.1808510638297873, -3.0212765957446805, 3.148936170212766,
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----------------------Iteração 3----------------------
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     160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173,
    174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188,
     189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200]
Não-Base: [1, 2, 124, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18,
    19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36,
    37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54,
    55, 56, 57, 58, 59, 60, 61, 62, 63, 159, 65, 66, 67, 68, 69, 70, 71, 72,
    73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90,
    91, 92, 93, 94, 95, 96, 97, 98, 99, 100]
Deixa a base: 3
Entra na base: 73
Função objetivo: 0.054369394396380576
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25 Variaveis: [0.0, 0.0, 0.005317882371616791, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
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    0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
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   12.900547662512897, 8.800619096753712, 25.92904198745932,
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   23.646479879355507, 9.202635129772204, 19.472616874355108,
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   25.09651559647591, 27.27593459798397, 25.096912453369317,
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   22.578895150408762, 5.842447813318517, 15.759623779665052,
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   15.71057226764029, 20.40435748868958, 20.03155012302563,
   24.796253670926266, 8.718549091197715, 22.812286689419796,
   20.112905786173506, 8.226287800619097, 24.256885467100563,
   14.901142947853005, 2.2056909278514176, 18.827367251369157,
   9.780300023811412, 6.712437495039289, 18.876101277879197,
   1.4097547424398769, 27.598063338360188, 29.51468370505596,
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   25.245654417017228, 13.17977617271212, 23.109334074132864,
   17.16604492420033, 2.734463052623225, 12.3632431145329, 16.1195729819827,
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    -3.5384554329708706, 1.7792681958885614, 5.4085244860703225,
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    7.891658068100642, -0.25581395348837077, -4.509167394237638,
    6.03285975077387, -5.068100642908167, 1.3809032462893862,
    -7.362647829192792, -4.307881577903007, -1.7360901658861785,
    6.991110405587743, -0.21049289626160927, 0.16255258353837476,
    9.437018811016745, -5.3990792920073005, -2.140011111993015,
    3.3238352250178576, 3.4329708707040223, -5.600920707992698,
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----------------------Iteração 4-----------------------
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    174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188,
     189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200]
Não-Base: [1, 2, 124, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18,
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    37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54,
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Deixa a base: 180
Entra na base: 37
Função objetivo: 0.17871263640676838
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   21.453582160366924, 8.391111814012339, 17.959196583900056,
   15.386050925193741, 7.273762454531079, 8.419421160841381,
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    -2.2835679266171134, -25.959512889451208, -19.779060572513046,
    -20.724814170488692, -17.392693341768144, -4.246718329906692,
    -9.306025620749647, -13.216827455321841, -13.040645263324372,
    -17.393958563972795, -13.91902577890242, -4.715166851178239,
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    -16.85908587695714, -5.337181717539146, -2.7336707259212396,
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    -23.938478570298912, -4.9082713901628985, -17.797248141704884,
    -20.185513205756763, -13.652696504823659, -30.665190574094574,
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    -20.908429542938478, 3.947493278507035, -10.266329274078757,
    -18.046813221572037, -14.696821129210818, -10.085086193262688,
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----------------------Iteração 5----------------------
Base: [101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114,
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    174, 175, 176, 177, 178, 179, 37, 181, 182, 183, 184, 185, 186, 187, 188,
    189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200]
Não-Base: [1, 2, 124, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18,
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Deixa a base: 175
Entra na base: 91
Função objetivo: 0.21052525741215047
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41 Variaveis: [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
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    -9.72676548154659, -10.251786315237243, -9.811361207401823,
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    -20.39198271084611, -7.339315614000951, -4.410542291061298,
    -12.569078248917208, -8.252360609449777, -4.934604981987511,
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     145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 64,
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    174, 91, 176, 177, 178, 179, 37, 181, 182, 183, 184, 185, 186, 187, 188,
    189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200]
Não-Base: [1, 2, 124, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18,
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Deixa a base: 73
Entra na base: 67
Função objetivo: 0.27425371743406124
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    189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200]
Não-Base: [1, 2, 124, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18,
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Deixa a base: 193
Entra na base: 10
Função objetivo: 0.28003381780935194
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