Rubik's Cubes and Genetic Algorithms in Swift

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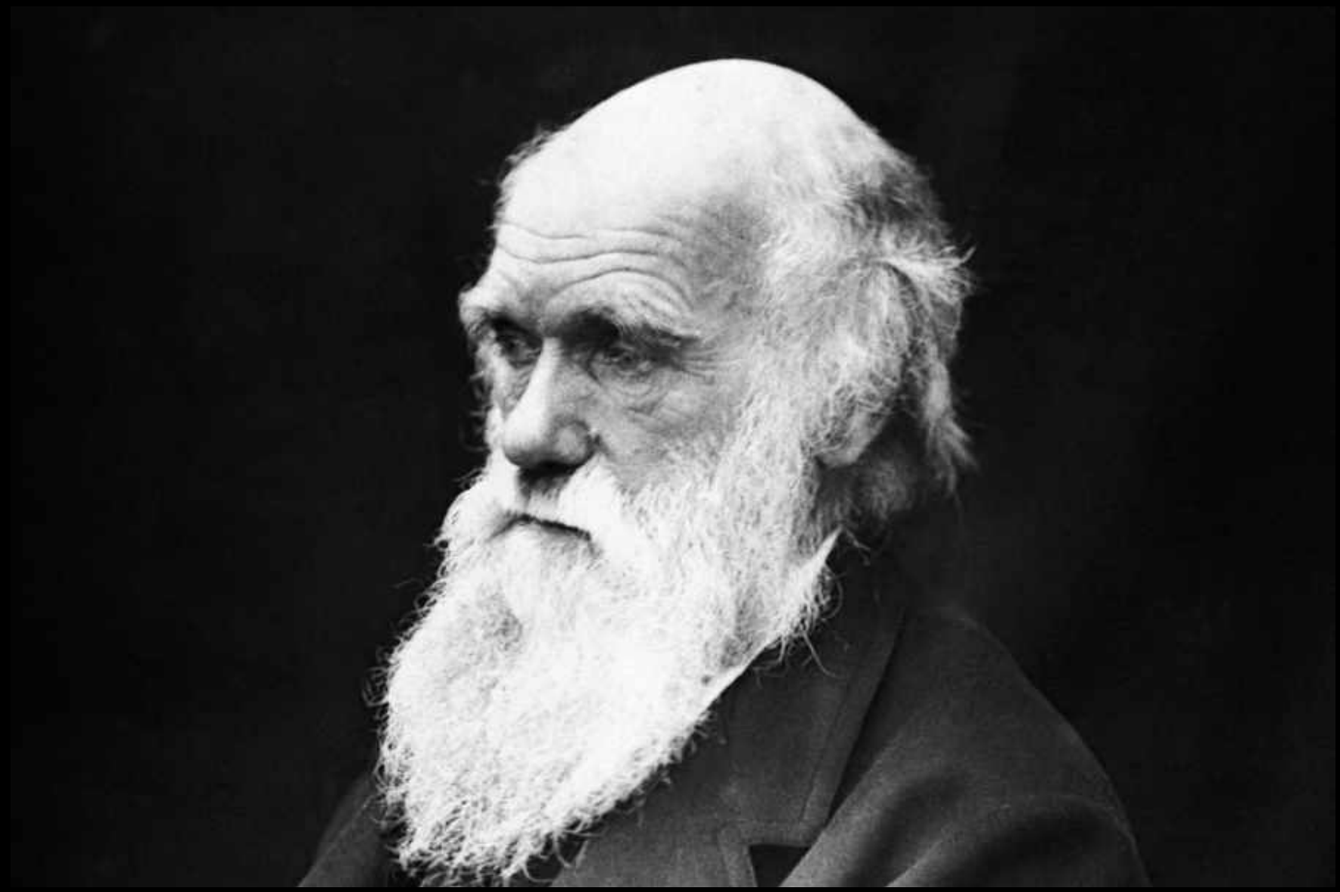
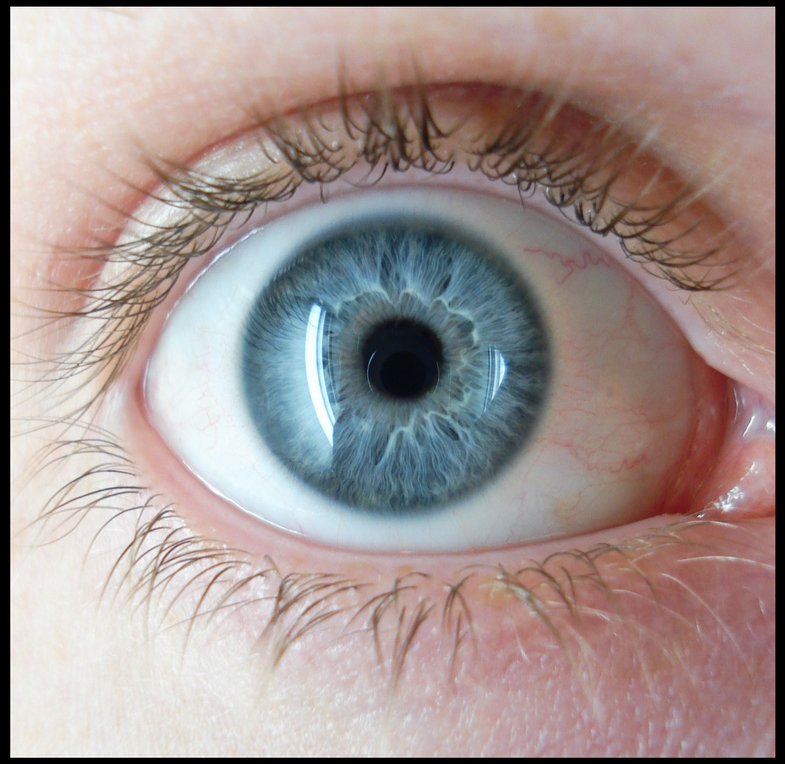
Evolution by Natural Selection



Evolution by Natural Selection



Evolution by Natural Selection

1. ?
2. *Random mutations* in genome
3. Survival of the *fittest*
4. (**Rinse and repeat**)

Genetic Algorithms

Genetic Algorithms

Genetic Algorithms - Example

1. *Goal*: find a number *'x'*
2. *Start* with *0000000000000000*
3. *Mutate* each randomly, *bit by bit*
4. Calc *fitness* comparing with *x*'s bits

Genetic Algorithms - Example

```
final class Individual {
    let number: UInt

    init(number: UInt) {
        self.number = number
    }
}
```

Genetic Algorithms - Example

```
typealias Fitness = Int

extension Individual {
    func fitness(withGoal goal: UInt) -> Fitness {
        return Fitness(self.number.numberOfBitsEqual(in: goal))
    }
}
```

Genetic Algorithms - Example

```
extension Individual {
    let likelihoodOfMutatingBit = 5

    func mutate() -> Individual {
        let mutatedBits = self.number.bits.map { bit -> Bool in
            let shouldMutate = Bool.random(percentage: likelihoodOfMutatingBit)

            return shouldMutate ? !bit : bit
        }

        return Individual(number: UInt(bits: mutatedBits))
    }
}
```

Genetic Algorithms - Example

```
final class GeneticSolver {
    var population: [Individual]

    init(numberToSolve: UInt, populationSize: Int)

    func runGeneration() {
        // 1: Natural selection (survival of the fittest)
        population.removeLast(Int(Double(population.count) * 0.8))

        // 2: Random mutations
        population += population.map { $0.mutate() }

        // 3: Sort by fitness
        population.sort { $0.fitness(towards: numberToSolve) > $1.fitness(towards: numberToSolve) }
    }
}
```

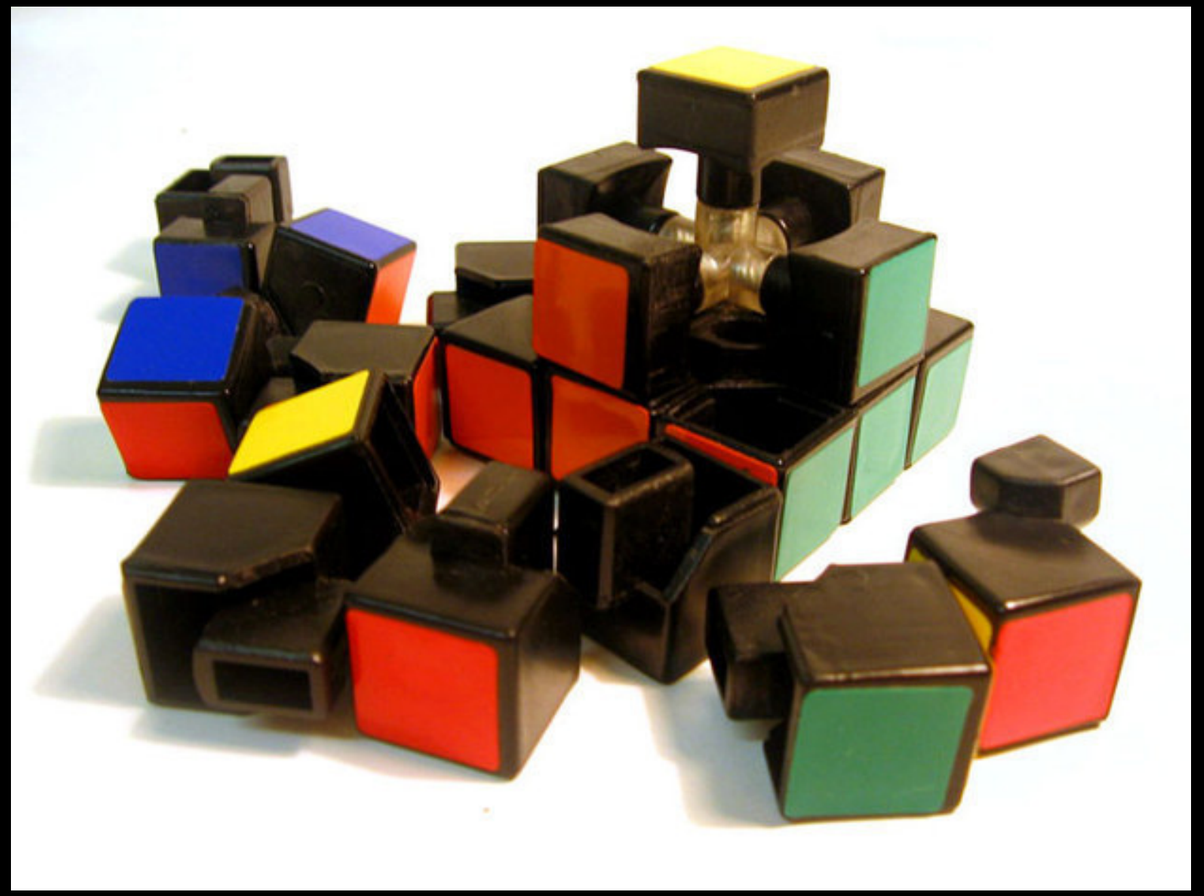
Genetic Algorithms - Example

```
Looking for:          00000000000000000000000000001000111110000001100010111110011O
Fittest individual:   00000000000000000000000000000000000011000000010000010000000000 (fitness: 81%)
Fittest individual:   00000000000000000000000000000000000011000000010000010001000010 (fitness: 84%)
Fittest individual:   00000000000000000000000000000000000011111000000110000000010100010 (fitness: 90%)
Fittest individual:   00000000000000000000000000000000000011111000000110000000010100010 (fitness: 90%)
Fittest individual:   00000000000000000000100000000010001111110000001100000011101001l0 (fitness: 93%)
Fittest individual:   00000000000000000000100000000010001111110000001100000011111001l0 (fitness: 95%)
Fittest individual:   00000000000000000000100000000010001111110000001100000011111001l0 (fitness: 95%)
Fittest individual:   00000000000000000000100000000010001111110000001100000011111001l0 (fitness: 95%)
Fittest individual:   00000000000000000000000000000010001111110000001100000011111001l0 (fitness: 96%)
Fittest individual:   00000000000000000000000000000010001111000000011000101111110011O (fitness: 98%)
Fittest individual:   00000000000000000000000000000010001111000000011000101111110011O (fitness: 98%)
Fittest individual:   00000000000000000000000000000010001111000000011000101111110011O (fitness: 100%)
!Solved! after 12 generations
```

Rubik's Cubes

Rubik's Cubes

Rubik's Cubes



Rubik's Cubes
43,252,003,274,489,856,000

Rubik's Cubes

RubikSwift

```
struct Cube {
    struct Pieces {
        var edges: EdgePieceCollection
        var corners: CornerPieceCollection
    }

    var pieces: Pieces
}
```

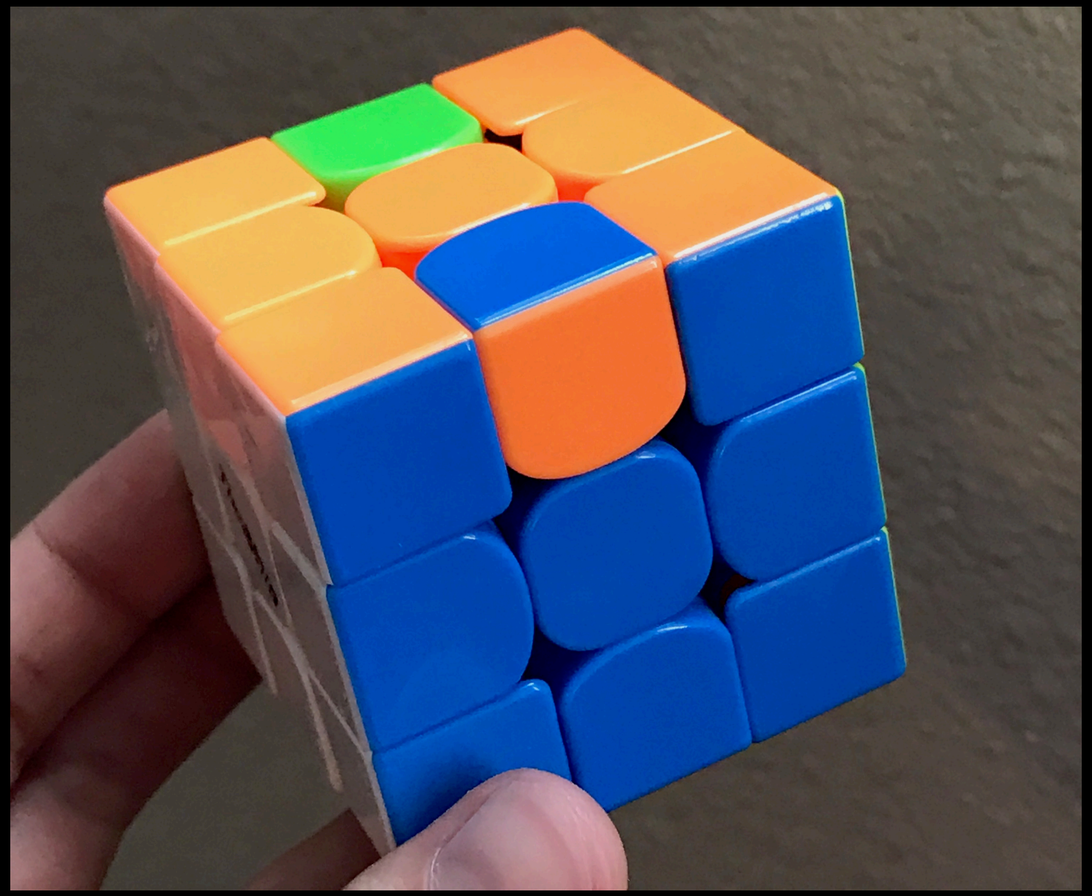
RubikSwift

```
enum EdgeLocation {
    case topRight, topFront, topLeft, topBack...
}

struct EdgePiece {
    enum Orientation {
        case correct
        case flipped
    }

    var location: EdgeLocation
    var orientation: Orientation
}
```

RubikSwift



RubikSwift

```
struct CornerPiece {
    enum Orientation {
        case correct
        case rotatedClockwise
        case rotatedCounterClockwise
    }

    var location: CornerLocation
    var orientation: Orientation
}
```

RubikSwift

```
struct Cube {
    struct Pieces {
        var edges: EdgePieceCollection
        var corners: CornerPieceCollection
    }

    var pieces: Pieces
}
```

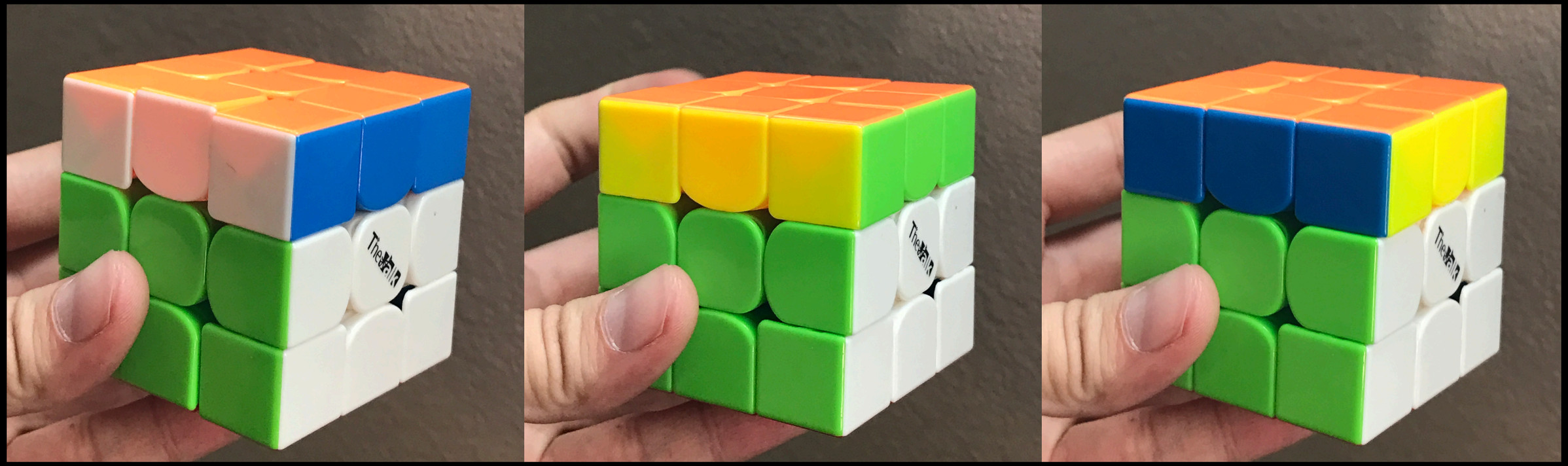
RubikSwift

```
enum Face {
    case top, bottom, left, right, front, back
}

struct Move {
    enum Magnitude {
        case clockwiseQuarterTurn
        case halfTurn
        case counterClockwiseQuarterTurn
    }

    let face: Face
    let magnitude: Magnitude
}
```

RubikSwift



RubikSwift

```
extension Cube {
    mutating func apply(_ move: Move)
}
```

RubikSwift

```
final class Individual {
    let moves: [Move]

    init(moves: [Move]) {
        self.moves = moves
    }
}
```

RubikSwift

```
typealias Fitness = Int

extension Individual {
    func fitness(solvingCube cube: Cube) -> Fitness {
        var cubeAfterApplyingMoves = cube
        cubeAfterApplyingMoves.apply(self.moves)

        return cubeAfterApplyingMoves.numberOfSolvedPieces
    }
}

extension Cube {
    // Number of pieces in the correct location and orientation
    var numberOfSolvedPieces: Int
}
```

RubikSwift

```
extension Individual {
    func mutate() -> Individual {
        var moves = self.moves

        let randomMoves = Move.randomMoves(count: Int.random(in: 5...20))

        moves += randomMoves

        return Individual(moves: moves)
    }
}
```

RubikSwift

```
final class Solver {
    private(set) var population: [Individual]

    init(scrambledCube: Cube, populationSize: Int)

    func runGeneration() {
        population.removeLast(Int(Double(population.count) * 0.8))

        population += population.map { $0.mutate() }

        population.sort {
            $0.fitness(solvingCube: scrambledCube) >
            $1.fitness(solvingCube: scrambledCube)
         }
    }
}
```

RubikSwift

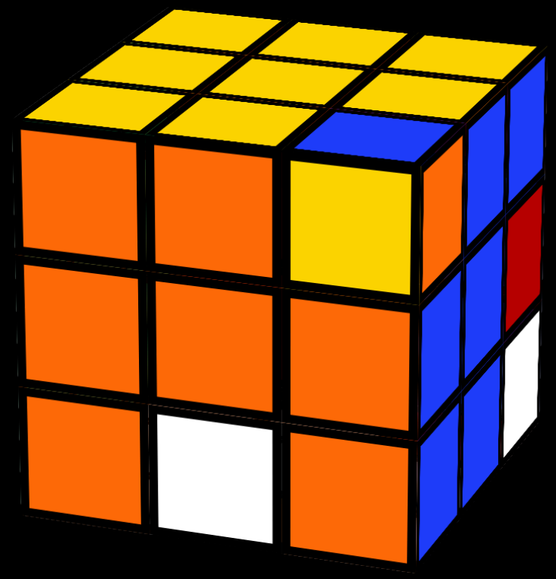
Does it *actually* work?

RubikSwift

```
Cube: R' F' B D2 L' R' D2 R' F2 B2 D F L' R2 F' U2 R' U' D F

1: New best: B2 (3.0)
3: New best: B2 U D' U2 F2 D2 B U2 D R B' [...] (6)
7: New best: B2 L2 U2 L' B2 F' U' U' D L2 [...] (7)
100 (avg fitness 3.6012, 23806 algs/sec, 0 min elapsed)
3465: New best: B2 D2 U R2 B2 U2 B' F2 D [...] (13)
10000 (avg fitness 6.462, 11217 algs/sec, 74 min elapsed)
25781: New best: L' D' B2 L2 B' D R2 F R' [...] (**16**)
80800 (avg fitness 9.2612, 7676 algs/sec, 877 min elapsed)
```

RubikSwift



Fitness: 16

Links

- http://github.com/JaviSoto/talks
- http://github.com/JaviSoto/RubikSwift
- https://rogeralsing.com/2008/12/07/genetic-programming-evolution-of-mona-lisa/

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Thank you