Wild Card Genetic Algorithm Assignment

Learning Abstract

This assignment features a genetic algorithm-based solution to the following creative problem: algorithmic melody composition. Five new fitness metrics are the main facet of this project with slight alterations to naming conventions surrounding mutation, crossovers, copies, and selection pulled from the previous RBG assignment.

About the GA

This genetic algorithm utilizes five different fitness metrics to compose melodies algorithmically that flow in C major. Unlike the RBG problem, the fitness metrics are designed more carefully to design melodies that have distinct types of motions to produce results that sound better than random notes. The five fitness metrics are:

- Stepwise motion melodies – melodies with sequential notes that move up or down 1 interval from one another are favored
- Pair-wise melodies – melodies with pairs of the same notes repeated are favored
- Ascending jumps and stepwise declines melodies – melodies with interval jumps going up the scale and stepwise declines down the scale are favored
- Stepwise slashing melodies – melodies with stepwise motion of 2 or 3 consecutive notes are favored (interval direction does not matter)
- Zig-zag melodies – melodies that have stepwise motion and turn on notes of degrees 1, 3, 5, or 7 are favored

Copies, crossovers, selection, and mutations occur similarly to the RBG problem.

The Tasks

Task 1: RBG-String

Code

```
; Global variable for the # of atoms in pitch-string
( setf *limit* 26 )

; Only supports C major key...could add more keys in the future
( setf *CMAJOR* '(C D E F G A B C2 D2 E2 F2 G2 A2 B2
                  C/2 D/2 E/2 F/2 G/2 A/2 B/2) )

; Global var for adding more keys in the future
( setf *CURRENT-KEY* *CMAJOR* )
```

```
; Function that returns a random pitch in the specified pitch-list
( defmethod derive-pitch ()
    ; C major + durations quarter note, half-note, and eighth note
    ( setf pitch-list *CMAJOR* )
    ( nth ( random ( length pitch-list ) ) pitch-list )
)

; Method that creates pitch-list
( defmethod pitch-string ()
    ( pitch-string-helper *limit* )
)

; Recursive function that creates pitch-list using parameter n = list size
( defmethod pitch-string-helper ( n )
    (cond
        (( = n 0 )
            '()
        )
        ( t
            ( cons ( derive-pitch ) ( pitch-string-helper ( - n 1 ) ) )
        )
    )
)
```

Demo

```
[1]> ( load "D:\\Programming Projects\\Lisp Projects\\Final
Assignment\\wildcardga.lisp" )
;; Loading file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp ...
;; Loaded file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp
T
[2]> *limit*
26
[3]> ( derive-pitch )
B/2
[4]> ( derive-pitch )
G
```

```
[5]> ( list ( derive-pitch ) ( derive-pitch ) ( derive-pitch ) (
derive-pitch ) ( derive-pitch ) )
(B/2 G D B/2 A2)
[6]> ( list ( derive-pitch ) ( derive-pitch ) ( derive-pitch ) (
derive-pitch ) ( derive-pitch ) )
(B/2 A2 C/2 B E/2)
[7]> ( pitch-string )
(D/2 B F/2 B G2 A/2 G/2 A2 D/2 C2 F/2 G2 B2 B2 A B/2 A/2 B/2 G/2
F/2 E/2 D F/2 E A2 B/2)
[8]> ( pitch-string )
(F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2 C B/2 G G2 E G
B/2 E2 F/2 F A/2 F/2)
[9]> ( pitch-string )
(B2 F/2 F2 E F2 A C2 G/2 F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2
D E2 G2 C2 E/2)
[10]> ( pitch-string )
(D2 G F/2 B2 C/2 D G/2 G/2 G/2 B2 G2 E F/2 B2 A G A F2 E/2 E/2 D
A/2 G2 A2 B/2 E/2)
[11]>
```

Task 2: Mutation

Code

```
; Method that mutates a given list
( defmethod mutation ( ( pitch-str list ) &aux position symbol )
    ( setf position ( random ( length pitch-str ) ) )
    ( setf symbol ( others *CURRENT-KEY* ( nth position pitch-str ) ) )
    ( change pitch-str ( pick symbol ) position )
)

; Recursive method that returns list of pitches from *CURRENT-KEY*
excluding
; the parameter atom
( defmethod others ( ( li list ) pitch )
    ( cond
        (( null li )
            '()
        )
        (( not ( equal pitch ( car li ) ) )
            ( cons ( car li ) ( others ( cdr li ) pitch ) )
```

```
        )
        (t
            ( others ( cdr li ) pitch )
        )
    )
)

; Method to pick a random element form a list
( defmethod pick ( ( symbols list ) )
    ( nth ( random ( length symbols ) ) symbols )
)

; Method that changes an element of a list at a specific position
; to a give symbol
( defmethod change ( ( str list ) symbol pos )
    ( cond
        (( = pos 0 )
            ( append ( list symbol ) ( cdr str ) )
        )
        (t
            ( cons ( car str ) ( change ( cdr str ) symbol ( - pos 1 ) ) )
        )
    )
)
```

Demo

```
[1]> ( load "D:\\Programming Projects\\Lisp Projects\\Final
Assignment\\wildcardga.lisp" )
;; Loading file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp ...
;; Loaded file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp
T
[2]> ( setf pitches '(C B D E ) )
(C B D E)
[3]> ( mutation pitches )
(C B C2 E)
[4]> pitches
```

```
(C B D E)
[5]> ( mutation pitches )
(C C2 D E)
[6]> pitches
(C B D E)
[7]> ( mutation pitches )
(C B D2 E)
[8]> ( setf s '( A B C D E F G ) )
(A B C D E F G)
[9]> ( setf s ( mutation s ) )
(A B C D E G G)
[10]> ( setf s ( mutation s ) )
(A B C D E C2 G)
[11]> ( setf s ( mutation s ) )
(A B C D E C2 E)
[12]> ( setf s ( mutation s ) )
(A C C D E C2 E)
[13]> ( setf x ( pitch-string ) )
(F/2 B G2 A/2 G/2 A2 D/2 C2 F/2 G2 B2 B2 A B/2 A/2 B/2 G/2 F/2
E/2 D F/2 E A2 B/2 F2 D/2)
[14]> ( setf x ( mutation x ) )
(F/2 B G2 A/2 G/2 A2 D/2 C2 F/2 G2 B2 B2 A B/2 E B/2 G/2 F/2 E/2
D F/2 E A2 B/2 F2 D/2)
[15]> ( setf x ( mutation x ) )
(F/2 B G2 A/2 G/2 A2 D/2 C2 F/2 G2 B2 B2 A B/2 E B/2 G/2 F/2 E/2
D F/2 E A2 C F2 D/2)
[16]>
```

Task 3: Crossover

Code

```
; Method that appends pieces of two lists together based on a pivot
( defmethod crossover ( ( m list ) ( f list ) &aux pos )
    ( setf pos ( + 1 ( random ( length m ) ) ) )
    ( append ( first-n m pos ) ( rest-n f pos ) )
)

; Recursive method that outputs the first n elements of a list as a list
( defmethod first-n ( ( m list ) pos )
    ( cond
```

```
        (( = pos 0 )
            '()
        )
        (t
            ( cons ( car m ) ( first-n ( cdr m ) ( - pos 1 ) ) )
        )
    )
)

; Recursive method that outputs the remaining n elements of a list as a
list
( defmethod rest-n ( ( f list  ) pos )
    (cond
        (( = pos 0 )
            f
        )
        (t
            ( rest-n ( cdr f ) ( - pos 1 ) )
        )
    )
)
```

Demo

```
[1]> ( load "D:\\Programming Projects\\Lisp Projects\\Final
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;; Loading file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp ...
;; Loaded file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp
T
[2]> ( setf m '( A B C D E F G ) )
(A B C D E F G)
[3]> ( setf f '( A2 B2 C2 D2 E2 F2 G2 ) )
(A2 B2 C2 D2 E2 F2 G2)
[4]> ( crossover m f )
(A B C D E F G)
[5]> ( crossover m f )
(A B C D E F2 G2)
[6]> ( crossover m f )
```

```
(A B C D E F G)
[7]> ( crossover m f )
(A B C D E F2 G2)
[8]> m
(A B C D E F G)
[9]> f
(A2 B2 C2 D2 E2 F2 G2)
[10]> ( setf m ( pitch-string ) )
(D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2 A2 D/2 C2 F/2
G2 B2 B2 A B/2 A/2 B/2)
[11]> ( setf f ( pitch-string ) )
(G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2
F/2 G/2 C2 C B/2 G G2)
[12]> ( crossover m f )
(D B/2 A2 B/2 A2 C/2 B E/2 D/2 B E/2 G F/2 B2 D/2 G/2 G A D/2
F/2 G/2 C2 C B/2 G G2)
[13]> ( crossover m f )
(D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2 A2 D/2 A D/2
F/2 G/2 C2 C B/2 G G2)
[14]> ( crossover m f )
(D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2 A2 G A D/2 F/2
G/2 C2 C B/2 G G2)
[15]> m
(D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2 A2 D/2 C2 F/2
G2 B2 B2 A B/2 A/2 B/2)
[16]> f
(G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2
F/2 G/2 C2 C B/2 G G2)
[17]>
```

Task 4: Demos for Mutation and Crossover

Code

```
; Method to demo the mutation method
( defmethod mutation-demo (&aux s m)
    ( setf s ( pitch-string ) )
    ( dotimes ( i 10 )
        ( format t "s = ~A~%" s )
        ( setf m ( mutation s ) )
        ( format t "m = ~A~%~%" m )
    )
)
```

```
; Method to demo the crossover method
( defmethod crossover-demo (&aux m f x)
    ( setf m ( pitch-string ) )
    ( setf f ( pitch-string ) )
    ( dotimes ( i 10 )
        ( format t "m = ~A~%" m )
        ( setf x ( crossover m f ) )
        ( format t "x = ~A~%" x )
        ( format t "f = ~A~%~%" f )
    )
)
```

Demo

```
[1]> ( load "D:\\Programming Projects\\Lisp Projects\\Final
Assignment\\wildcardga.lisp" )
;; Loading file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp ...
;; Loaded file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp
T
[2]> ( mutation-demo )
s = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2
G/2 A2 D/2 C2 F/2 G2 B2 B2)
m = (B/2 G B/2 G D B/2 A2 E2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2
A2 D/2 C2 F/2 G2 B2 B2)

s = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2
G/2 A2 D/2 C2 F/2 G2 B2 B2)
m = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2
G/2 A2 E2 C2 F/2 G2 B2 B2)

s = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2
G/2 A2 D/2 C2 F/2 G2 B2 B2)
m = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B B B G2 A/2 G/2
A2 D/2 C2 F/2 G2 B2 B2)

s = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2
G/2 A2 D/2 C2 F/2 G2 B2 B2)
```

```
m = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B F/2 A/2
G/2 A2 D/2 C2 F/2 G2 B2 B2)

s = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2
G/2 A2 D/2 C2 F/2 G2 B2 B2)
m = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B B/2 A/2
G/2 A2 D/2 C2 F/2 G2 B2 B2)

s = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2
G/2 A2 D/2 C2 F/2 G2 B2 B2)
m = (B/2 G F G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2
A2 D/2 C2 F/2 G2 B2 B2)

s = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2
G/2 A2 D/2 C2 F/2 G2 B2 B2)
m = (B/2 G B/2 G D B/2 A2 B/2 B2 C/2 B E/2 D/2 B F/2 B G2 A/2
G/2 A2 D/2 C2 F/2 G2 B2 B2)

s = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2
G/2 A2 D/2 C2 F/2 G2 B2 B2)
m = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B E B G2 A/2 G/2
A2 D/2 C2 F/2 G2 B2 B2)

s = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2
G/2 A2 D/2 C2 F/2 G2 B2 B2)
m = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2
G/2 A2 D/2 C2 F/2 C B2 B2)

s = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2
G/2 A2 D/2 C2 F/2 G2 B2 B2)
m = (B/2 G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2
G/2 A2 D/2 C2 E/2 G2 B2 B2)

NIL
[3]> ( crossover-demo )
m = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2
F/2 F2 E F2 A C2 G/2)
x = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2
F/2 F2 E F2 A C2 G/2)
f = (F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G
F/2 B2 C/2 D G/2 G/2)
```

```
m = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2
F/2 F2 E F2 A C2 G/2)
x = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2
F/2 F2 E F2 A C2 G/2)
f = (F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G
F/2 B2 C/2 D G/2 G/2)

m = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2
F/2 F2 E F2 A C2 G/2)
x = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 D2 G
F/2 B2 C/2 D G/2 G/2)
f = (F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G
F/2 B2 C/2 D G/2 G/2)

m = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2
F/2 F2 E F2 A C2 G/2)
x = (G A D/2 F/2 G/2 C2 C B/2 G G2 E A/2 D/2 D E2 G2 C2 E/2 D2 G
F/2 B2 C/2 D G/2 G/2)
f = (F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G
F/2 B2 C/2 D G/2 G/2)

m = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2
F/2 F2 E F2 A C2 G/2)
x = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2
F/2 F/2 B2 C/2 D G/2 G/2)
f = (F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G
F/2 B2 C/2 D G/2 G/2)

m = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2
F/2 F2 E F2 A C2 G/2)
x = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2
F/2 F2 E C/2 D G/2 G/2)
f = (F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G
F/2 B2 C/2 D G/2 G/2)

m = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2
F/2 F2 E F2 A C2 G/2)
x = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 D2 G
F/2 B2 C/2 D G/2 G/2)
```

```
f = (F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G
F/2 B2 C/2 D G/2 G/2)

m = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2
F/2 F2 E F2 A C2 G/2)
x = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2
F/2 F/2 B2 C/2 D G/2 G/2)
f = (F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G
F/2 B2 C/2 D G/2 G/2)

m = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2
F/2 F2 E F2 A C2 G/2)
x = (G A D/2 F/2 G/2 C2 C B/2 G G2 A2 A/2 D/2 D E2 G2 C2 E/2 D2
G F/2 B2 C/2 D G/2 G/2)
f = (F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G
F/2 B2 C/2 D G/2 G/2)

m = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2
F/2 F2 E F2 A C2 G/2)
x = (G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2 F A/2 E/2 D2 G
F/2 B2 C/2 D G/2 G/2)
f = (F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G
F/2 B2 C/2 D G/2 G/2)

NIL
[4]>
```

Task 5: The Fitness Metric

---

1. The fitness metric definition task …

```
; Fitness metric for "stepwise motion" in a melody
;    -If pitches are 1 jump away from each other add 1
;    -If pitches are 2 jumps away from each other add 0.5
;    -If pitches are 0 jumps away from each other add 0.8
;    -Otherwise, add nothing
( defmethod fitness-stepwise-motion ( ( li list ) )
   ; use mod to account for duplicate notes with different durations
   ( cond
      (( > (length li ) 1 )
         ( setf first-pitch-int ( mod ( position ( car li )
*CURRENT-KEY* ) 7 ) )
```

```
            ( setf second-pitch-int ( mod ( position ( cadr li )
*CURRENT-KEY* ) 7 ) )
            ( setf pitch-distance ( abs ( - second-pitch-int
first-pitch-int ) ) )
        )
    )
    (cond
        (( = ( length li ) 1 )
            0
        )
        (( = pitch-distance 1 )
            ( + 1 ( fitness-stepwise-motion ( cdr li ) ) )
        )
        (( = pitch-distance 2 )
            ( + 0.5 ( fitness-stepwise-motion ( cdr li ) ) )
        )
        (( = pitch-distance 0 )
            ( + 0.8 ( fitness-stepwise-motion ( cdr li ) ) )
        )
        (t
            ( fitness-stepwise-motion ( cdr li ) )
        )

    )

)

; Fitness method that favors pairs of notes
;    -reward +1 if first and second notes are equal if last two notes
;    -reward +1 if first note = second note and first note pitch != third
note pitch
( defmethod fitness-pairs ( ( li list ) )
    ( cond
        (( > (length li ) 2 )
            ( setf first-pitch-int ( mod ( position ( car li )
*CURRENT-KEY* ) 7 ) )
            ( setf third-pitch-int ( mod ( position ( third li )
*CURRENT-KEY* ) 7 ) )
            ( setf pitch-distance ( abs ( - third-pitch-int
first-pitch-int ) ) )
```

```
        )
    )
    (cond
        (( < ( length li ) 2 )
            0
        )
        ((AND ( equal ( car li ) ( second li )  ) ( = ( length li ) 2 ) )
                ( + 1 ( fitness-pairs ( cddr li ) ) )
        )
        ((AND ( equal ( car li ) ( second li ) ) ( not ( = 0
pitch-distance ) ) )
            (+ 1 ( fitness-pairs ( cddr li ) ) )
        )
        (t
            ( + 0 ( fitness-pairs ( cddr li ) ) )
        )
    )
)

; Fitness method that favors melodies with ascending jumps and
; descending lines of two or three or four notes
;    -award +1 point for pitch-distance greater than 1
;    -award +1 point for pitch-distance equal to -1
( defmethod fitness-ascending-jumps ( ( li list ) )
    (cond
        (( > ( length li ) 1 )
            ( setf first-pitch-int ( mod ( position ( car li )
*CURRENT-KEY* ) 7 ) )
            ( setf second-pitch-int ( mod ( position ( cadr li )
*CURRENT-KEY* ) 7 ) )
            ( setf pitch-distance ( - second-pitch-int first-pitch-int ) )
        )
    )
    (cond
        (( = ( length li ) 1 )
            0
        )
        (( > pitch-distance 1 )
            ( + 1 ( fitness-ascending-jumps ( cdr li ) ) )
        )
```

```
        (( = pitch-distance -1 )
            ( + 1 ( fitness-ascending-jumps ( cdr li ) ) )
        )
        (t
            (+ 0 ( fitness-ascending-jumps ( cdr li ) ) )
        )
    )
)

; Fitness method that favors slashing melodies consisting of ascending and
descending lines of two
; or three or four notes
( defmethod fitness-stepwise-slashing ( ( li list ) )
    ( fitness-slashing-helper li 0 0 )
)

; Helper recursion method that favors slashing melodies consisting of
ascending and descending lines of two
; or three or four notes -- prev-pitch-dist stores pitch distance of
previous note pair
; -+1 if stepwise for 2, 3, or 4 notes in a row

( defmethod fitness-slashing-helper ( ( li list ) prev-pitch-dist
notes-num )
    ( cond
        (( > ( length li ) 1 )
            ( setf first-pitch-int ( mod ( position ( car li )
*CURRENT-KEY* ) 7 ) )
            ( setf second-pitch-int ( mod ( position ( cadr li )
*CURRENT-KEY* ) 7 ) )
            ( setf pitch-distance ( - second-pitch-int first-pitch-int ) )
        )
    )
    ( cond
        (( = ( length li ) 1 )
            0
        )
        (   ( and
                ( > notes-num 0 )
                ( < notes-num 3 )
```

```
                ( fitness-ascending-descending-p prev-pitch-dist
pitch-distance )
            )
            ( + 1 ( fitness-slashing-helper ( cdr li ) pitch-distance ( +
notes-num 1 ) ) )
        )
        ; check if first two notes are stepwise, if so, reward +1
        ( ( and
                ( or ( = pitch-distance 1 ) ( = pitch-distance -1 ) )
                ( = notes-num 0 )
          )
            ( + 1 ( fitness-slashing-helper ( cdr li ) pitch-distance ( +
notes-num 1 ) ) )
        )
        (t
            ( fitness-slashing-helper ( cdr li ) pitch-distance 0 )
        )
    )

)

; Predicate used to determine if notes are stepwise ascending/descending
compared to a previous
; direction
( defmethod fitness-ascending-descending-p ( prev-direction pitch-distance
)
        ( or
            ( and ( = pitch-distance 1) ( = prev-direction 1 ) )
            ( and ( = pitch-distance -1 ) ( = prev-direction -1 ) )
        )
)

; Fitness method used to favor melodies which zig and zag but only turn on
certain notes ( degrees
; 1, 3, 5, and 7 of the scale ), with some repeated notes
( defmethod fitness-zig-zag ( ( li list ) )
    ( fitness-zig-zag-helper li 0 )
)
; Recursive helper method method for fitness-zig-zag
;   -+1 point is rewarded for turning (stepwise) on degree 1, 3, 5, or 7
```

```
;   -+0.6 is rewarded for stepwise motion
;   -+0.3 is rewarded for repeated notes
( defmethod fitness-zig-zag-helper ( ( li list ) prev-pitch-dist )
    (cond
        (( > ( length li ) 1 )
            ( setf first-pitch-int ( mod ( position ( car li )
*CURRENT-KEY* ) 7 ) )
            ( setf second-pitch-int ( mod ( position ( cadr li )
*CURRENT-KEY* ) 7 ) )
            ( setf pitch-distance ( - second-pitch-int first-pitch-int ) )
        )
    )
    (cond
        (( = ( length li ) 1 )
            0
        )
        (   (and
                ( fitness-zig-zag-p prev-pitch-dist pitch-distance )
                ( or
                    ( = ( + first-pitch-int 1 ) 1 )
                    ( = ( + first-pitch-int 1 ) 3 )
                    ( = ( + first-pitch-int 1 ) 5 )
                    ( = ( + first-pitch-int 1 ) 7 )
                )
            )
                ( + 1 ( fitness-zig-zag-helper ( cdr li ) pitch-distance )
)
        )
        (( or ( = pitch-distance 1 ) ( = pitch-distance -1 ) )
            ( + 0.6 ( fitness-zig-zag-helper ( cdr li ) pitch-distance ) )
        )
        ((= pitch-distance 0 )
            ( + 0.3 ( fitness-zig-zag-helper ( cdr li ) pitch-distance ) )
        )
        (t
            ( fitness-zig-zag-helper ( cdr li ) pitch-distance  )
        )

    )
)
```

```
; Predicate function to check if a note pair "zig zags" based on note
before
( defmethod fitness-zig-zag-p ( prev-direction pitch-distance )
    ( or
        ( and ( = pitch-distance 1 ) ( < prev-direction 0 ) )
        ( and ( = pitch-distance -1 ) ( > prev-direction 0 ) )
    )
)
```

2. The interactive demo task …

```
[1]> ( load "D:\\Programming Projects\\Lisp Projects\\Final
Assignment\\wildcardga.lisp" )
;; Loading file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp ...
;; Loaded file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp
T
[2]> ( setf x ( pitch-string ) )
(G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2 A2 D/2
C2 F/2 G2 B2 B2 A)
[3]> x
(G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2 A2 D/2
C2 F/2 G2 B2 B2 A)
[4]> ( fitness-stepwise-motion x )
12.8
[5]> ( fitness-pairs x )
0
[6]> ( fitness-ascending-jumps x )
13
[7]> ( fitness-stepwise-slashing x )
8
[8]> ( fitness-zig-zag x )
7.8999996
[9]> ( setf fitness #'fitness-stepwise-motion )
#<STANDARD-GENERIC-FUNCTION FITNESS-STEPWISE-MOTION>
[10]> ( funcall fitness x )
12.8
```

```
[11]> ( setf fitness #'fitness-pairs )
#<STANDARD-GENERIC-FUNCTION FITNESS-PAIRS>
[12]> ( funcall fitness x )
0
[13]> ( setf fitness #'fitness-ascending-jumps )
#<STANDARD-GENERIC-FUNCTION FITNESS-ASCENDING-JUMPS>
[14]> ( funcall fitness x )
13
[15]> ( setf fitness #'fitness-stepwise-slashing )
#<STANDARD-GENERIC-FUNCTION FITNESS-STEPWISE-SLASHING>
[16]> ( funcall fitness x )
8
[17]> ( setf fitness #'fitness-zig-zag )
#<STANDARD-GENERIC-FUNCTION FITNESS-ZIG-ZAG>
[18]> ( funcall fitness x )
7.8999996
[19]>
```

3. The encapsulated fitness function task …

```
; Method to test the five fitness methods
( defmethod fitness-demo (&aux x fitness)
    ( setf x ( pitch-string ) )
    ( format t "x = ~A~%" x )
    ( format t "Directly applying the fitness metrics ...~%" )
    ( format t "fitness-stepwise-motion = ~A~%" ( fitness-stepwise-motion
x ) )
    ( format t "fitness-pairs = ~A~%" ( fitness-pairs x ) )
    ( format t "fitness-ascending-jumps = ~A~%" ( fitness-ascending-jumps
x ) )
    ( format t "fitness-stepwise-slashing = ~A~%" (
fitness-stepwise-slashing x ) )
    ( format t "fitness-zig-zag = ~A~%" ( fitness-zig-zag x ) )
    ( format t "Indirectly applying the fitness metrics ... ~%" )
    ( setf fitness #'fitness-stepwise-motion )
    ( format t "fitness-stepwise-motion = ~A~%" ( funcall fitness x ) )
    ( setf fitness #'fitness-pairs )
    ( format t "fitness-pairs = ~A~%" ( funcall fitness x ) )
    ( setf fitness #'fitness-ascending-jumps )
    ( format t "fitness-ascending-jumps = ~A~%" ( funcall fitness x ) )
```

```
    ( setf fitness #'fitness-stepwise-slashing )
    ( format t "fitness-stepwise-slashing = ~A~%" ( funcall fitness x ) )
    ( setf fitness #'fitness-zig-zag )
    ( format t "fitness-zig-zag = ~A~%" ( funcall fitness x ) )
)
```

4. The thinking task …

As mentioned before, setting a fitness variable allows the program to easily switch between different fitness functions without changing code in multiple places.

5. The encapsulated demo task …

```
[1]> ( load "D:\\Programming Projects\\Lisp Projects\\Final
Assignment\\wildcardga.lisp" )
;; Loading file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp ...
;; Loaded file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp
T
[2]> ( fitness-demo )
x = (G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2 A2
D/2 C2 F/2 G2 B2 B2 A)
Directly applying the fitness metrics ...
fitness-stepwise-motion = 12.8
fitness-pairs = 0
fitness-ascending-jumps = 13
fitness-stepwise-slashing = 8
fitness-zig-zag = 7.8999996
Indirectly applying the fitness metrics ...
fitness-stepwise-motion = 12.8
fitness-pairs = 0
fitness-ascending-jumps = 13
fitness-stepwise-slashing = 8
fitness-zig-zag = 7.8999996
NIL
[3]>
```

Task 6: The Individual Class

---

1. The Lisp code task …

```
; Class for an individual in a population
; -fields:
```

```
;       -melody -> pitch-string
;       -fitness -> the fitness of the pitch-string
;       -number -> the number of the individual in the population
( defclass individual ()
    (
        ( melody :accessor individual-melody :initarg :melody )
        ( fitness :accessor individual-fitness :initarg :fitness )
        ( number :accessor individual-number :initarg :number )
    )
)

; Method for creating a random individual object
( defmethod random-individual (&aux melody )
    ( setf melody ( pitch-string ) )
    ( make-instance 'individual
        :melody melody
        :fitness ( funcall *fitness* melody )
        :number 0
    )
)

; Method to create a new individual with number and pitch string inputs
( defmethod new-individual ( ( nr number ) ( notes list ) )
    ( make-instance 'individual
        :melody notes
        :fitness ( funcall *fitness* notes )
        :number nr
    )
)

; Method to display an individual
( defmethod display ( ( i individual ) )
    ( display-nnl i ) ( terpri )
)

; Method to display an individual with better format
( defmethod display-nnl ( ( i individual ) )
    ( prin1 ( individual-number i ) )
    ( princ ( filler ( individual-number i ) ) )
    ( prin1 ( individual-melody i ) )
```

```
    ( princ "   " )
    ( prin1 ( individual-fitness i ) )
    ( princ ( filler ( individual-fitness i ) ) )
)

; Method to create space based on number passed in
( defmethod filler ( ( n number ) )
    ( cond
        ( ( < n 10 ) "     " )
        ( ( < n 100 ) "    " )
        ( ( < n 1000 ) "   " )
        ( ( < n 10000 ) "  " )
        ( ( < n 100000 ) " ")
    )
)

; Method for fitness-stepwise-motion with individual param
( defmethod fitness-stepwise-motion ( ( i individual ) )
    ( fitness-stepwise-motion ( individual-melody i ) )
)

; Method for fitness-pairs with individual param
( defmethod fitness-pairs ( ( i individual ) )
    ( fitness-pairs ( individual-melody i ) )
)

; Method for fitness-ascending-jumps with individual param
( defmethod fitness-ascending-jumps ( ( i individual ) )
    ( fitness-ascending-jumps ( individual-melody i ) )
)

; Method for fitness-stepwise-slashing with individual param
( defmethod fitness-stepwise-slashing ( ( i individual ) )
    ( fitness-stepwise-slashing ( individual-melody i ) )
)

; Method for fitness-zig-zag with individual param
( defmethod fitness-zig-zag ( ( i individual ) )
    ( fitness-zig-zag ( individual-melody i ) )
)
```

2. The interactive demo task …

```
[1]> ( load "D:\\Programming Projects\\Lisp Projects\\Final
Assignment\\wildcardga.lisp" )
;; Loading file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp ...
;; Loaded file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp
T
[2]> ( setf melody ( pitch-string ) )
(G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2 A2 D/2
C2 F/2 G2 B2 B2 A)
[3]> melody
(G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2 A2 D/2
C2 F/2 G2 B2 B2 A)
[4]> ( setf *fitness* #'fitness-stepwise-motion )
#<STANDARD-GENERIC-FUNCTION FITNESS-STEPWISE-MOTION>
[5]> ( setf melody-i ( new-individual 1 melody ) )
#<INDIVIDUAL #x1AAE7965>
[6]> ( individual-number melody-i )
1
[7]> ( individual-melody melody-i )
(G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2 A2 D/2
C2 F/2 G2 B2 B2 A)
[8]> ( display melody-i )
1     (G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2
A2 D/2 C2 F/2 G2 B2 B2 A)  12.8
NIL
[9]> ( funcall *fitness* melody )
12.8
[10]> ( setf r ( random-individual ) )
#<INDIVIDUAL #x1AAD20ED>
[11]> ( display r )
0     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
NIL
[12]> ( setf r ( random-individual ) )
#<INDIVIDUAL #x1AAE93AD>
[13]> ( display r )
```

```
0      (B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2 F/2 F2 E F2 A C2 G/2
F/2 A E/2 G2 C B E)  10.900001
NIL
[14]>
```

3. The encapsulated demo code task …

```
; Demo for individual class methods
( defmethod individual-demo (&aux i0 i1 i2 i3 one two three)
    ( setf *fitness* #'fitness-stepwise-motion )
    ( setf i0 ( random-individual ) )
    ( display i0 )
    ( setf one ( pitch-string  ) )
    ( setf i1 ( new-individual 1 one ) )
    ( display i1 )
    ( setf two ( pitch-string  ) )
    ( setf i2 ( new-individual 2 two ) )
    ( display i2 )
    ( setf three ( pitch-string ) )
    ( setf i3 ( new-individual 3 three ) )
    ( display i3 )
    ( format t "Fitness of i0 = ~A~%" ( funcall *fitness* i0 ) )
    ( format t "Fitness of i1 = ~A~%" ( funcall *fitness* i1 ) )
    ( format t "Fitness of i2 = ~A~%" ( funcall *fitness* i2 ) )
    ( format t "Fitness of i3 = ~A~%" ( funcall *fitness* i3 ) )
    nil
)
```

4. The encapsulated demo task …

```
[1]> ( load "D:\\Programming Projects\\Lisp Projects\\Final
Assignment\\wildcardga.lisp" )
;; Loading file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp ...
;; Loaded file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp
T
[2]> ( individual-demo )
0      (G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2
A2 D/2 C2 F/2 G2 B2 B2 A)  12.8
```

```
1     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
2     (B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2 F/2 F2 E F2 A C2 G/2
F/2 A E/2 G2 C B E)  10.900001
3     (C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G F/2 B2 C/2 D G/2
G/2 G/2 B2 G2 E F/2 B2 A)  13.500001
Fitness of i0 = 12.8
Fitness of i1 = 15.1
Fitness of i2 = 10.900001
Fitness of i3 = 13.500001
NIL
```

Task 7: The Population Class

---

1. The demo task …

```
[1]> ( load "D:\\Programming Projects\\Lisp Projects\\Final
Assignment\\wildcardga.lisp" )
;; Loading file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp ...
;; Loaded file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp
T
[2]> ( setf p ( initial-population ) )
#<POPULATION #x1AABD405>
[3]> ( display p )


Generation 0 population ...

1     (G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2
A2 D/2 C2 F/2 G2 B2 B2 A)  12.8
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
3     (B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2 F/2 F2 E F2 A C2 G/2
F/2 A E/2 G2 C B E)  10.900001
4     (C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G F/2 B2 C/2 D G/2
G/2 G/2 B2 G2 E F/2 B2 A)  13.500001
5     (G A F2 E/2 E/2 D A/2 G2 A2 B/2 E/2 B2 B F/2 G2 G/2 B/2 G
A A2 C/2 G2 C/2 E/2 E/2 F2)  15.000001
```

6 (A A2 E2 C2 G/2 G2 D/2 C2 E A2 E G2 F E B G/2 G2 B/2 F/2 E2 A/2 F/2 D/2 D2 A2 D2) 10.700001
7 (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A B/2 D2 E2 E2 A2 G A B C2) 13.200001
8 (G2 D/2 E G2 F2 B C/2 E G/2 F/2 D G2 D2 B2 E/2 G G F B A/2 A/2 D/2 G2 C G C2) 9.1
9 (C2 B C2 B/2 G/2 D/2 A C C D E2 F/2 F C2 E/2 B/2 E E/2 G/2 D2 F E/2 B G/2 F2 D) 10.400001
10 (E2 D/2 D D2 G B E2 A2 B/2 C2 C A D/2 F2 E2 D C2 A B/2 C2 E/2 C G2 D D/2 A2) 11.200001
11 (C B/2 D B2 D D/2 E2 C F E2 E B/2 A F/2 C2 G E2 E/2 G D C2 B2 B2 B2 D2 G) 10.0
12 (E2 D/2 A2 A2 A/2 G/2 F/2 D/2 F/2 B F F/2 C A F C2 D/2 G C2 A2 F/2 G2 F A B F/2) 11.900001
13 (A/2 A F D2 F/2 F D/2 A A/2 B F E2 F/2 G/2 D C/2 F/2 C/2 F D/2 C/2 A C G2 E/2 D2) 12.400001
14 (G2 G/2 D2 C G/2 F2 E/2 C A/2 A/2 F/2 D D/2 B/2 G/2 C C/2 B2 C C/2 B2 E2 G/2 C B2 G) 10.0
15 (E B2 E E2 A/2 B/2 B2 B C C2 E F2 B2 D/2 G2 A F/2 D/2 G/2 F/2 B/2 E/2 F2 F/2 G2 B2) 12.000001
16 (D2 G2 G2 G G A A2 F2 D2 E/2 F D D2 B2 D A2 E2 C/2 D/2 G F2 B/2 D/2 B2 G E) 12.000001
17 (C2 A B2 A G/2 G2 B A F/2 B/2 G2 F/2 D C D2 C2 E E2 G2 B/2 E2 D/2 E2 C C B/2) 16.400002
18 (E G/2 B2 B E G/2 D E F/2 D2 C/2 D G/2 A F/2 B2 D F2 E F/2 F2 F A/2 G2 D2 D) 14.7
19 (D2 D2 D2 E/2 C2 D/2 A/2 B E/2 C/2 A C/2 E/2 F2 F2 D B/2 D B G/2 E2 B2 G2 F A2 E/2) 11.400001
20 (G2 B G2 F/2 B B2 G A/2 E2 A/2 G2 G2 E/2 A E A2 C/2 E G/2 E/2 G/2 D2 B/2 A/2 B2 B/2) 11.400001
21 (A/2 A B2 F/2 A2 D/2 B G C/2 B A/2 D C2 A2 B A/2 A2 F2 D/2 D/2 C/2 E F2 E2 D/2 B) 13.900001
22 (E2 C2 G C A/2 G/2 C E2 A F D2 D2 E/2 F/2 E D/2 F2 A2 A2 D2 A E/2 C2 A B/2 A2) 12.1
23 (G2 B/2 F E/2 D2 G D2 D C/2 F B2 F/2 C2 F E/2 F C/2 G/2 E/2 G/2 F/2 E/2 F2 E/2 C F) 11.8
24 (G/2 B/2 C2 E/2 A/2 F2 G2 A/2 E2 E/2 D/2 D/2 G G2 E E/2 E/2 C G G/2 A C G2 F D E/2) 13.800001
25 (F G2 G2 B C G/2 E/2 E F/2 A2 C/2 G/2 C2 A E2 B F2 C F2 B E G G F/2 F/2 G2) 9.2

26 (F C/2 D/2 E/2 C2 D2 A2 D2 F2 D G/2 D/2 C B F2 D/2 D2 C/2 A/2 G/2 E/2 F/2 A A C2 C/2) 12.4
27 (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 A/2 F/2 A/2 A D/2 E F/2) 13.1
28 (D/2 F G/2 D/2 E2 E2 F D/2 G E2 B2 G C2 G/2 B E F2 E2 C2 D/2 E B2 E/2 A/2 B2 E/2) 11.8
29 (G2 C2 D/2 G2 E G2 E/2 B/2 B B/2 C2 D/2 A2 E/2 E F2 A D E F2 F/2 C/2 G E/2 C/2 E/2) 11.700001
30 (F/2 F2 C2 B/2 E F/2 B C2 C2 B A C A G2 F A2 F F2 F2 C C/2 B2 B/2 A/2 D E2) 11.800001
31 (B/2 B/2 C2 D2 G2 E2 B/2 F2 A2 G E/2 D/2 D/2 A2 F C/2 E2 C B/2 D/2 A/2 D2 D2 G G A) 10.2
32 (E2 A2 A/2 B/2 F2 B2 F/2 F A2 D2 F2 A F/2 F2 C/2 B F/2 F2 B2 C2 C2 G B/2 C2 A/2 A/2) 8.3
33 (D E2 F E/2 G2 A2 F2 F/2 E/2 D2 G F2 E2 F/2 D2 G2 G2 G/2 B D F/2 D/2 C E2 G2 B/2) 16.900002
34 (G E2 A/2 G/2 A2 F/2 C/2 D E2 G/2 C/2 B2 G2 E/2 B2 G2 D C E F2 E2 E2 F2 E2 A2 A/2) 14.1
35 (E G G/2 D2 D/2 D F/2 F2 A2 F A/2 C/2 B A E F/2 B/2 C2 F G B G2 F F/2 B C/2) 11.500001
36 (C F D/2 G2 F/2 F/2 E2 A B A2 E2 D/2 E F D/2 F B2 D A2 E2 B2 G2 G2 D/2 D/2 B/2) 11.400001
37 (B D/2 D2 E/2 C A/2 G/2 E2 D/2 B/2 C/2 F E/2 A2 C2 G2 A2 F2 A C/2 G2 B/2 D2 C2 D D2) 11.1
38 (E G C D/2 C2 F/2 B D/2 A2 A F D2 E A D C B/2 E/2 A2 E2 C2 D A/2 F C/2 C) 9.1
39 (C E2 E/2 B2 B B2 G/2 C/2 C/2 E D/2 G/2 C/2 F/2 E G/2 E E2 G/2 A/2 G2 B D D G2 A) 13.300001
40 (D2 F F2 C/2 G/2 G2 G2 G/2 D/2 B2 A2 G/2 D/2 E F2 E G G/2 A2 A E2 F/2 D/2 A/2 G2 C) 14.300001
41 (B/2 C G2 G G B/2 F/2 G G G B/2 G2 E/2 A B/2 D2 D2 E C/2 A F E F2 C2 C A/2) 12.800001
42 (A2 F A/2 F E B G2 A/2 B2 D/2 C/2 A2 B2 B F2 F2 C2 D/2 F2 F B/2 D/2 B2 C/2 F2 E/2) 11.9
43 (G/2 E2 B A2 D2 B D2 E/2 D C/2 C/2 E C/2 A2 D/2 E G/2 D/2 B B E D2 F2 E F2 D2) 12.6
44 (D2 E F/2 C E2 G/2 G2 C2 G/2 E A/2 E2 E D/2 D D2 A/2 F2 A2 D A F G2 E B2 B2) 11.5
45 (G/2 B2 G2 A/2 D B B2 E/2 A A2 D B F/2 C/2 G2 D2 B/2 C2 B2 D2 F D2 G2 D/2 F F) 5.8999996

46 (B2 E D2 E/2 C2 F/2 C G2 A B E A A2 A/2 B2 A2 C/2 D2 A B2 E F F/2 A2 E2 B) 12.400001
47 (C/2 E B A/2 D/2 G B2 E/2 D2 D B C2 F D C B D/2 B B2 A2 D2 E C G G2 G2) 10.200001
48 (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2) 14.7
49 (C G E2 F/2 E/2 E/2 D2 E2 C2 E2 E/2 C/2 D/2 E2 G2 D2 D E2 C E E/2 E/2 F/2 C2 A2 D2) 15.5
50 (C E2 C A/2 G/2 A E/2 A2 F/2 G/2 E E2 B/2 B E C A C B/2 B C/2 C/2 A2 C/2 E C2) 9.7
51 (F/2 B A2 C/2 D/2 A B2 B B2 D2 C/2 A2 F2 A2 B2 B B/2 A/2 F/2 B/2 D/2 E C B2 B2 E) 13.0
52 (G/2 C2 B B D A/2 A F2 G2 C2 A B E/2 B2 D/2 A G/2 E E2 E D F2 G2 B C F) 10.200001
53 (D/2 B F F/2 F/2 F/2 F/2 C/2 G G A/2 B2 A/2 G2 F2 A E A/2 G/2 A E2 E/2 G2 E/2 A G/2) 14.300001
54 (G2 A2 G/2 D E B B2 E/2 E/2 D F/2 A D F B/2 A E E/2 B/2 F/2 E C D2 G/2 E2 A2) 11.900001
55 (G/2 B/2 B C B2 E/2 F/2 F/2 C2 D A C B2 E B C/2 B F F/2 D2 F2 A2 G/2 E2 A C2) 7.9000006
56 (A/2 C G2 C D E2 C/2 A/2 A C2 E A/2 E/2 E/2 F2 F E/2 C F/2 C2 G A2 E2 D/2 A2 G) 10.900001
57 (C/2 D/2 C/2 E2 A/2 E2 C B/2 C2 A A2 B2 B2 E2 C D2 B2 E2 C2 A/2 F/2 B2 A C/2 E2 A) 9.6
58 (F A F2 C/2 C E C F D2 B B2 D D B C2 A2 D/2 G A/2 A/2 F/2 D/2 C2 A2 F/2 G/2) 10.200001
59 (G2 C/2 F E B/2 B2 F F2 G A/2 D D/2 E2 A2 E2 D2 F2 E2 E/2 C B C/2 B F2 C2 D2) 11.200001
60 (B/2 B E G/2 D C2 F/2 C2 D2 C/2 D G B/2 B D/2 E E F/2 E2 D2 A2 E/2 B/2 F2 C2 G) 11.400001
61 (E/2 D B/2 A/2 D B2 B C/2 B C2 F/2 C C/2 B D/2 A2 B C C2 B2 C C B B2 F/2 E/2) 8.0
62 (D2 E/2 F2 G/2 F2 D/2 B/2 F2 B F C/2 G C E2 B/2 C2 D2 B D E2 C/2 E E/2 C2 G2 F2) 10.3
63 (C/2 F A A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B) 12.900001
64 (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 F D/2 F G/2) 15.500001
65 (A/2 E2 F/2 A/2 F A E/2 B G/2 C/2 G/2 B2 D2 G/2 C2 D C/2 F/2 G B2 G/2 B/2 E/2 D B/2 E2) 9.0

66 (B2 C/2 G/2 G D D E D2 B2 B D C2 E2 D E2 A2 C2 A G C/2 E/2 G A2 F/2 D D2) 12.700001
67 (A/2 E/2 B/2 G/2 B/2 A F/2 A2 G B A E2 B A/2 G B/2 D/2 D/2 G C2 G/2 D D2 C2 A/2 D2) 10.6
68 (A2 D E E/2 C/2 G C/2 F/2 E F G/2 C2 E/2 F2 B/2 F2 F G/2 F2 C A/2 B/2 E G E C/2) 12.1
69 (A2 F D2 G2 A/2 B D2 F D E/2 B/2 F/2 A/2 G/2 E/2 C/2 D2 G/2 G2 A/2 G/2 G/2 G/2 A2 E/2 A/2) 13.9
70 (D/2 G/2 G A D D2 G B G F/2 A D2 F2 C/2 C/2 B/2 E2 F2 F2 D2 A/2 E2 D F/2 E/2 C) 11.700001
71 (F2 A2 B2 C/2 A B/2 G2 C E2 D E/2 C F D2 G/2 G/2 E2 D2 D2 F/2 A2 A E2 G2 C2 F2) 11.9
72 (A2 C/2 B2 D C A2 D A F2 E2 C2 F/2 E/2 F G B/2 A E F/2 C2 B2 D/2 C G D/2 B2) 9.5
73 (E C A2 A2 B E/2 C2 A2 B2 A G/2 E2 F F/2 B B E2 B A/2 D/2 A/2 F F C/2 F F) 12.0
74 (A2 E/2 A C/2 E B/2 F2 D/2 G2 A C/2 C2 E2 C2 B2 D C/2 D2 F C2 D F2 E2 B2 A E2) 9.8
75 (A/2 F2 C2 G/2 A2 F A/2 D/2 F2 F E2 C2 B F/2 F2 G2 B E G E A/2 A G2 A2 G2 F/2) 13.400001
76 (D C2 F/2 A C/2 F2 C A2 B2 F C/2 B2 D F/2 E F/2 B2 E/2 G G/2 A/2 F/2 D2 F2 B2 G/2) 9.3
77 (D/2 D/2 B B E/2 E/2 G2 G E E2 A C/2 F/2 D G2 C B/2 D/2 D D2 B/2 C/2 E2 G2 G A2) 9.900001
78 (A2 E2 C/2 G/2 D/2 C2 C2 F/2 C2 F2 G F C2 A2 D C2 E A2 B A/2 E/2 B2 A E2 D2 A2) 9.8
79 (B D2 A F/2 D/2 F2 G2 E2 C2 F C/2 F/2 E F B2 D2 C2 E/2 C/2 C C A2 B/2 A2 A2 B/2) 12.9
80 (E G/2 B G2 F2 G2 A2 B2 E C E G/2 B/2 D G/2 D/2 A2 F2 B D/2 F/2 F2 C/2 B D2 F/2) 9.8
81 (E/2 D F/2 F B/2 E C2 B2 E/2 B/2 E2 D/2 E A/2 G/2 B/2 F/2 G2 B/2 E2 C A/2 F2 D/2 F/2 C2) 9.8
82 (E F/2 E F/2 C2 B2 D D2 D E/2 G2 A/2 F2 D2 F2 D2 A/2 E C D2 E E/2 E/2 C/2 E2 G2) 14.700001
83 (F2 A2 E/2 B/2 E F G/2 C/2 A2 G F/2 B2 G F2 F/2 C G2 B A2 F/2 B/2 G B G E2 B/2) 10.8
84 (C/2 C2 E2 A2 B C/2 D/2 E2 B/2 B A G/2 C D/2 G2 A A2 B E/2 B2 C B/2 E/2 F C F) 11.900001
85 (A C G2 C B/2 D2 E/2 D/2 G/2 C E2 A F C B E/2 C2 A G2 B/2 A/2 A C2 G F/2 D) 8.3

```
86    (G F/2 D/2 D2 D/2 E2 G/2 D C2 D E A C2 E2 G C/2 G2 B/2 E
A2 A2 A2 C2 F2 C/2 B)  10.7
87    (G B/2 A2 C2 C/2 G/2 C A/2 G B/2 D2 B/2 E2 D2 A/2 G2 F2 D
E B2 E2 E E E C/2 E2)  11.7
88    (D2 C/2 C2 C2 D G/2 F2 D2 D2 E A/2 E F A/2 C A/2 B E2 C2
F2 C/2 F2 F2 E/2 A2 C2)  11.700001
89    (E/2 E2 E/2 C2 D/2 D2 F2 E E2 G D G2 A F/2 F/2 D2 C2 G C/2
F B/2 G2 B/2 C2 E/2 E/2)  12.8
90    (E2 D G/2 A E F/2 A2 F2 D G F/2 A C/2 D2 F C E B F D/2 C2
G/2 A/2 F/2 C C/2)  11.8
91    (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  15.4
92    (A/2 B C2 F2 B E E G2 C/2 F2 D2 G2 D/2 F A A2 E B F/2 A2
A/2 C/2 D E D/2 C)  9.900001
93    (C2 G2 B2 D/2 G A2 E D/2 G/2 D2 A/2 D2 E F C G F2 G/2 E
B/2 A D2 C2 G F2 A/2)  10.5
94    (B2 G2 C A C G2 E2 B2 F/2 B/2 C G/2 C E2 B/2 E2 D2 F E2
E/2 B G2 F2 C F E)  7.3
95    (F2 E G/2 C A A G A2 A A F G/2 A B D2 D/2 B2 E A/2 F/2 D B
D2 B2 C2 B)  11.200001
96    (A2 E G A G2 D2 C2 D A E2 D/2 F2 G2 E/2 C/2 G/2 D/2 G G/2
A2 B2 F/2 F/2 B F E)  12.6
97    (E/2 D2 G G/2 E2 A2 A2 G D/2 F/2 A2 D2 G2 G/2 B2 B C2 F/2
D/2 E/2 C2 D/2 B2 A2 C2 G)  11.200001
98    (F2 C/2 C2 C/2 D2 A A/2 E C/2 E E A E2 C2 E2 A2 C2 E2 E
D/2 D/2 A/2 C2 D D C2)  12.100001
99    (G2 B/2 B2 G2 F C/2 C F C/2 C/2 F C2 C A D/2 A/2 G2 F2 D
F2 C2 C2 B/2 C/2 B/2 G/2)  9.500001
100   (A2 A/2 E/2 B F/2 A/2 F2 E/2 F2 D C/2 B D/2 A F C/2 G/2
C/2 A D/2 F2 B G2 E2 B2 E/2)  7.3

NIL
[4]> ( average p )
11.599
[5]> ( select-individual p )
#<INDIVIDUAL #x1AA867AD>
[6]> ( display ( select-individual p ) )
63    (C/2 F A A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2
E D A/2 F/2 F B)  12.900001
NIL
[7]> ( display ( select-individual p ) )
```

```
51    (F/2 B A2 C/2 D/2 A B2 B B2 D2 C/2 A2 F2 A2 B2 B B/2 A/2
F/2 B/2 D/2 E C B2 B2 E)  13.0
NIL
[8]> ( display ( select-individual p ) )
27    (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2
G/2 A/2 F/2 A/2 A D/2 E F/2)  13.1
NIL
[9]> ( setf *select-demo* t )
T
[10]> ( display ( select-individual p ) )
the sample of individuals ...
51    (F/2 B A2 C/2 D/2 A B2 B B2 D2 C/2 A2 F2 A2 B2 B B/2 A/2
F/2 B/2 D/2 E C B2 B2 E)  13.0
63    (C/2 F A A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2
E D A/2 F/2 F B)  12.900001
7     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  13.200001
23    (G2 B/2 F E/2 D2 G D2 D C/2 F B2 F/2 C2 F E/2 F C/2 G/2
E/2 G/2 F/2 E/2 F2 E/2 C F)  11.8
85    (A C G2 C B/2 D2 E/2 D/2 G/2 C E2 A F C B E/2 C2 A G2 B/2
A/2 A C2 G F/2 D)  8.3
44    (D2 E F/2 C E2 G/2 G2 C2 G/2 E A/2 E2 E D/2 D D2 A/2 F2 A2
D A F G2 E B2 B2)  11.5
76    (D C2 F/2 A C/2 F2 C A2 B2 F C/2 B2 D F/2 E F/2 B2 E/2 G
G/2 A/2 F/2 D2 F2 B2 G/2)  9.3
61    (E/2 D B/2 A/2 D B2 B C/2 B C2 F/2 C C/2 B D/2 A2 B C C2
B2 C C B B2 F/2 E/2)  8.0

the most fit of the sample ...
7     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  13.200001

7     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  13.200001
NIL
[11]> ( display ( select-individual p ) )
the sample of individuals ...
89    (E/2 E2 E/2 C2 D/2 D2 F2 E E2 G D G2 A F/2 F/2 D2 C2 G C/2
F B/2 G2 B/2 C2 E/2 E/2)  12.8
39    (C E2 E/2 B2 B B2 G/2 C/2 C/2 E D/2 G/2 C/2 F/2 E G/2 E E2
G/2 A/2 G2 B D D G2 A)  13.300001
```

```
95    (F2 E G/2 C A A G A2 A A F G/2 A B D2 D/2 B2 E A/2 F/2 D B
D2 B2 C2 B)  11.200001
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
28    (D/2 F G/2 D/2 E2 E2 F D/2 G E2 B2 G C2 G/2 B E F2 E2 C2
D/2 E B2 E/2 A/2 B2 E/2)  11.8
3     (B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2 F/2 F2 E F2 A C2 G/2
F/2 A E/2 G2 C B E)  10.900001
14    (G2 G/2 D2 C G/2 F2 E/2 C A/2 A/2 F/2 D D/2 B/2 G/2 C C/2
B2 C C/2 B2 E2 G/2 C B2 G)  10.0
22    (E2 C2 G C A/2 G/2 C E2 A F D2 D2 E/2 F/2 E D/2 F2 A2 A2
D2 A E/2 C2 A B/2 A2)  12.1

the most fit of the sample ...
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1

2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
NIL
[12]> ( display ( select-individual p ) )
the sample of individuals ...
91    (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  15.4
13    (A/2 A F D2 F/2 F D/2 A A/2 B F E2 F/2 G/2 D C/2 F/2 C/2 F
D/2 C/2 A C G2 E/2 D2)  12.400001
8     (G2 D/2 E G2 F2 B C/2 E G/2 F/2 D G2 D2 B2 E/2 G G F B A/2
A/2 D/2 G2 C G C2)  9.1
58    (F A F2 C/2 C E C F D2 B B2 D D B C2 A2 D/2 G A/2 A/2 F/2
D/2 C2 A2 F/2 G/2)  10.200001
3     (B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2 F/2 F2 E F2 A C2 G/2
F/2 A E/2 G2 C B E)  10.900001
75    (A/2 F2 C2 G/2 A2 F A/2 D/2 F2 F E2 C2 B F/2 F2 G2 B E G E
A/2 A G2 A2 G2 F/2)  13.400001
58    (F A F2 C/2 C E C F D2 B B2 D D B C2 A2 D/2 G A/2 A/2 F/2
D/2 C2 A2 F/2 G/2)  10.200001
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1

the most fit of the sample ...
```

```
91    (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  15.4

91    (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  15.4
NIL
[13]> ( display ( select-individual p ) )
the sample of individuals ...
67    (A/2 E/2 B/2 G/2 B/2 A F/2 A2 G B A E2 B A/2 G B/2 D/2 D/2
G C2 G/2 D D2 C2 A/2 D2)  10.6
64    (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.500001
48    (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F
F/2 E D2 C2 C/2)  14.7
35    (E G G/2 D2 D/2 D F/2 F2 A2 F A/2 C/2 B A E F/2 B/2 C2 F G
B G2 F F/2 B C/2)  11.500001
56    (A/2 C G2 C D E2 C/2 A/2 A C2 E A/2 E/2 E/2 F2 F E/2 C F/2
C2 G A2 E2 D/2 A2 G)  10.900001
70    (D/2 G/2 G A D D2 G B G F/2 A D2 F2 C/2 C/2 B/2 E2 F2 F2
D2 A/2 E2 D F/2 E/2 C)  11.700001
96    (A2 E G A G2 D2 C2 D A E2 D/2 F2 G2 E/2 C/2 G/2 D/2 G G/2
A2 B2 F/2 F/2 B F E)  12.6
90    (E2 D G/2 A E F/2 A2 F2 D G F/2 A C/2 D2 F C E B F D/2 C2
G/2 A/2 F/2 C C/2)  11.8

the most fit of the sample ...
64    (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.500001

64    (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.500001
NIL
[14]>
```

2. The Lisp task …

```
; Global variable for population size
( defconstant *population-size* 100 )
; Size of population sample for selection
( defconstant *selection-size* 8 )
; Fitness function for testing
( setf *fitness* #'fitness-stepwise-motion )
```

```
; Class for population
;   Field:
;       -individuals -> all of the individuals (objs) in a population
;       -generation -> generation #
( defclass population ()
    (
        ( individuals :accessor population-individuals :initarg
:individuals )
        ( generation :accessor population-generation :initform 0 )
    )
)

; Method to determine the number of individuals in a population
( defmethod size ( ( p population ) )
    ( length ( population-individuals p ) )
)

; Method to display a population
( defmethod display ( ( p population ) )
    ( terpri ) ( terpri )
    ( princ "Generation " )
    ( prin1 ( population-generation p ) )
    ( princ " population ... " )
    ( terpri ) ( terpri )
    ( dolist ( i ( population-individuals p ) )
        ( display i )
    )
    ( terpri )
)

; Method to create an initial population
; -populates with individuals based on *population-size* parameter
( defmethod initial-population (&aux individuals )
    ( setf individuals () )
    ( dotimes ( i *population-size* )
        ( push ( new-individual ( + i 1 ) ( pitch-string ) ) individuals )
    )
    ( make-instance 'population :individuals ( reverse individuals ) )
)
```

```
; Method to determine the average fitness of population
; -uses mapcar to convert individuals to a list of fitness metrics
; -then calls on helper method to sum all fitness
( defmethod average ( ( p population ) &aux ( sum 0 ) )
    ( setf indiv-list ( population-individuals p ) )
    ( setf sum ( sum-nums ( mapcar #'individual-fitness indiv-list ) ) )
    ( float ( / sum *population-size* ) )
)

; Helper method that calculates the sum of a list of numbers
( defmethod sum-nums ( ( li list ) )
    (cond
        ((null li)
            0
        )
        (t
            ( + ( car li ) ( sum-nums ( cdr li ) ) )
        )
    )
)

; Param for printing extra info during demo mode
( setf *select-demo*  nil )

; Method that obtains selection sample and most fit individual from sample
( defmethod select-individual ( ( p population )
    &aux i candidates rn )
    ( setf candidates ( select-individuals p ) )
    ( setf mfi ( most-fit-individual candidates ) )
    ( if *select-demo* ( select-demo-helper candidates mfi ) )
    mfi
)

; Method that selects random individuals from the population for selection
( defmethod select-individuals ( ( p population )
    &aux individuals candidates rn )
    ( setf individuals ( population-individuals p ) )
    ( setf candidates () )
    ( dotimes ( i *selection-size* )
```

```
        ( setf rn ( random *population-size* ) )
        ( push ( nth rn individuals ) candidates )
    )
    candidates
)

; Method that selects the individual with the largest fitness metric from
; a list
( defmethod most-fit-individual ( ( l list ) &aux max-value max-individual
)
    ( setf max-individual ( max-val l 0 ) )
    ( setf max-value ( individual-fitness max-individual ) )
    max-individual
)

; Helper method that returns the individual with maximum fitness using
recursion
( defmethod max-val ( ( l list ) current-max )
    (cond
        ((null l)
            current-max
        )
        ((or (equal current-max 0 ) ( > ( individual-fitness ( car l ) ) (
individual-fitness current-max ) ) )
            ( max-val ( cdr l ) ( car l ) )
        )
        (t
            ( max-val (cdr l ) current-max )
        )
    )
)

; Demo method for selection
( defmethod select-demo-helper ( ( l list ) ( i individual ) )
    ( princ "the sample of individuals ..." ) ( terpri )
    ( mapcar #'display l )
    ( terpri )
    ( princ "the most fit of the sample ... " ) ( terpri )
    ( display i )
    ( terpri )
```

```
    nil
)
```

3. Encapsulated demo code …

```
; Demo method for population
( defmethod population-demo (&aux p)
    ( setf p ( initial-population ) )
    ( display p )
    ( format t "Average fitness = ~A~%~%" ( average p ) )
    ( setf *select-demo* t )
    ( format t "Sampling ... ~%~%" )
    ( select-individual p ) ( terpri )
    ( format t "Sampling ... ~%~%" )
    ( select-individual p ) ( terpri )
    ( format t "Sampling ... ~%~%" )
    ( select-individual p ) ( terpri )
)
```

4. Encapsulated demo …

```
[1]> ( load "D:\\Programming Projects\\Lisp Projects\\Final
Assignment\\wildcardga.lisp" )
;; Loading file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp ...
;; Loaded file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp
T
[2]> ( population-demo )


Generation 0 population ...

1      (G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2
A2 D/2 C2 F/2 G2 B2 B2 A)  12.8
2      (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
3      (B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2 F/2 F2 E F2 A C2 G/2
F/2 A E/2 G2 C B E)  10.900001
```

4 (C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G F/2 B2 C/2 D G/2 G/2 G/2 B2 G2 E F/2 B2 A) 13.500001
5 (G A F2 E/2 E/2 D A/2 G2 A2 B/2 E/2 B2 B F/2 G2 G/2 B/2 G A A2 C/2 G2 C/2 E/2 E/2 F2) 15.000001
6 (A A2 E2 C2 G/2 G2 D/2 C2 E A2 E G2 F E B G/2 G2 B/2 F/2 E2 A/2 F/2 D/2 D2 A2 D2) 10.700001
7 (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A B/2 D2 E2 E2 A2 G A B C2) 13.200001
8 (G2 D/2 E G2 F2 B C/2 E G/2 F/2 D G2 D2 B2 E/2 G G F B A/2 A/2 D/2 G2 C G C2) 9.1
9 (C2 B C2 B/2 G/2 D/2 A C C D E2 F/2 F C2 E/2 B/2 E E/2 G/2 D2 F E/2 B G/2 F2 D) 10.400001
10 (E2 D/2 D D2 G B E2 A2 B/2 C2 C A D/2 F2 E2 D C2 A B/2 C2 E/2 C G2 D D/2 A2) 11.200001
11 (C B/2 D B2 D D/2 E2 C F E2 E B/2 A F/2 C2 G E2 E/2 G D C2 B2 B2 B2 D2 G) 10.0
12 (E2 D/2 A2 A2 A/2 G/2 F/2 D/2 F/2 B F F/2 C A F C2 D/2 G C2 A2 F/2 G2 F A B F/2) 11.900001
13 (A/2 A F D2 F/2 F D/2 A A/2 B F E2 F/2 G/2 D C/2 F/2 C/2 F D/2 C/2 A C G2 E/2 D2) 12.400001
14 (G2 G/2 D2 C G/2 F2 E/2 C A/2 A/2 F/2 D D/2 B/2 G/2 C C/2 B2 C C/2 B2 E2 G/2 C B2 G) 10.0
15 (E B2 E E2 A/2 B/2 B2 B C C2 E F2 B2 D/2 G2 A F/2 D/2 G/2 F/2 B/2 E/2 F2 F/2 G2 B2) 12.000001
16 (D2 G2 G2 G G A A2 F2 D2 E/2 F D D2 B2 D A2 E2 C/2 D/2 G F2 B/2 D/2 B2 G E) 12.000001
17 (C2 A B2 A G/2 G2 B A F/2 B/2 G2 F/2 D C D2 C2 E E2 G2 B/2 E2 D/2 E2 C C B/2) 16.400002
18 (E G/2 B2 B E G/2 D E F/2 D2 C/2 D G/2 A F/2 B2 D F2 E F/2 F2 F A/2 G2 D2 D) 14.7
19 (D2 D2 D2 E/2 C2 D/2 A/2 B E/2 C/2 A C/2 E/2 F2 F2 D B/2 D B G/2 E2 B2 G2 F A2 E/2) 11.400001
20 (G2 B G2 F/2 B B2 G A/2 E2 A/2 G2 G2 E/2 A E A2 C/2 E G/2 E/2 G/2 D2 B/2 A/2 B2 B/2) 11.400001
21 (A/2 A B2 F/2 A2 D/2 B G C/2 B A/2 D C2 A2 B A/2 A2 F2 D/2 D/2 C/2 E F2 E2 D/2 B) 13.900001
22 (E2 C2 G C A/2 G/2 C E2 A F D2 D2 E/2 F/2 E D/2 F2 A2 A2 D2 A E/2 C2 A B/2 A2) 12.1
23 (G2 B/2 F E/2 D2 G D2 D C/2 F B2 F/2 C2 F E/2 F C/2 G/2 E/2 G/2 F/2 E/2 F2 E/2 C F) 11.8

24 (G/2 B/2 C2 E/2 A/2 F2 G2 A/2 E2 E/2 D/2 D/2 G G2 E E/2 E/2 C G G/2 A C G2 F D E/2) 13.800001
25 (F G2 G2 B C G/2 E/2 E F/2 A2 C/2 G/2 C2 A E2 B F2 C F2 B E G G F/2 F/2 G2) 9.2
26 (F C/2 D/2 E/2 C2 D2 A2 D2 F2 D G/2 D/2 C B F2 D/2 D2 C/2 A/2 G/2 E/2 F/2 A A C2 C/2) 12.4
27 (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 A/2 F/2 A/2 A D/2 E F/2) 13.1
28 (D/2 F G/2 D/2 E2 E2 F D/2 G E2 B2 G C2 G/2 B E F2 E2 C2 D/2 E B2 E/2 A/2 B2 E/2) 11.8
29 (G2 C2 D/2 G2 E G2 E/2 B/2 B B/2 C2 D/2 A2 E/2 E F2 A D E F2 F/2 C/2 G E/2 C/2 E/2) 11.700001
30 (F/2 F2 C2 B/2 E F/2 B C2 C2 B A C A G2 F A2 F F2 F2 C C/2 B2 B/2 A/2 D E2) 11.800001
31 (B/2 B/2 C2 D2 G2 E2 B/2 F2 A2 G E/2 D/2 D/2 A2 F C/2 E2 C B/2 D/2 A/2 D2 D2 G G A) 10.2
32 (E2 A2 A/2 B/2 F2 B2 F/2 F A2 D2 F2 A F/2 F2 C/2 B F/2 F2 B2 C2 C2 G B/2 C2 A/2 A/2) 8.3
33 (D E2 F E/2 G2 A2 F2 F/2 E/2 D2 G F2 E2 F/2 D2 G2 G2 G/2 B D F/2 D/2 C E2 G2 B/2) 16.900002
34 (G E2 A/2 G/2 A2 F/2 C/2 D E2 G/2 C/2 B2 G2 E/2 B2 G2 D C E F2 E2 E2 F2 E2 A2 A/2) 14.1
35 (E G G/2 D2 D/2 D F/2 F2 A2 F A/2 C/2 B A E F/2 B/2 C2 F G B G2 F F/2 B C/2) 11.500001
36 (C F D/2 G2 F/2 F/2 E2 A B A2 E2 D/2 E F D/2 F B2 D A2 E2 B2 G2 G2 D/2 D/2 B/2) 11.400001
37 (B D/2 D2 E/2 C A/2 G/2 E2 D/2 B/2 C/2 F E/2 A2 C2 G2 A2 F2 A C/2 G2 B/2 D2 C2 D D2) 11.1
38 (E G C D/2 C2 F/2 B D/2 A2 A F D2 E A D C B/2 E/2 A2 E2 C2 D A/2 F C/2 C) 9.1
39 (C E2 E/2 B2 B B2 G/2 C/2 C/2 E D/2 G/2 C/2 F/2 E G/2 E E2 G/2 A/2 G2 B D D G2 A) 13.300001
40 (D2 F F2 C/2 G/2 G2 G2 G/2 D/2 B2 A2 G/2 D/2 E F2 E G G/2 A2 A E2 F/2 D/2 A/2 G2 C) 14.300001
41 (B/2 C G2 G G B/2 F/2 G G G B/2 G2 E/2 A B/2 D2 D2 E C/2 A F E F2 C2 C A/2) 12.800001
42 (A2 F A/2 F E B G2 A/2 B2 D/2 C/2 A2 B2 B F2 F2 C2 D/2 F2 F B/2 D/2 B2 C/2 F2 E/2) 11.9
43 (G/2 E2 B A2 D2 B D2 E/2 D C/2 C/2 E C/2 A2 D/2 E G/2 D/2 B B E D2 F2 E F2 D2) 12.6

44 (D2 E F/2 C E2 G/2 G2 C2 G/2 E A/2 E2 E D/2 D D2 A/2 F2 A2 D A F G2 E B2 B2) 11.5
45 (G/2 B2 G2 A/2 D B B2 E/2 A A2 D B F/2 C/2 G2 D2 B/2 C2 B2 D2 F D2 G2 D/2 F F) 5.8999996
46 (B2 E D2 E/2 C2 F/2 C G2 A B E A A2 A/2 B2 A2 C/2 D2 A B2 E F F/2 A2 E2 B) 12.400001
47 (C/2 E B A/2 D/2 G B2 E/2 D2 D B C2 F D C B D/2 B B2 A2 D2 E C G G2 G2) 10.200001
48 (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2) 14.7
49 (C G E2 F/2 E/2 E/2 D2 E2 C2 E2 E/2 C/2 D/2 E2 G2 D2 D E2 C E E/2 E/2 F/2 C2 A2 D2) 15.5
50 (C E2 C A/2 G/2 A E/2 A2 F/2 G/2 E E2 B/2 B E C A C B/2 B C/2 C/2 A2 C/2 E C2) 9.7
51 (F/2 B A2 C/2 D/2 A B2 B B2 D2 C/2 A2 F2 A2 B2 B B/2 A/2 F/2 B/2 D/2 E C B2 B2 E) 13.0
52 (G/2 C2 B B D A/2 A F2 G2 C2 A B E/2 B2 D/2 A G/2 E E2 E D F2 G2 B C F) 10.200001
53 (D/2 B F F/2 F/2 F/2 F/2 C/2 G G A/2 B2 A/2 G2 F2 A E A/2 G/2 A E2 E/2 G2 E/2 A G/2) 14.300001
54 (G2 A2 G/2 D E B B2 E/2 E/2 D F/2 A D F B/2 A E E/2 B/2 F/2 E C D2 G/2 E2 A2) 11.900001
55 (G/2 B/2 B C B2 E/2 F/2 F/2 C2 D A C B2 E B C/2 B F F/2 D2 F2 A2 G/2 E2 A C2) 7.9000006
56 (A/2 C G2 C D E2 C/2 A/2 A C2 E A/2 E/2 E/2 F2 F E/2 C F/2 C2 G A2 E2 D/2 A2 G) 10.900001
57 (C/2 D/2 C/2 E2 A/2 E2 C B/2 C2 A A2 B2 B2 E2 C D2 B2 E2 C2 A/2 F/2 B2 A C/2 E2 A) 9.6
58 (F A F2 C/2 C E C F D2 B B2 D D B C2 A2 D/2 G A/2 A/2 F/2 D/2 C2 A2 F/2 G/2) 10.200001
59 (G2 C/2 F E B/2 B2 F F2 G A/2 D D/2 E2 A2 E2 D2 F2 E2 E/2 C B C/2 B F2 C2 D2) 11.200001
60 (B/2 B E G/2 D C2 F/2 C2 D2 C/2 D G B/2 B D/2 E E F/2 E2 D2 A2 E/2 B/2 F2 C2 G) 11.400001
61 (E/2 D B/2 A/2 D B2 B C/2 B C2 F/2 C C/2 B D/2 A2 B C C2 B2 C C B B2 F/2 E/2) 8.0
62 (D2 E/2 F2 G/2 F2 D/2 B/2 F2 B F C/2 G C E2 B/2 C2 D2 B D E2 C/2 E E/2 C2 G2 F2) 10.3
63 (C/2 F A A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B) 12.900001

64 (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 F D/2 F G/2) 15.500001
65 (A/2 E2 F/2 A/2 F A E/2 B G/2 C/2 G/2 B2 D2 G/2 C2 D C/2 F/2 G B2 G/2 B/2 E/2 D B/2 E2) 9.0
66 (B2 C/2 G/2 G D D E D2 B2 B D C2 E2 D E2 A2 C2 A G C/2 E/2 G A2 F/2 D D2) 12.700001
67 (A/2 E/2 B/2 G/2 B/2 A F/2 A2 G B A E2 B A/2 G B/2 D/2 D/2 G C2 G/2 D D2 C2 A/2 D2) 10.6
68 (A2 D E E/2 C/2 G C/2 F/2 E F G/2 C2 E/2 F2 B/2 F2 F G/2 F2 C A/2 B/2 E G E C/2) 12.1
69 (A2 F D2 G2 A/2 B D2 F D E/2 B/2 F/2 A/2 G/2 E/2 C/2 D2 G/2 G2 A/2 G/2 G/2 G/2 A2 E/2 A/2) 13.9
70 (D/2 G/2 G A D D2 G B G F/2 A D2 F2 C/2 C/2 B/2 E2 F2 F2 D2 A/2 E2 D F/2 E/2 C) 11.700001
71 (F2 A2 B2 C/2 A B/2 G2 C E2 D E/2 C F D2 G/2 G/2 E2 D2 D2 F/2 A2 A E2 G2 C2 F2) 11.9
72 (A2 C/2 B2 D C A2 D A F2 E2 C2 F/2 E/2 F G B/2 A E F/2 C2 B2 D/2 C G D/2 B2) 9.5
73 (E C A2 A2 B E/2 C2 A2 B2 A G/2 E2 F F/2 B B E2 B A/2 D/2 A/2 F F C/2 F F) 12.0
74 (A2 E/2 A C/2 E B/2 F2 D/2 G2 A C/2 C2 E2 C2 B2 D C/2 D2 F C2 D F2 E2 B2 A E2) 9.8
75 (A/2 F2 C2 G/2 A2 F A/2 D/2 F2 F E2 C2 B F/2 F2 G2 B E G E A/2 A G2 A2 G2 F/2) 13.400001
76 (D C2 F/2 A C/2 F2 C A2 B2 F C/2 B2 D F/2 E F/2 B2 E/2 G G/2 A/2 F/2 D2 F2 B2 G/2) 9.3
77 (D/2 D/2 B B E/2 E/2 G2 G E E2 A C/2 F/2 D G2 C B/2 D/2 D D2 B/2 C/2 E2 G2 G A2) 9.900001
78 (A2 E2 C/2 G/2 D/2 C2 C2 F/2 C2 F2 G F C2 A2 D C2 E A2 B A/2 E/2 B2 A E2 D2 A2) 9.8
79 (B D2 A F/2 D/2 F2 G2 E2 C2 F C/2 F/2 E F B2 D2 C2 E/2 C/2 C C A2 B/2 A2 A2 B/2) 12.9
80 (E G/2 B G2 F2 G2 A2 B2 E C E G/2 B/2 D G/2 D/2 A2 F2 B D/2 F/2 F2 C/2 B D2 F/2) 9.8
81 (E/2 D F/2 F B/2 E C2 B2 E/2 B/2 E2 D/2 E A/2 G/2 B/2 F/2 G2 B/2 E2 C A/2 F2 D/2 F/2 C2) 9.8
82 (E F/2 E F/2 C2 B2 D D2 D E/2 G2 A/2 F2 D2 F2 D2 A/2 E C D2 E E/2 E/2 C/2 E2 G2) 14.700001
83 (F2 A2 E/2 B/2 E F G/2 C/2 A2 G F/2 B2 G F2 F/2 C G2 B A2 F/2 B/2 G B G E2 B/2) 10.8

84 (C/2 C2 E2 A2 B C/2 D/2 E2 B/2 B A G/2 C D/2 G2 A A2 B E/2 B2 C B/2 E/2 F C F) 11.900001
85 (A C G2 C B/2 D2 E/2 D/2 G/2 C E2 A F C B E/2 C2 A G2 B/2 A/2 A C2 G F/2 D) 8.3
86 (G F/2 D/2 D2 D/2 E2 G/2 D C2 D E A C2 E2 G C/2 G2 B/2 E A2 A2 A2 C2 F2 C/2 B) 10.7
87 (G B/2 A2 C2 C/2 G/2 C A/2 G B/2 D2 B/2 E2 D2 A/2 G2 F2 D E B2 E2 E E E C/2 E2) 11.7
88 (D2 C/2 C2 C2 D G/2 F2 D2 D2 E A/2 E F A/2 C A/2 B E2 C2 F2 C/2 F2 F2 E/2 A2 C2) 11.700001
89 (E/2 E2 E/2 C2 D/2 D2 F2 E E2 G D G2 A F/2 F/2 D2 C2 G C/2 F B/2 G2 B/2 C2 E/2 E/2) 12.8
90 (E2 D G/2 A E F/2 A2 F2 D G F/2 A C/2 D2 F C E B F D/2 C2 G/2 A/2 F/2 C C/2) 11.8
91 (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2 E/2 G/2 E2 B/2 B D2 D2 F) 15.4
92 (A/2 B C2 F2 B E E G2 C/2 F2 D2 G2 D/2 F A A2 E B F/2 A2 A/2 C/2 D E D/2 C) 9.900001
93 (C2 G2 B2 D/2 G A2 E D/2 G/2 D2 A/2 D2 E F C G F2 G/2 E B/2 A D2 C2 G F2 A/2) 10.5
94 (B2 G2 C A C G2 E2 B2 F/2 B/2 C G/2 C E2 B/2 E2 D2 F E2 E/2 B G2 F2 C F E) 7.3
95 (F2 E G/2 C A A G A2 A A F G/2 A B D2 D/2 B2 E A/2 F/2 D B D2 B2 C2 B) 11.200001
96 (A2 E G A G2 D2 C2 D A E2 D/2 F2 G2 E/2 C/2 G/2 D/2 G G/2 A2 B2 F/2 F/2 B F E) 12.6
97 (E/2 D2 G G/2 E2 A2 A2 G D/2 F/2 A2 D2 G2 G/2 B2 B C2 F/2 D/2 E/2 C2 D/2 B2 A2 C2 G) 11.200001
98 (F2 C/2 C2 C/2 D2 A A/2 E C/2 E E A E2 C2 E2 A2 C2 E2 E D/2 D/2 A/2 C2 D D C2) 12.100001
99 (G2 B/2 B2 G2 F C/2 C F C/2 C/2 F C2 C A D/2 A/2 G2 F2 D F2 C2 C2 B/2 C/2 B/2 G/2) 9.500001
100 (A2 A/2 E/2 B F/2 A/2 F2 E/2 F2 D C/2 B D/2 A F C/2 G/2 C/2 A D/2 F2 B G2 E2 B2 E/2) 7.3

Average fitness = 11.599

Sampling ...

the sample of individuals ...

```
64    (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.500001
26    (F C/2 D/2 E/2 C2 D2 A2 D2 F2 D G/2 D/2 C B F2 D/2 D2 C/2
A/2 G/2 E/2 F/2 A A C2 C/2)  12.4
94    (B2 G2 C A C G2 E2 B2 F/2 B/2 C G/2 C E2 B/2 E2 D2 F E2
E/2 B G2 F2 C F E)  7.3
50    (C E2 C A/2 G/2 A E/2 A2 F/2 G/2 E E2 B/2 B E C A C B/2 B
C/2 C/2 A2 C/2 E C2)  9.7
26    (F C/2 D/2 E/2 C2 D2 A2 D2 F2 D G/2 D/2 C B F2 D/2 D2 C/2
A/2 G/2 E/2 F/2 A A C2 C/2)  12.4
45    (G/2 B2 G2 A/2 D B B2 E/2 A A2 D B F/2 C/2 G2 D2 B/2 C2 B2
D2 F D2 G2 D/2 F F)  5.8999996
61    (E/2 D B/2 A/2 D B2 B C/2 B C2 F/2 C C/2 B D/2 A2 B C C2
B2 C C B B2 F/2 E/2)  8.0
80    (E G/2 B G2 F2 G2 A2 B2 E C E G/2 B/2 D G/2 D/2 A2 F2 B
D/2 F/2 F2 C/2 B D2 F/2)  9.8

the most fit of the sample ...
64    (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.500001


Sampling ...

the sample of individuals ...
88    (D2 C/2 C2 C2 D G/2 F2 D2 D2 E A/2 E F A/2 C A/2 B E2 C2
F2 C/2 F2 F2 E/2 A2 C2)  11.700001
83    (F2 A2 E/2 B/2 E F G/2 C/2 A2 G F/2 B2 G F2 F/2 C G2 B A2
F/2 B/2 G B G E2 B/2)  10.8
14    (G2 G/2 D2 C G/2 F2 E/2 C A/2 A/2 F/2 D D/2 B/2 G/2 C C/2
B2 C C/2 B2 E2 G/2 C B2 G)  10.0
41    (B/2 C G2 G G B/2 F/2 G G G B/2 G2 E/2 A B/2 D2 D2 E C/2 A
F E F2 C2 C A/2)  12.800001
63    (C/2 F A A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2
E D A/2 F/2 F B)  12.900001
98    (F2 C/2 C2 C/2 D2 A A/2 E C/2 E E A E2 C2 E2 A2 C2 E2 E
D/2 D/2 A/2 C2 D D C2)  12.100001
56    (A/2 C G2 C D E2 C/2 A/2 A C2 E A/2 E/2 E/2 F2 F E/2 C F/2
C2 G A2 E2 D/2 A2 G)  10.900001
47    (C/2 E B A/2 D/2 G B2 E/2 D2 D B C2 F D C B D/2 B B2 A2 D2
E C G G2 G2)  10.200001
```

```
the most fit of the sample ...
63    (C/2 F A A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2
E D A/2 F/2 F B)  12.900001


Sampling ...

the sample of individuals ...
87    (G B/2 A2 C2 C/2 G/2 C A/2 G B/2 D2 B/2 E2 D2 A/2 G2 F2 D
E B2 E2 E E E C/2 E2)  11.7
94    (B2 G2 C A C G2 E2 B2 F/2 B/2 C G/2 C E2 B/2 E2 D2 F E2
E/2 B G2 F2 C F E)  7.3
51    (F/2 B A2 C/2 D/2 A B2 B B2 D2 C/2 A2 F2 A2 B2 B B/2 A/2
F/2 B/2 D/2 E C B2 B2 E)  13.0
93    (C2 G2 B2 D/2 G A2 E D/2 G/2 D2 A/2 D2 E F C G F2 G/2 E
B/2 A D2 C2 G F2 A/2)  10.5
14    (G2 G/2 D2 C G/2 F2 E/2 C A/2 A/2 F/2 D D/2 B/2 G/2 C C/2
B2 C C/2 B2 E2 G/2 C B2 G)  10.0
73    (E C A2 A2 B E/2 C2 A2 B2 A G/2 E2 F F/2 B B E2 B A/2 D/2
A/2 F F C/2 F F)  12.0
19    (D2 D2 D2 E/2 C2 D/2 A/2 B E/2 C/2 A C/2 E/2 F2 F2 D B/2 D
B G/2 E2 B2 G2 F A2 E/2)  11.400001
57    (C/2 D/2 C/2 E2 A/2 E2 C B/2 C2 A A2 B2 B2 E2 C D2 B2 E2
C2 A/2 F/2 B2 A C/2 E2 A)  9.6

the most fit of the sample ...
51    (F/2 B A2 C/2 D/2 A B2 B B2 D2 C/2 A2 F2 A2 B2 B B/2 A/2
F/2 B/2 D/2 E C B2 B2 E)  13.0


NIL
[3]>
```

Task 8: Incorporating Mutation

---

1. The Lisp task …

```
; Method that mutates an individual and returns a new instance
; of the mutated individual
( defmethod mutate ( ( i individual ) &aux mutation )
    ( setf mutation ( mutation ( individual-melody i ) ) )
    ( make-instance 'individual
```

```
        :number ( individual-number i )
        :melody mutation
        :fitness ( funcall *fitness* mutation )
    )
)

; Global variable for the percent mutation
( defconstant *pc-m* 50 )

; Method that determines when an individual mutates
; based on percent mutation
( defmethod maybe-mutate ( ( i individual ) )
    ( if ( <= ( + 1 ( random 100 ) ) *pc-m* )
        ( mutate i )
        i
    )
```

2. The demo task …

```
[1]> ( load "D:\\Programming Projects\\Lisp Projects\\Final
Assignment\\wildcardga.lisp" )
;; Loading file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp ...
;; Loaded file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp
T
[2]> ( setf i ( random-individual ) )
#<INDIVIDUAL #x1AC01929>
[3]> ( display i )
0     (G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2
A2 D/2 C2 F/2 G2 B2 B2 A)  12.8
NIL
[4]> ( display ( mutate i ) )
0     (G B/2 G D B/2 F2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2
A2 D/2 C2 F/2 G2 B2 B2 A)  10.8
NIL
[5]> ( display i )
0     (G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2
A2 D/2 C2 F/2 G2 B2 B2 A)  12.8
NIL
[6]> ( display ( mutate i ) )
```

```
0     (G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2
A2 D/2 C2 F/2 G2 A2 B2 A)  13.5
NIL
[7]> ( display i )
0     (G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2
A2 D/2 C2 F/2 G2 B2 B2 A)  12.8
NIL
[8]> ( display ( maybe-mutate i ) )
0     (G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 E/2 G/2
A2 D/2 C2 F/2 G2 B2 B2 A)  11.8
NIL
[9]> ( display ( maybe-mutate i ) )
0     (G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 C/2 B F/2 B G2 A/2 G/2
A2 D/2 C2 F/2 G2 B2 B2 A)  12.3
NIL
[10]> ( display ( maybe-mutate i ) )
0     (G B/2 G D B/2 A2 B/2 A2 A2 B E/2 D/2 B F/2 B G2 A/2 G/2
A2 D/2 C2 F/2 G2 B2 B2 A)  14.6
NIL
[11]> ( display ( maybe-mutate i ) )
0     (G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2
A2 D/2 C2 F/2 G2 B2 B2 A)  12.8
NIL
[12]> ( display ( maybe-mutate i ) )
0     (G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2
A2 D/2 C2 F/2 G2 C B2 A)  11.5
NIL
[13]> ( display ( maybe-mutate i ) )
0     (G B/2 G D B/2 A2 B/2 A2 A/2 B E/2 D/2 B F/2 B G2 A/2 G/2
A2 D/2 C2 F/2 G2 B2 B2 A)  14.6
NIL
[14]>
```

3. The encapsulated demo task …

```
; Demo method for mutate
( defmethod mutate-demo ()
    ( setf i ( random-individual ) )
    ( display i )
    ( dotimes ( x 20 )
        ( setf i ( mutate i ) )
        ( display i )
```

```
    )
)

; Demo method for maybe-mutate
( defmethod maybe-mutate-demo ()
    ( setf i ( random-individual ) )
    ( display i )
    ( dotimes ( x 20 )
        ( setf n ( maybe-mutate i ) )
        ( display-nnl n )
        ( if ( not ( equal n i ) ) ( princ " *" ) )
        ( terpri )
        ( setf i n )
    )
)
```

4. The encapsulated demo …

```
[1]> ( load "D:\\Programming Projects\\Lisp Projects\\Final Assignment\\wildcardga.lisp" )
;; Loading file D:\Programming Projects\Lisp Projects\Final Assignment\wildcardga.lisp ...
;; Loaded file D:\Programming Projects\Lisp Projects\Final Assignment\wildcardga.lisp
T
[2]> ( mutate-demo )
0     (G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2 A2 D/2 C2 F/2 G2 B2 B2 A)
12.8
0     (G B/2 G D B/2 F2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2 A2 D/2 C2 F/2 G2 B2 B2 A)
10.8
0     (G B/2 G D B/2 F2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2 A2 D/2 C2 F/2 G2 A2 B2 A)
11.5
0     (G B/2 G D B/2 F2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 D2 G/2 A2 D/2 C2 F/2 G2 A2 B2 A)  9.5
0     (G B/2 G D B/2 F2 A2 A2 C/2 B E/2 D/2 B F/2 B G2 D2 G/2 A2 D/2 C2 F/2 G2 A2 B2 A)  9.8
0     (G B/2 G D B/2 F2 A2 A2 C/2 B E/2 C/2 B F/2 B G2 D2 G/2 A2 D/2 C2 F/2 G2 A2 B2 A)  9.3
0     (G B/2 G D B/2 F2 A2 A2 C/2 B E/2 C/2 B F/2 B G2 D2 G/2 A2 B C2 F/2 G2 A2 B2 A)  9.3
0     (G B/2 B2 D B/2 F2 A2 A2 C/2 B E/2 C/2 B F/2 B G2 D2 G/2 A2 B C2 F/2 G2 A2 B2 A)  9.6
0     (D B/2 B2 D B/2 F2 A2 A2 C/2 B E/2 C/2 B F/2 B G2 D2 G/2 A2 B C2 F/2 G2 A2 B2 A)  9.1
0     (G2 B/2 B2 D B/2 F2 A2 A2 C/2 B E/2 C/2 B F/2 B G2 D2 G/2 A2 B C2 F/2 G2 A2 B2 A)  9.6
0     (G2 B/2 B2 D B/2 F2 A2 A2 A/2 B E/2 C/2 B F/2 B G2 D2 G/2 A2 B C2 F/2 G2 A2 B2 A)
11.400001
0     (G2 B/2 B2 D D F2 A2 A2 A/2 B E/2 C/2 B F/2 B G2 D2 G/2 A2 B C2 F/2 G2 A2 B2 A)
12.700001
0     (G2 B/2 B2 D D F2 A2 A2 A/2 B E/2 G/2 B F/2 B G2 D2 G/2 A2 B C2 F/2 G2 A2 B2 A)
13.200001
0     (G2 B/2 B2 D D F2 A2 A2 A/2 B E/2 G/2 B F/2 B G2 D2 G/2 A2 B C2 F/2 G2 D2 B2 A)
11.200001
0     (G2 B/2 B2 D D F2 A2 A2 A/2 B E/2 G/2 B2 F/2 B G2 D2 G/2 A2 B C2 F/2 G2 D2 B2 A)
11.200001
0     (G2 B/2 B2 D D F2 A2 A2 A/2 B E/2 G/2 B2 F/2 D G2 D2 G/2 A2 B C2 F/2 G2 D2 B2 A)
11.200001
0     (G2 B/2 B2 D D F2 A2 A2 A/2 B E/2 G/2 B2 F/2 D G2 D G/2 A2 B C2 F/2 G2 D2 B2 A)
11.200001
0     (G2 B/2 B2 D D F2 A2 A2 A/2 B E/2 G/2 B2 F/2 D G2 D G/2 A2 B C2 F/2 G2 D2 F/2 A)
11.200001
```

```
0     (G2 F2 B2 D D F2 A2 A2 A/2 B E/2 G/2 B2 F/2 D G2 D G/2 A2 B C2 F/2 G2 D2 F/2 A)
10.900001
0     (G2 F2 B2 D D F2 A2 A2 A/2 B B G/2 B2 F/2 D G2 D G/2 A2 B C2 F/2 G2 D2 F/2 A)  11.700001
0     (G2 F2 B2 D D F2 A2 A2 A/2 B B G/2 B2 F/2 D/2 G2 D G/2 A2 B C2 F/2 G2 D2 F/2 A)
11.700001
NIL
[3]> ( maybe-mutate-demo )
0     (E F2 A C2 G/2 F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G F/2)
11.400001
0     (E F2 A C2 G/2 F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G F/2)
11.400001
0     (E F2 A C2 G/2 F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G F/2)
11.400001
0     (G2 F2 A C2 G/2 F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G F/2)
11.400001     *
0     (G2 F2 A C2 G/2 F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G G2)
11.200001     *
0     (G2 F2 A C2 G/2 F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D A2 G2 C2 E/2 D2 G G2)
10.700001     *
0     (G2 F2 A C2 G/2 F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 D C2 G2 C2 E/2 D2 G G2)
10.700001     *
0     (G2 F2 A C2 G/2 F/2 A E/2 G2 C B E C2 B2 A2 A2 A/2 D/2 F C2 G2 C2 E/2 D2 G G2)  9.4
*
0     (G2 F2 A C2 G/2 F/2 A E/2 G2 C B E C2 B2 A2 A2 D D/2 F C2 G2 C2 E/2 D2 G G2)  9.4      *
0     (G2 F2 A C2 G/2 F/2 A E/2 G2 C B E C2 B2 A2 A2 D D/2 F C2 G2 C2 E/2 A G G2)  9.4      *
0     (G2 F2 A C2 G/2 F/2 A E/2 G2 C B E C2 B2 A2 A2 D D/2 F C2 G2 C2 E/2 A G G2)  9.4
0     (G2 F2 A C2 G/2 F/2 A E/2 G2 C B E C2 B2 A2 A2 D D/2 B2 C2 G2 C2 E/2 A G G2)  8.9      *
0     (G2 F2 A C2 G/2 F/2 A E/2 G2 C B E C2 B2 A2 A2 D D/2 E2 C2 G2 C2 E/2 A G G2)  10.4     *
0     (G2 F2 A C2 G/2 F/2 A E/2 G2 C G E C2 B2 A2 A2 D D/2 E2 C2 G2 C2 E/2 A G G2)  10.9     *
0     (G2 F2 A C2 G/2 F/2 A E/2 G2 C G E C2 B2 A2 A2 D D/2 E2 C2 G2 C2 E/2 A G G2)  10.9
0     (G2 F2 A C2 G/2 F/2 A E/2 G2 C G E C2 B2 A2 A2 D D/2 E2 C2 G2 C2 E/2 A G G2)  10.9
0     (G2 F2 A C2 G/2 F/2 A E/2 G2 C G E C2 B2 A2 A2 D D/2 E2 C2 G2 C2 E/2 A G G2)  10.9
0     (G2 F2 A C2 G/2 F/2 A E/2 G2 C G E C2 B2 A2 A2 D D/2 E2 C2 G2 C2 E/2 A G G2)  10.9
0     (G2 F2 B2 C2 G/2 F/2 A E/2 G2 C G E C2 B2 A2 A2 D D/2 E2 C2 G2 C2 E/2 A G G2)  10.4
*
0     (G2 F2 B2 C2 G/2 F/2 A E/2 G2 C G E C2 B2 A2 A2 D D/2 E C2 G2 C2 E/2 A G G2)  10.4     *
0     (G2 F2 B2 C2 G/2 F/2 A E/2 G2 C G E C2 B2 A2 A2 D D/2 E C2 G2 C2 E/2 A G G2)  10.4
NIL
[4]>
```

Task 9: Copy

1. The Lisp task …

```
; Global bool for "demo mode"
( setf *copy-demo* nil )

; Global variable for percentage of copies
( defconstant *pc-c* 40 )

; Method that performs copies based on the number of copies specified
( defmethod perform-copies ( ( cp population ) ( np population ) )
   ( dotimes ( i ( nr-copies ) )
      ( perform-one-copy cp np )
```

```
    )
)

; Method that determines the number of copies based on
; population size and percent copies
( defmethod nr-copies ()
    ( * ( / *pc-c* 100 ) *population-size* )
)

; Method that selects an individual, maybe-mutates, and copies that
individual
; to the new population
( defmethod perform-one-copy ( ( cp population ) ( np population )
    &aux x m mm new-i )
    ( setf m ( select-individual cp ) )
    ( if *copy-demo* ( format t "Selected individual = ~%" ) )
    ( if *copy-demo* ( display m ) )
    ( setf mm ( maybe-mutate m ) )
    ( if *copy-demo* ( format t "Possibly mutated individual = ~&" ) )
    ( if *copy-demo* ( display mm ) )
    ( setf ( individual-number mm ) ( + 1 ( size np ) ) )
    ( if *copy-demo* ( format t "Renumbered individual = ~& " ) )
    ( if *copy-demo* ( display mm ) )
    ( setf new-i ( new-individual ( + 1 ( size np ) ) ( individual-melody
mm ) ) )
    ( setf
        ( population-individuals np )
        ( append ( population-individuals np ) ( list new-i ) )
    )
    nil
)

; Method that clears a population
( defmethod empty-population ( ( cp population ) &aux np )
    ( setf np ( make-instance 'population ) )
    ( setf ( population-individuals np ) () )
    ( setf ( population-generation np ) ( + 1 ( population-generation cp )
) )
    np
)
```

2. The embodied demo task …

```
; Demo method for perform-copies
( defmethod perform-copies-demo ( &aux cp np )
    ( setf cp ( initial-population ) )
    ( setf np ( empty-population cp ) )
    ( format t
"------------------------------------------------------------------------" )
    ( display np )
    ( format t
"~%~%------------------------------------------------------------------------" )
    ( setf *select-demo* t )
    ( setf *copy-demo* t )
    ( dotimes ( i 10 )
        ( perform-one-copy cp np )
        ( format t
"------------------------------------------------------------------------" )
        ( display np )
        ( format t
"~%~%------------------------------------------------------------------------"
)
    )
    ( setf *select-demo* nil )
    ( setf *copy-demo* nil )
    nil
)
```

3. The embodied demo …

```
[1]> ( load "D:\\Programming Projects\\Lisp Projects\\Final
Assignment\\wildcardga.lisp" )
;; Loading file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp ...
;; Loaded file D:\Programming Projects\Lisp Projects\Final
Assignment\wildcardga.lisp
T
[2]> ( perform-copies-demo )
------------------------------------------------------------------------
---
```

```
Generation 1 population ...



------------------------------------------------------------t
he sample of individuals ...
64    (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.500001
26    (F C/2 D/2 E/2 C2 D2 A2 D2 F2 D G/2 D/2 C B F2 D/2 D2 C/2
A/2 G/2 E/2 F/2 A A C2 C/2)  12.4
94    (B2 G2 C A C G2 E2 B2 F/2 B/2 C G/2 C E2 B/2 E2 D2 F E2
E/2 B G2 F2 C F E)  7.3
50    (C E2 C A/2 G/2 A E/2 A2 F/2 G/2 E E2 B/2 B E C A C B/2 B
C/2 C/2 A2 C/2 E C2)  9.7
26    (F C/2 D/2 E/2 C2 D2 A2 D2 F2 D G/2 D/2 C B F2 D/2 D2 C/2
A/2 G/2 E/2 F/2 A A C2 C/2)  12.4
45    (G/2 B2 G2 A/2 D B B2 E/2 A A2 D B F/2 C/2 G2 D2 B/2 C2 B2
D2 F D2 G2 D/2 F F)  5.8999996
61    (E/2 D B/2 A/2 D B2 B C/2 B C2 F/2 C C/2 B D/2 A2 B C C2
B2 C C B B2 F/2 E/2)  8.0
80    (E G/2 B G2 F2 G2 A2 B2 E C E G/2 B/2 D G/2 D/2 A2 F2 B
D/2 F/2 F2 C/2 B D2 F/2)  9.8

the most fit of the sample ...
64    (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.500001

Selected individual =
64    (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.500001
Possibly mutated individual =
64    (A2 G B/2 F F F/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.100001
Renumbered individual =
 1     (A2 G B/2 F F F/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.100001
------------------------------------------------------------
---

Generation 1 population ...
```

```
1     (A2 G B/2 F F F/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.100001



------------------------------------------------------------
---the sample of individuals ...
73    (E C A2 A2 B E/2 C2 A2 B2 A G/2 E2 F F/2 B B E2 B A/2 D/2
A/2 F F C/2 F F)  12.0
19    (D2 D2 D2 E/2 C2 D/2 A/2 B E/2 C/2 A C/2 E/2 F2 F2 D B/2 D
B G/2 E2 B2 G2 F A2 E/2)  11.400001
57    (C/2 D/2 C/2 E2 A/2 E2 C B/2 C2 A A2 B2 B2 E2 C D2 B2 E2
C2 A/2 F/2 B2 A C/2 E2 A)  9.6
88    (D2 C/2 C2 C2 D G/2 F2 D2 D2 E A/2 E F A/2 C A/2 B E2 C2
F2 C/2 F2 F2 E/2 A2 C2)  11.700001
83    (F2 A2 E/2 B/2 E F G/2 C/2 A2 G F/2 B2 G F2 F/2 C G2 B A2
F/2 B/2 G B G E2 B/2)  10.8
14    (G2 G/2 D2 C G/2 F2 E/2 C A/2 A/2 F/2 D D/2 B/2 G/2 C C/2
B2 C C/2 B2 E2 G/2 C B2 G)  10.0
41    (B/2 C G2 G G B/2 F/2 G G G B/2 G2 E/2 A B/2 D2 D2 E C/2 A
F E F2 C2 C A/2)  12.800001
63    (C/2 F A A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2
E D A/2 F/2 F B)  12.900001

the most fit of the sample ...
63    (C/2 F A A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2
E D A/2 F/2 F B)  12.900001

Selected individual =
63    (C/2 F A A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2
E D A/2 F/2 F B)  12.900001
Possibly mutated individual =
63    (C/2 F A A2 G B F2 D F2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E
D A/2 F/2 F B)  13.900001
Renumbered individual =
 2     (C/2 F A A2 G B F2 D F2 D G/2 F A/2 G E2 C F/2 E D/2 D/2
E D A/2 F/2 F B)  13.900001
------------------------------------------------------------
---
```

```
Generation 1 population ...

1     (A2 G B/2 F F F/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.100001
2     (C/2 F A A2 G B F2 D F2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E
D A/2 F/2 F B)  13.900001



-----------------------------------------------------------------
---the sample of individuals ...
16    (D2 G2 G2 G G A A2 F2 D2 E/2 F D D2 B2 D A2 E2 C/2 D/2 G
F2 B/2 D/2 B2 G E)  12.000001
14    (G2 G/2 D2 C G/2 F2 E/2 C A/2 A/2 F/2 D D/2 B/2 G/2 C C/2
B2 C C/2 B2 E2 G/2 C B2 G)  10.0
78    (A2 E2 C/2 G/2 D/2 C2 C2 F/2 C2 F2 G F C2 A2 D C2 E A2 B
A/2 E/2 B2 A E2 D2 A2)  9.8
95    (F2 E G/2 C A A G A2 A A F G/2 A B D2 D/2 B2 E A/2 F/2 D B
D2 B2 C2 B)  11.200001
27    (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2
G/2 A/2 F/2 A/2 A D/2 E F/2)  13.1
74    (A2 E/2 A C/2 E B/2 F2 D/2 G2 A C/2 C2 E2 C2 B2 D C/2 D2 F
C2 D F2 E2 B2 A E2)  9.8
87    (G B/2 A2 C2 C/2 G/2 C A/2 G B/2 D2 B/2 E2 D2 A/2 G2 F2 D
E B2 E2 E E E C/2 E2)  11.7
94    (B2 G2 C A C G2 E2 B2 F/2 B/2 C G/2 C E2 B/2 E2 D2 F E2
E/2 B G2 F2 C F E)  7.3

the most fit of the sample ...
27    (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2
G/2 A/2 F/2 A/2 A D/2 E F/2)  13.1

Selected individual =
27    (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2
G/2 A/2 F/2 A/2 A D/2 E F/2)  13.1
Possibly mutated individual =
27    (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2
G/2 C F/2 A/2 A D/2 E F/2)  11.6
Renumbered individual =
 3     (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2
G/2 C F/2 A/2 A D/2 E F/2)  11.6
```

```
------------------------------------------------------------------
---

Generation 1 population ...

1     (A2 G B/2 F F F/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.100001
2     (C/2 F A A2 G B F2 D F2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E
D A/2 F/2 F B)  13.900001
3     (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2
G/2 C F/2 A/2 A D/2 E F/2)  11.6



------------------------------------------------------------------
---the sample of individuals ...
22    (E2 C2 G C A/2 G/2 C E2 A F D2 D2 E/2 F/2 E D/2 F2 A2 A2
D2 A E/2 C2 A B/2 A2)  12.1
51    (F/2 B A2 C/2 D/2 A B2 B B2 D2 C/2 A2 F2 A2 B2 B B/2 A/2
F/2 B/2 D/2 E C B2 B2 E)  13.0
63    (C/2 F A A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2
E D A/2 F/2 F B)  12.900001
7     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  13.200001
23    (G2 B/2 F E/2 D2 G D2 D C/2 F B2 F/2 C2 F E/2 F C/2 G/2
E/2 G/2 F/2 E/2 F2 E/2 C F)  11.8
85    (A C G2 C B/2 D2 E/2 D/2 G/2 C E2 A F C B E/2 C2 A G2 B/2
A/2 A C2 G F/2 D)  8.3
44    (D2 E F/2 C E2 G/2 G2 C2 G/2 E A/2 E2 E D/2 D D2 A/2 F2 A2
D A F G2 E B2 B2)  11.5
76    (D C2 F/2 A C/2 F2 C A2 B2 F C/2 B2 D F/2 E F/2 B2 E/2 G
G/2 A/2 F/2 D2 F2 B2 G/2)  9.3

the most fit of the sample ...
7     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  13.200001

Selected individual =
7     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  13.200001
Possibly mutated individual =
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7     (G F/2 A/2 B/2 F/2 B2 B/2 A C2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  12.700001
Renumbered individual =
 4     (G F/2 A/2 B/2 F/2 B2 B/2 A C2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  12.700001
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Generation 1 population ...

1     (A2 G B/2 F F F/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.100001
2     (C/2 F A A2 G B F2 D F2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E
D A/2 F/2 F B)  13.900001
3     (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2
G/2 C F/2 A/2 A D/2 E F/2)  11.6
4     (G F/2 A/2 B/2 F/2 B2 B/2 A C2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  12.700001



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---the sample of individuals ...
3     (B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2 F/2 F2 E F2 A C2 G/2
F/2 A E/2 G2 C B E)  10.900001
75    (A/2 F2 C2 G/2 A2 F A/2 D/2 F2 F E2 C2 B F/2 F2 G2 B E G E
A/2 A G2 A2 G2 F/2)  13.400001
58    (F A F2 C/2 C E C F D2 B B2 D D B C2 A2 D/2 G A/2 A/2 F/2
D/2 C2 A2 F/2 G/2)  10.200001
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
89    (E/2 E2 E/2 C2 D/2 D2 F2 E E2 G D G2 A F/2 F/2 D2 C2 G C/2
F B/2 G2 B/2 C2 E/2 E/2)  12.8
39    (C E2 E/2 B2 B B2 G/2 C/2 C/2 E D/2 G/2 C/2 F/2 E G/2 E E2
G/2 A/2 G2 B D D G2 A)  13.300001
95    (F2 E G/2 C A A G A2 A A F G/2 A B D2 D/2 B2 E A/2 F/2 D B
D2 B2 C2 B)  11.200001
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1

the most fit of the sample ...
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2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1

Selected individual =
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
Possibly mutated individual =
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
Renumbered individual =
 5     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
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Generation 1 population ...

1     (A2 G B/2 F F F/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.100001
2     (C/2 F A A2 G B F2 D F2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E
D A/2 F/2 F B)  13.900001
3     (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2
G/2 C F/2 A/2 A D/2 E F/2)  11.6
4     (G F/2 A/2 B/2 F/2 B2 B/2 A C2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  12.700001
5     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1



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---the sample of individuals ...
35    (E G G/2 D2 D/2 D F/2 F2 A2 F A/2 C/2 B A E F/2 B/2 C2 F G
B G2 F F/2 B C/2)  11.500001
56    (A/2 C G2 C D E2 C/2 A/2 A C2 E A/2 E/2 E/2 F2 F E/2 C F/2
C2 G A2 E2 D/2 A2 G)  10.900001
70    (D/2 G/2 G A D D2 G B G F/2 A D2 F2 C/2 C/2 B/2 E2 F2 F2
D2 A/2 E2 D F/2 E/2 C)  11.700001
96    (A2 E G A G2 D2 C2 D A E2 D/2 F2 G2 E/2 C/2 G/2 D/2 G G/2
A2 B2 F/2 F/2 B F E)  12.6
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90    (E2 D G/2 A E F/2 A2 F2 D G F/2 A C/2 D2 F C E B F D/2 C2
G/2 A/2 F/2 C C/2)  11.8
91    (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  15.4
13    (A/2 A F D2 F/2 F D/2 A A/2 B F E2 F/2 G/2 D C/2 F/2 C/2 F
D/2 C/2 A C G2 E/2 D2)  12.400001
8     (G2 D/2 E G2 F2 B C/2 E G/2 F/2 D G2 D2 B2 E/2 G G F B A/2
A/2 D/2 G2 C G C2)  9.1

the most fit of the sample ...
91    (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  15.4

Selected individual =
91    (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  15.4
Possibly mutated individual =
91    (E/2 D A D/2 E/2 B D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  13.9
Renumbered individual =
 6     (E/2 D A D/2 E/2 B D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  13.9
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Generation 1 population ...

1     (A2 G B/2 F F F/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.100001
2     (C/2 F A A2 G B F2 D F2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E
D A/2 F/2 F B)  13.900001
3     (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2
G/2 C F/2 A/2 A D/2 E F/2)  11.6
4     (G F/2 A/2 B/2 F/2 B2 B/2 A C2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  12.700001
5     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
6     (E/2 D A D/2 E/2 B D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  13.9
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---the sample of individuals ...
20    (G2 B G2 F/2 B B2 G A/2 E2 A/2 G2 G2 E/2 A E A2 C/2 E G/2
E/2 G/2 D2 B/2 A/2 B2 B/2)  11.400001
96    (A2 E G A G2 D2 C2 D A E2 D/2 F2 G2 E/2 C/2 G/2 D/2 G G/2
A2 B2 F/2 F/2 B F E)  12.6
67    (A/2 E/2 B/2 G/2 B/2 A F/2 A2 G B A E2 B A/2 G B/2 D/2 D/2
G C2 G/2 D D2 C2 A/2 D2)  10.6
24    (G/2 B/2 C2 E/2 A/2 F2 G2 A/2 E2 E/2 D/2 D/2 G G2 E E/2
E/2 C G G/2 A C G2 F D E/2)  13.800001
80    (E G/2 B G2 F2 G2 A2 B2 E C E G/2 B/2 D G/2 D/2 A2 F2 B
D/2 F/2 F2 C/2 B D2 F/2)  9.8
12    (E2 D/2 A2 A2 A/2 G/2 F/2 D/2 F/2 B F F/2 C A F C2 D/2 G
C2 A2 F/2 G2 F A B F/2)  11.900001
91    (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  15.4
47    (C/2 E B A/2 D/2 G B2 E/2 D2 D B C2 F D C B D/2 B B2 A2 D2
E C G G2 G2)  10.200001

the most fit of the sample ...
91    (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  15.4

Selected individual =
91    (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  15.4
Possibly mutated individual =
91    (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G2 E2 B/2 B D2 D2 F)  15.4
Renumbered individual =
 7     (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G2 E2 B/2 B D2 D2 F)  15.4
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Generation 1 population ...

1     (A2 G B/2 F F F/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.100001
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2     (C/2 F A A2 G B F2 D F2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E
D A/2 F/2 F B)  13.900001
3     (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2
G/2 C F/2 A/2 A D/2 E F/2)  11.6
4     (G F/2 A/2 B/2 F/2 B2 B/2 A C2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  12.700001
5     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
6     (E/2 D A D/2 E/2 B D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  13.9
7     (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G2 E2 B/2 B D2 D2 F)  15.4



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---the sample of individuals ...
37    (B D/2 D2 E/2 C A/2 G/2 E2 D/2 B/2 C/2 F E/2 A2 C2 G2 A2
F2 A C/2 G2 B/2 D2 C2 D D2)  11.1
7     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  13.200001
32    (E2 A2 A/2 B/2 F2 B2 F/2 F A2 D2 F2 A F/2 F2 C/2 B F/2 F2
B2 C2 C2 G B/2 C2 A/2 A/2)  8.3
9     (C2 B C2 B/2 G/2 D/2 A C C D E2 F/2 F C2 E/2 B/2 E E/2 G/2
D2 F E/2 B G/2 F2 D)  10.400001
71    (F2 A2 B2 C/2 A B/2 G2 C E2 D E/2 C F D2 G/2 G/2 E2 D2 D2
F/2 A2 A E2 G2 C2 F2)  11.9
22    (E2 C2 G C A/2 G/2 C E2 A F D2 D2 E/2 F/2 E D/2 F2 A2 A2
D2 A E/2 C2 A B/2 A2)  12.1
71    (F2 A2 B2 C/2 A B/2 G2 C E2 D E/2 C F D2 G/2 G/2 E2 D2 D2
F/2 A2 A E2 G2 C2 F2)  11.9
95    (F2 E G/2 C A A G A2 A A F G/2 A B D2 D/2 B2 E A/2 F/2 D B
D2 B2 C2 B)  11.200001

the most fit of the sample ...
7     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  13.200001

Selected individual =
7     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  13.200001
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Possibly mutated individual =
7     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  13.200001
Renumbered individual =
 8     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  13.200001
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Generation 1 population ...

1     (A2 G B/2 F F F/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.100001
2     (C/2 F A A2 G B F2 D F2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E
D A/2 F/2 F B)  13.900001
3     (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2
G/2 C F/2 A/2 A D/2 E F/2)  11.6
4     (G F/2 A/2 B/2 F/2 B2 B/2 A C2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  12.700001
5     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
6     (E/2 D A D/2 E/2 B D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  13.9
7     (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G2 E2 B/2 B D2 D2 F)  15.4
8     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  13.200001



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---the sample of individuals ...
85    (A C G2 C B/2 D2 E/2 D/2 G/2 C E2 A F C B E/2 C2 A G2 B/2
A/2 A C2 G F/2 D)  8.3
30    (F/2 F2 C2 B/2 E F/2 B C2 C2 B A C A G2 F A2 F F2 F2 C C/2
B2 B/2 A/2 D E2)  11.800001
15    (E B2 E E2 A/2 B/2 B2 B C C2 E F2 B2 D/2 G2 A F/2 D/2 G/2
F/2 B/2 E/2 F2 F/2 G2 B2)  12.000001
86    (G F/2 D/2 D2 D/2 E2 G/2 D C2 D E A C2 E2 G C/2 G2 B/2 E
A2 A2 A2 C2 F2 C/2 B)  10.7
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5     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
100   (A2 A/2 E/2 B F/2 A/2 F2 E/2 F2 D C/2 B D/2 A F C/2 G/2
C/2 A D/2 F2 B G2 E2 B2 E/2)  7.3
99    (G2 B/2 B2 G2 F C/2 C F C/2 C/2 F C2 C A D/2 A/2 G2 F2 D
F2 C2 C2 B/2 C/2 B/2 G/2)  9.500001
80    (E G/2 B G2 F2 G2 A2 B2 E C E G/2 B/2 D G/2 D/2 A2 F2 B
D/2 F/2 F2 C/2 B D2 F/2)  9.8

the most fit of the sample ...
5     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1

Selected individual =
5     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
Possibly mutated individual =
5     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
Renumbered individual =
 9     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
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Generation 1 population ...

1     (A2 G B/2 F F F/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.100001
2     (C/2 F A A2 G B F2 D F2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E
D A/2 F/2 F B)  13.900001
3     (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2
G/2 C F/2 A/2 A D/2 E F/2)  11.6
4     (G F/2 A/2 B/2 F/2 B2 B/2 A C2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  12.700001
5     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
6     (E/2 D A D/2 E/2 B D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  13.9
7     (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G2 E2 B/2 B D2 D2 F)  15.4
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8     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  13.200001
9     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1



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---the sample of individuals ...
98    (F2 C/2 C2 C/2 D2 A A/2 E C/2 E E A E2 C2 E2 A2 C2 E2 E
D/2 D/2 A/2 C2 D D C2)  12.100001
86    (G F/2 D/2 D2 D/2 E2 G/2 D C2 D E A C2 E2 G C/2 G2 B/2 E
A2 A2 A2 C2 F2 C/2 B)  10.7
61    (E/2 D B/2 A/2 D B2 B C/2 B C2 F/2 C C/2 B D/2 A2 B C C2
B2 C C B B2 F/2 E/2)  8.0
32    (E2 A2 A/2 B/2 F2 B2 F/2 F A2 D2 F2 A F/2 F2 C/2 B F/2 F2
B2 C2 C2 G B/2 C2 A/2 A/2)  8.3
94    (B2 G2 C A C G2 E2 B2 F/2 B/2 C G/2 C E2 B/2 E2 D2 F E2
E/2 B G2 F2 C F E)  7.3
40    (D2 F F2 C/2 G/2 G2 G2 G/2 D/2 B2 A2 G/2 D/2 E F2 E G G/2
A2 A E2 F/2 D/2 A/2 G2 C)  14.300001
43    (G/2 E2 B A2 D2 B D2 E/2 D C/2 C/2 E C/2 A2 D/2 E G/2 D/2
B B E D2 F2 E F2 D2)  12.6
15    (E B2 E E2 A/2 B/2 B2 B C C2 E F2 B2 D/2 G2 A F/2 D/2 G/2
F/2 B/2 E/2 F2 F/2 G2 B2)  12.000001

the most fit of the sample ...
40    (D2 F F2 C/2 G/2 G2 G2 G/2 D/2 B2 A2 G/2 D/2 E F2 E G G/2
A2 A E2 F/2 D/2 A/2 G2 C)  14.300001

Selected individual =
40    (D2 F F2 C/2 G/2 G2 G2 G/2 D/2 B2 A2 G/2 D/2 E F2 E G G/2
A2 A E2 F/2 D/2 A/2 G2 C)  14.300001
Possibly mutated individual =
40    (D2 F F2 C/2 G/2 G2 G2 G/2 D/2 B2 A2 G/2 D/2 E F2 E G G/2
A2 A E2 F/2 D/2 A/2 G2 C)  14.300001
Renumbered individual =
 10    (D2 F F2 C/2 G/2 G2 G2 G/2 D/2 B2 A2 G/2 D/2 E F2 E G G/2
A2 A E2 F/2 D/2 A/2 G2 C)  14.300001
------------------------------------------------------------
---
```

```
Generation 1 population ...

1      (A2 G B/2 F F F/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2
E2 D/2 D2 C/2 F D/2 F G/2)  15.100001
2      (C/2 F A A2 G B F2 D F2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E
D A/2 F/2 F B)  13.900001
3      (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2
G/2 C F/2 A/2 A D/2 E F/2)  11.6
4      (G F/2 A/2 B/2 F/2 B2 B/2 A C2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  12.700001
5      (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
6      (E/2 D A D/2 E/2 B D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G/2 E2 B/2 B D2 D2 F)  13.9
7      (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2
E/2 G2 E2 B/2 B D2 D2 F)  15.4
8      (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A
B/2 D2 E2 E2 A2 G A B C2)  13.200001
9      (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2
B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  15.1
10     (D2 F F2 C/2 G/2 G2 G2 G/2 D/2 B2 A2 G/2 D/2 E F2 E G G/2
A2 A E2 F/2 D/2 A/2 G2 C)  14.300001



------------------------------------------------------------------
---
NIL
[3]>
```

Task 10: Crossover

1. The Lisp task …

```
; Global bool demoing crossover
( setf *crossover-demo* nil )

; Percentage of crossovers
( defconstant *pc-x* 60 )

; Method that performs crossovers a certain number of times
```

```
( defmethod perform-crossovers ( ( cp population ) ( np population ) )
    ( dotimes ( i ( nr-crossovers ) )
        ( perform-one-crossover cp np )
    )
)

; Method that generates the number of crossovers based
; on percent crossovers and population-size
( defmethod nr-crossovers ()
    ( * ( / *pc-x* 100 ) *population-size* )
)

; Method that performs one crossover by selecting a mother
; and father, maybe mutating, combining, and adding the
; resultant individual to the new population
( defmethod perform-one-crossover ( ( cp population ) ( np population ) )
    ( let ( x m mm mother father new-i )
        ( setf mother ( select-individual cp ) )
        ( setf father ( select-individual cp ) )
        ( if *crossover-demo* ( format t "Selected mother = ~%" ) )
        ( if *crossover-demo* ( display mother ) )
        ( if *crossover-demo* ( format t "Selected father = ~&" ) )
        ( if *crossover-demo* ( display father ) )
        ( setf m ( crossover mother father ) )
        ( if *crossover-demo* ( format t "the crossover = ~&" ) )
        ( if *crossover-demo* ( display m ) )
        ( setf mm ( maybe-mutate m ) )
        ( if *crossover-demo* ( format t "the possibly mutated individual
= ~&" ) )
        ( if *crossover-demo* ( display mm ) )
        ( setf ( individual-number mm ) ( + 1 ( size np ) ) )
        ( if *crossover-demo* ( format t "the renumbered individual = ~&"
) )
        ( if *crossover-demo* ( display mm ) )
        ( setf new-i ( new-individual ( + 1 ( size np ) ) (
individual-melody mm ) ) )
        ( setf
            ( population-individuals np )
            ( append ( population-individuals np ) ( list new-i ) )
        )
```

```
    )
    nil
)

; Method that performs the crossover of the melody strings of two
; individuals
( defmethod crossover ( ( mother individual ) ( father individual )
    &aux mi fi x i )
    ( setf mi ( individual-melody mother ) )
    ( setf fi ( individual-melody father ) )
    ( setf x ( crossover mi fi ) )
    ( setf i ( new-individual 0 x ) )
    i
)
```

2. The embodied demo task …

```
; Demo method for perform-crossovers
( defmethod perform-crossovers-demo ( &aux cp np )
    ( setf cp ( initial-population ) )
    ( setf np ( empty-population cp ) )
    ( format t
"------------------------------------------------------------------------")
    ( setf *select-demo* t )
    ( setf *crossover-demo* t )
    ( dotimes ( i 10 )
        ( perform-one-crossover cp np )
        ( format t
"------------------------------------------------------------------------" )
        ( display np )
        ( format t
"~%~%------------------------------------------------------------------------" )
    )
    ( setf *select-demo* nil )
    ( setf *crossover-demo*  nil )
    nil
)
```

3. The embodied demo …

```
[1]> ( load "D:\\Programming Projects\\Lisp Projects\\Final Assignment\\wildcardga.lisp" )
;; Loading file D:\Programming Projects\Lisp Projects\Final Assignment\wildcardga.lisp ...
```

```
;; Loaded file D:\Programming Projects\Lisp Projects\Final Assignment\wildcardga.lisp
T
[2]> ( perform-crossovers-demo )
----------------------------------------------------------------------the sample of individuals
...
64    (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 F D/2 F G/2)
15.500001
26    (F C/2 D/2 E/2 C2 D2 A2 D2 F2 D G/2 D/2 C B F2 D/2 D2 C/2 A/2 G/2 E/2 F/2 A A C2 C/2)
12.4
94    (B2 G2 C A C G2 E2 B2 F/2 B/2 C G/2 C E2 B/2 E2 D2 F E2 E/2 B G2 F2 C F E)  7.3
50    (C E2 C A/2 G/2 A E/2 A2 F/2 G/2 E E2 B/2 B E C A C B/2 B C/2 C/2 A2 C/2 E C2)  9.7
26    (F C/2 D/2 E/2 C2 D2 A2 D2 F2 D G/2 D/2 C B F2 D/2 D2 C/2 A/2 G/2 E/2 F/2 A A C2 C/2)
12.4
45    (G/2 B2 G2 A/2 D B B2 E/2 A A2 D B F/2 C/2 G2 D2 B/2 C2 B2 D2 F D2 G2 D/2 F F)
5.8999996
61    (E/2 D B/2 A/2 D B2 B C/2 B C2 F/2 C C/2 B D/2 A2 B C C2 B2 C C B B2 F/2 E/2)  8.0
80    (E G/2 B G2 F2 G2 A2 B2 E C E G/2 B/2 D G/2 D/2 A2 F2 B D/2 F/2 F2 C/2 B D2 F/2)  9.8

the most fit of the sample ...
64    (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 F D/2 F G/2)
15.500001

the sample of individuals ...
88    (D2 C/2 C2 C2 D G/2 F2 D2 D2 E A/2 E F A/2 C A/2 B E2 C2 F2 C/2 F2 F2 E/2 A2 C2)
11.700001
83    (F2 A2 E/2 B/2 E F G/2 C/2 A2 G F/2 B2 G F2 F/2 C G2 B A2 F/2 B/2 G B G E2 B/2)  10.8
14    (G2 G/2 D2 C G/2 F2 E/2 C A/2 A/2 F/2 D D/2 B/2 G/2 C C/2 B2 C C/2 B2 E2 G/2 C B2 G)
10.0
41    (B/2 C G2 G G B/2 F/2 G G G B/2 G2 E/2 A B/2 D2 D2 E C/2 A F E F2 C2 C A/2)  12.800001
63    (C/2 F A A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  12.900001
98    (F2 C/2 C2 C/2 D2 A A/2 E C/2 E E A E2 C2 E2 A2 C2 E2 E D/2 D/2 A/2 C2 D D C2)
12.100001
56    (A/2 C G2 C D E2 C/2 A/2 A C2 E A/2 E/2 E/2 F2 F E/2 C F/2 C2 G A2 E2 D/2 A2 G)
10.900001
47    (C/2 E B A/2 D/2 G B2 E/2 D2 D B C2 F D C B D/2 B B2 A2 D2 E C G G2 G2)  10.200001

the most fit of the sample ...
63    (C/2 F A A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  12.900001

Selected mother =
64    (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 F D/2 F G/2)
15.500001
Selected father =
63    (C/2 F A A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  12.900001
the crossover =
0     (A2 G B/2 A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  14.1
the possibly mutated individual =
0     (A2 G B2 A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  14.1
the renumbered individual =
1     (A2 G B2 A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  14.1
----------------------------------------------------------------------

Generation 1 population ...

1     (A2 G B2 A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  14.1



----------------------------------------------------------------the sample of individuals ...
78    (A2 E2 C/2 G/2 D/2 C2 C2 F/2 C2 F2 G F C2 A2 D C2 E A2 B A/2 E/2 B2 A E2 D2 A2)  9.8
95    (F2 E G/2 C A A G A2 A A F G/2 A B D2 D/2 B2 E A/2 F/2 D B D2 B2 C2 B)  11.200001
```

```
27    (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 A/2 F/2 A/2 A D/2 E F/2)
13.1
74    (A2 E/2 A C/2 E B/2 F2 D/2 G2 A C/2 C2 E2 C2 B2 D C/2 D2 F C2 D F2 E2 B2 A E2)  9.8
87    (G B/2 A2 C2 C/2 G/2 C A/2 G B/2 D2 B/2 E2 D2 A/2 G2 F2 D E B2 E2 E E E C/2 E2)  11.7
94    (B2 G2 C A C G2 E2 B2 F/2 B/2 C G/2 C E2 B/2 E2 D2 F E2 E/2 B G2 F2 C F E)  7.3
51    (F/2 B A2 C/2 D/2 A B2 B B2 D2 C/2 A2 F2 A2 B2 B B/2 A/2 F/2 B/2 D/2 E C B2 B2 E)  13.0
93    (C2 G2 B2 D/2 G A2 E D/2 G/2 D2 A/2 D2 E F C G F2 G/2 E B/2 A D2 C2 G F2 A/2)  10.5

the most fit of the sample ...
27    (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 A/2 F/2 A/2 A D/2 E F/2)
13.1

the sample of individuals ...
85    (A C G2 C B/2 D2 E/2 D/2 G/2 C E2 A F C B E/2 C2 A G2 B/2 A/2 A C2 G F/2 D)  8.3
44    (D2 E F/2 C E2 G/2 G2 C2 G/2 E A/2 E2 E D/2 D D2 A/2 F2 A2 D A F G2 E B2 B2)  11.5
76    (D C2 F/2 A C/2 F2 C A2 B2 F C/2 B2 D F/2 E F/2 B2 E/2 G G/2 A/2 F/2 D2 F2 B2 G/2)  9.3
61    (E/2 D B/2 A/2 D B2 B C/2 B C2 F/2 C C/2 B D/2 A2 B C C2 B2 C C B B2 F/2 E/2)  8.0
72    (A2 C/2 B2 D C A2 D A F2 E2 C2 F/2 E/2 F G B/2 A E F/2 C2 B2 D/2 C G D/2 B2)  9.5
22    (E2 C2 G C A/2 G/2 C E2 A F D2 D2 E/2 F/2 E D/2 F2 A2 A2 D2 A E/2 C2 A B/2 A2)  12.1
16    (D2 G2 G2 G G A A2 F2 D2 E/2 F D D2 B2 D A2 E2 C/2 D/2 G F2 B/2 D/2 B2 G E)  12.000001
14    (G2 G/2 D2 C G/2 F2 E/2 C A/2 A/2 F/2 D D/2 B/2 G/2 C C/2 B2 C C/2 B2 E2 G/2 C B2 G)
10.0

the most fit of the sample ...
22    (E2 C2 G C A/2 G/2 C E2 A F D2 D2 E/2 F/2 E D/2 F2 A2 A2 D2 A E/2 C2 A B/2 A2)  12.1

Selected mother =
27    (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 A/2 F/2 A/2 A D/2 E F/2)
13.1
Selected father =
22    (E2 C2 G C A/2 G/2 C E2 A F D2 D2 E/2 F/2 E D/2 F2 A2 A2 D2 A E/2 C2 A B/2 A2)  12.1
the crossover =
0     (E/2 G/2 A D2 F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 D2 A E/2 C2 A B/2 A2)  10.8
the possibly mutated individual =
0     (E/2 G/2 A D2 F2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 D2 A E/2 C2 A B/2 A2)  10.8
the renumbered individual =
2     (E/2 G/2 A D2 F2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 D2 A E/2 C2 A B/2 A2)  10.8
----------------------------------------------------------------------

Generation 1 population ...

1     (A2 G B2 A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  14.1
2     (E/2 G/2 A D2 F2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 D2 A E/2 C2 A B/2 A2)  10.8



----------------------------------------------------------------------the sample of individuals ...
89    (E/2 E2 E/2 C2 D/2 D2 F2 E E2 G D G2 A F/2 F/2 D2 C2 G C/2 F B/2 G2 B/2 C2 E/2 E/2)
12.8
39    (C E2 E/2 B2 B B2 G/2 C/2 C/2 E D/2 G/2 C/2 F/2 E G/2 E E2 G/2 A/2 G2 B D D G2 A)
13.300001
95    (F2 E G/2 C A A G A2 A A F G/2 A B D2 D/2 B2 E A/2 F/2 D B D2 B2 C2 B)  11.200001
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2
C)  15.1
28    (D/2 F G/2 D/2 E2 E2 F D/2 G E2 B2 G C2 G/2 B E F2 E2 C2 D/2 E B2 E/2 A/2 B2 E/2)  11.8
3     (B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2 F/2 F2 E F2 A C2 G/2 F/2 A E/2 G2 C B E)
10.900001
14    (G2 G/2 D2 C G/2 F2 E/2 C A/2 A/2 F/2 D D/2 B/2 G/2 C C/2 B2 C C/2 B2 E2 G/2 C B2 G)
10.0
22    (E2 C2 G C A/2 G/2 C E2 A F D2 D2 E/2 F/2 E D/2 F2 A2 A2 D2 A E/2 C2 A B/2 A2)  12.1

the most fit of the sample ...
```

```
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2
C)  15.1

the sample of individuals ...
91    (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2 E/2 G/2 E2 B/2 B D2 D2 F)  15.4
13    (A/2 A F D2 F/2 F D/2 A A/2 B F E2 F/2 G/2 D C/2 F/2 C/2 F D/2 C/2 A C G2 E/2 D2)
12.400001
8     (G2 D/2 E G2 F2 B C/2 E G/2 F/2 D G2 D2 B2 E/2 G G F B A/2 A/2 D/2 G2 C G C2)  9.1
58    (F A F2 C/2 C E C F D2 B B2 D D B C2 A2 D/2 G A/2 A/2 F/2 D/2 C2 A2 F/2 G/2)  10.200001
3     (B/2 G G2 E G B/2 E2 F/2 F A/2 F/2 B2 F/2 F2 E F2 A C2 G/2 F/2 A E/2 G2 C B E)
10.900001
75    (A/2 F2 C2 G/2 A2 F A/2 D/2 F2 F E2 C2 B F/2 F2 G2 B E G E A/2 A G2 A2 G2 F/2)
13.400001
58    (F A F2 C/2 C E C F D2 B B2 D D B C2 A2 D/2 G A/2 A/2 F/2 D/2 C2 A2 F/2 G/2)  10.200001
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2
C)  15.1

the most fit of the sample ...
91    (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2 E/2 G/2 E2 B/2 B D2 D2 F)  15.4

Selected mother =
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2
C)  15.1
Selected father =
91    (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2 E/2 G/2 E2 B/2 B D2 D2 F)  15.4
the crossover =
0     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 F/2 G2 D/2 D/2 E/2 G/2 E2 B/2 B D2 D2
F)  16.4
the possibly mutated individual =
0     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 F/2 G2 D/2 D/2 E/2 G/2 E2 B/2 B D2 D2
F)  16.4
the renumbered individual =
3     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 F/2 G2 D/2 D/2 E/2 G/2 E2 B/2 B D2 D2
F)  16.4
------------------------------------------------------------------------

Generation 1 population ...

1     (A2 G B2 A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  14.1
2     (E/2 G/2 A D2 F2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 D2 A E/2 C2 A B/2 A2)  10.8
3     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 F/2 G2 D/2 D/2 E/2 G/2 E2 B/2 B D2 D2
F)  16.4



------------------------------------------------------------------the sample of individuals ...
91    (E/2 D A D/2 E/2 C2 D/2 F2 C D E/2 D2 F G F/2 G2 D/2 D/2 E/2 G/2 E2 B/2 B D2 D2 F)  15.4
47    (C/2 E B A/2 D/2 G B2 E/2 D2 D B C2 F D C B D/2 B B2 A2 D2 E C G G2 G2)  10.200001
67    (A/2 E/2 B/2 G/2 B/2 A F/2 A2 G B A E2 B A/2 G B/2 D/2 D/2 G C2 G/2 D D2 C2 A/2 D2)
10.6
64    (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 F D/2 F G/2)
15.500001
48    (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2)  14.7
35    (E G G/2 D2 D/2 D F/2 F2 A2 F A/2 C/2 B A E F/2 B/2 C2 F G B G2 F F/2 B C/2)  11.500001
56    (A/2 C G2 C D E2 C/2 A/2 A C2 E A/2 E/2 E/2 F2 F E/2 C F/2 C2 G A2 E2 D/2 A2 G)
10.900001
70    (D/2 G/2 G A D D2 G B G F/2 A D2 F2 C/2 C/2 B/2 E2 F2 F2 D2 A/2 E2 D F/2 E/2 C)
11.700001

the most fit of the sample ...
64    (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 F D/2 F G/2)
15.500001
```

```
the sample of individuals ...
74    (A2 E/2 A C/2 E B/2 F2 D/2 G2 A C/2 C2 E2 C2 B2 D C/2 D2 F C2 D F2 E2 B2 A E2)  9.8
46    (B2 E D2 E/2 C2 F/2 C G2 A B E A A2 A/2 B2 A2 C/2 D2 A B2 E F F/2 A2 E2 B)  12.400001
20    (G2 B G2 F/2 B B2 G A/2 E2 A/2 G2 G2 E/2 A E A2 C/2 E G/2 E/2 G/2 D2 B/2 A/2 B2 B/2)
11.400001
96    (A2 E G A G2 D2 C2 D A E2 D/2 F2 G2 E/2 C/2 G/2 D/2 G G/2 A2 B2 F/2 F/2 B F E)  12.6
67    (A/2 E/2 B/2 G/2 B/2 A F/2 A2 G B A E2 B A/2 G B/2 D/2 D/2 G C2 G/2 D D2 C2 A/2 D2)
10.6
24    (G/2 B/2 C2 E/2 A/2 F2 G2 A/2 E2 E/2 D/2 D/2 G G2 E E/2 E/2 C G G/2 A C G2 F D E/2)
13.800001
80    (E G/2 B G2 F2 G2 A2 B2 E C E G/2 B/2 D G/2 D/2 A2 F2 B D/2 F/2 F2 C/2 B D2 F/2)  9.8
12    (E2 D/2 A2 A2 A/2 G/2 F/2 D/2 F/2 B F F/2 C A F C2 D/2 G C2 A2 F/2 G2 F A B F/2)
11.900001

the most fit of the sample ...
24    (G/2 B/2 C2 E/2 A/2 F2 G2 A/2 E2 E/2 D/2 D/2 G G2 E E/2 E/2 C G G/2 A C G2 F D E/2)
13.800001

Selected mother =
64    (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 F D/2 F G/2)
15.500001
Selected father =
24    (G/2 B/2 C2 E/2 A/2 F2 G2 A/2 E2 E/2 D/2 D/2 G G2 E E/2 E/2 C G G/2 A C G2 F D E/2)
13.800001
the crossover =
0     (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 G2 F D E/2)  16.0
the possibly mutated individual =
0     (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 G2 F D E/2)  16.0
the renumbered individual =
4     (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 G2 F D E/2)  16.0
----------------------------------------------------------------------

Generation 1 population ...

1     (A2 G B2 A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  14.1
2     (E/2 G/2 A D2 F2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 D2 A E/2 C2 A B/2 A2)  10.8
3     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 F/2 G2 D/2 D/2 E/2 G/2 E2 B/2 B D2 D2
F)  16.4
4     (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 G2 F D E/2)  16.0



----------------------------------------------------------------the sample of individuals ...
96    (A2 E G A G2 D2 C2 D A E2 D/2 F2 G2 E/2 C/2 G/2 D/2 G G/2 A2 B2 F/2 F/2 B F E)  12.6
37    (B D/2 D2 E/2 C A/2 G/2 E2 D/2 B/2 C/2 F E/2 A2 C2 G2 A2 F2 A C/2 G2 B/2 D2 C2 D D2)
11.1
7     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A B/2 D2 E2 E2 A2 G A B C2)
13.200001
32    (E2 A2 A/2 B/2 F2 B2 F/2 F A2 D2 F2 A F/2 F2 C/2 B F/2 F2 B2 C2 C2 G B/2 C2 A/2 A/2)
8.3
9     (C2 B C2 B/2 G/2 D/2 A C C D E2 F/2 F C2 E/2 B/2 E E/2 G/2 D2 F E/2 B G/2 F2 D)
10.400001
71    (F2 A2 B2 C/2 A B/2 G2 C E2 D E/2 C F D2 G/2 G/2 E2 D2 D2 F/2 A2 A E2 G2 C2 F2)  11.9
22    (E2 C2 G C A/2 G/2 C E2 A F D2 D2 E/2 F/2 E D/2 F2 A2 A2 D2 A E/2 C2 A B/2 A2)  12.1
71    (F2 A2 B2 C/2 A B/2 G2 C E2 D E/2 C F D2 G/2 G/2 E2 D2 D2 F/2 A2 A E2 G2 C2 F2)  11.9

the most fit of the sample ...
7     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A B/2 D2 E2 E2 A2 G A B C2)
13.200001

the sample of individuals ...
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85    (A C G2 C B/2 D2 E/2 D/2 G/2 C E2 A F C B E/2 C2 A G2 B/2 A/2 A C2 G F/2 D)  8.3
30    (F/2 F2 C2 B/2 E F/2 B C2 C2 B A C A G2 F A2 F F2 F2 C C/2 B2 B/2 A/2 D E2)  11.800001
15    (E B2 E E2 A/2 B/2 B2 B C C2 E F2 B2 D/2 G2 A F/2 D/2 G/2 F/2 B/2 E/2 F2 F/2 G2 B2)
12.000001
86    (G F/2 D/2 D2 D/2 E2 G/2 D C2 D E A C2 E2 G C/2 G2 B/2 E A2 A2 A2 C2 F2 C/2 B)  10.7
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2
C)  15.1
100   (A2 A/2 E/2 B F/2 A/2 F2 E/2 F2 D C/2 B D/2 A F C/2 G/2 C/2 A D/2 F2 B G2 E2 B2 E/2)
7.3
99    (G2 B/2 B2 G2 F C/2 C F C/2 C/2 F C2 C A D/2 A/2 G2 F2 D F2 C2 C2 B/2 C/2 B/2 G/2)
9.500001
80    (E G/2 B G2 F2 G2 A2 B2 E C E G/2 B/2 D G/2 D/2 A2 F2 B D/2 F/2 F2 C/2 B D2 F/2)  9.8

the most fit of the sample ...
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2
C)  15.1

Selected mother =
7     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A B/2 D2 E2 E2 A2 G A B C2)
13.200001
Selected father =
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2
C)  15.1
the crossover =
0     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A B/2 D2 E2 E2 D/2 F/2 G/2 C2 C)
13.5
the possibly mutated individual =
0     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A B/2 B/2 E2 E2 D/2 F/2 G/2 C2
C)  13.3
the renumbered individual =
5     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A B/2 B/2 E2 E2 D/2 F/2 G/2 C2
C)  13.3
----------------------------------------------------------------------

Generation 1 population ...

1     (A2 G B2 A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  14.1
2     (E/2 G/2 A D2 F2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 D2 A E/2 C2 A B/2 A2)  10.8
3     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 F/2 G2 D/2 D/2 E/2 G/2 E2 B/2 B D2 D2
F)  16.4
4     (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 G2 F D E/2)  16.0
5     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A B/2 B/2 E2 E2 D/2 F/2 G/2 C2
C)  13.3



----------------------------------------------------------------------the sample of individuals ...
100   (A2 A/2 E/2 B F/2 A/2 F2 E/2 F2 D C/2 B D/2 A F C/2 G/2 C/2 A D/2 F2 B G2 E2 B2 E/2)
7.3
14    (G2 G/2 D2 C G/2 F2 E/2 C A/2 A/2 F/2 D D/2 B/2 G/2 C C/2 B2 C C/2 B2 E2 G/2 C B2 G)
10.0
69    (A2 F D2 G2 A/2 B D2 F D E/2 B/2 F/2 A/2 G/2 E/2 C/2 D2 G/2 G2 A/2 G/2 G/2 G/2 A2 E/2
A/2)  13.9
98    (F2 C/2 C2 C/2 D2 A A/2 E C/2 E E A E2 C2 E2 A2 C2 E2 E D/2 D/2 A/2 C2 D D C2)
12.100001
86    (G F/2 D/2 D2 D/2 E2 G/2 D C2 D E A C2 E2 G C/2 G2 B/2 E A2 A2 A2 C2 F2 C/2 B)  10.7
61    (E/2 D B/2 A/2 D B2 B C/2 B C2 F/2 C C/2 B D/2 A2 B C C2 B2 C C B B2 F/2 E/2)  8.0
32    (E2 A2 A/2 B/2 F2 B2 F/2 F A2 D2 F2 A F/2 F2 C/2 B F/2 F2 B2 C2 C2 G B/2 C2 A/2 A/2)
8.3
94    (B2 G2 C A C G2 E2 B2 F/2 B/2 C G/2 C E2 B/2 E2 D2 F E2 E/2 B G2 F2 C F E)  7.3

the most fit of the sample ...
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69    (A2 F D2 G2 A/2 B D2 F D E/2 B/2 F/2 A/2 G/2 E/2 C/2 D2 G/2 G2 A/2 G/2 G/2 G/2 A2 E/2
A/2)  13.9

the sample of individuals ...
76    (D C2 F/2 A C/2 F2 C A2 B2 F C/2 B2 D F/2 E F/2 B2 E/2 G G/2 A/2 F/2 D2 F2 B2 G/2)  9.3
84    (C/2 C2 E2 A2 B C/2 D/2 E2 B/2 B A G/2 C D/2 G2 A A2 B E/2 B2 C B/2 E/2 F C F)
11.900001
89    (E/2 E2 E/2 C2 D/2 D2 F2 E E2 G D G2 A F/2 F/2 D2 C2 G C/2 F B/2 G2 B/2 C2 E/2 E/2)
12.8
86    (G F/2 D/2 D2 D/2 E2 G/2 D C2 D E A C2 E2 G C/2 G2 B/2 E A2 A2 A2 C2 F2 C/2 B)  10.7
85    (A C G2 C B/2 D2 E/2 D/2 G/2 C E2 A F C B E/2 C2 A G2 B/2 A/2 A C2 G F/2 D)  8.3
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2
C)  15.1
36    (C F D/2 G2 F/2 F/2 E2 A B A2 E2 D/2 E F D/2 F B2 D A2 E2 B2 G2 G2 D/2 D/2 B/2)
11.400001
94    (B2 G2 C A C G2 E2 B2 F/2 B/2 C G/2 C E2 B/2 E2 D2 F E2 E/2 B G2 F2 C F E)  7.3

the most fit of the sample ...
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2
C)  15.1

Selected mother =
69    (A2 F D2 G2 A/2 B D2 F D E/2 B/2 F/2 A/2 G/2 E/2 C/2 D2 G/2 G2 A/2 G/2 G/2 G/2 A2 E/2
A/2)  13.9
Selected father =
2     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2
C)  15.1
the crossover =
0     (A2 F D2 G2 A/2 B D2 F D A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  12.1
the possibly mutated individual =
0     (A2 F D2 G2 A/2 B D2 F D A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  12.1
the renumbered individual =
6     (A2 F D2 G2 A/2 B D2 F D A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  12.1
----------------------------------------------------------------------

Generation 1 population ...

1     (A2 G B2 A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  14.1
2     (E/2 G/2 A D2 F2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 D2 A E/2 C2 A B/2 A2)  10.8
3     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 F/2 G2 D/2 D/2 E/2 G/2 E2 B/2 B D2 D2
F)  16.4
4     (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 G2 F D E/2)  16.0
5     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A B/2 B/2 E2 E2 D/2 F/2 G/2 C2
C)  13.3
6     (A2 F D2 G2 A/2 B D2 F D A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  12.1



----------------------------------------------------------------the sample of individuals ...
81    (E/2 D F/2 F B/2 E C2 B2 E/2 B/2 E2 D/2 E A/2 G/2 B/2 F/2 G2 B/2 E2 C A/2 F2 D/2 F/2 C2)
9.8
11    (C B/2 D B2 D D/2 E2 C F E2 E B/2 A F/2 C2 G E2 E/2 G D C2 B2 B2 B2 D2 G)  10.0
15    (E B2 E E2 A/2 B/2 B2 B C C2 E F2 B2 D/2 G2 A F/2 D/2 G/2 F/2 B/2 E/2 F2 F/2 G2 B2)
12.000001
93    (C2 G2 B2 D/2 G A2 E D/2 G/2 D2 A/2 D2 E F C G F2 G/2 E B/2 A D2 C2 G F2 A/2)  10.5
37    (B D/2 D2 E/2 C A/2 G/2 E2 D/2 B/2 C/2 F E/2 A2 C2 G2 A2 F2 A C/2 G2 B/2 D2 C2 D D2)
11.1
63    (C/2 F A A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  12.900001
26    (F C/2 D/2 E/2 C2 D2 A2 D2 F2 D G/2 D/2 C B F2 D/2 D2 C/2 A/2 G/2 E/2 F/2 A A C2 C/2)
12.4
48    (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2)  14.7
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the most fit of the sample ...
48    (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2)  14.7

the sample of individuals ...
16    (D2 G2 G2 G G A A2 F2 D2 E/2 F D D2 B2 D A2 E2 C/2 D/2 G F2 B/2 D/2 B2 G E)  12.000001
29    (G2 C2 D/2 G2 E G2 E/2 B/2 B B/2 C2 D/2 A2 E/2 E F2 A D E F2 F/2 C/2 G E/2 C/2 E/2)
11.700001
9     (C2 B C2 B/2 G/2 D/2 A C C D E2 F/2 F C2 E/2 B/2 E E/2 G/2 D2 F E/2 B G/2 F2 D)
10.400001
19    (D2 D2 D2 E/2 C2 D/2 A/2 B E/2 C/2 A C/2 E/2 F2 F2 D B/2 D B G/2 E2 B2 G2 F A2 E/2)
11.400001
44    (D2 E F/2 C E2 G/2 G2 C2 G/2 E A/2 E2 E D/2 D D2 A/2 F2 A2 D A F G2 E B2 B2)  11.5
8     (G2 D/2 E G2 F2 B C/2 E G/2 F/2 D G2 D2 B2 E/2 G G F B A/2 A/2 D/2 G2 C G C2)  9.1
48    (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2)  14.7
6     (A A2 E2 C2 G/2 G2 D/2 C2 E A2 E G2 F E B G/2 G2 B/2 F/2 E2 A/2 F/2 D/2 D2 A2 D2)
10.700001

the most fit of the sample ...
48    (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2)  14.7

Selected mother =
48    (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2)  14.7
Selected father =
48    (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2)  14.7
the crossover =
0     (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2)  14.7
the possibly mutated individual =
0     (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2)  14.7
the renumbered individual =
7     (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2)  14.7
----------------------------------------------------------------------

Generation 1 population ...

1     (A2 G B2 A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  14.1
2     (E/2 G/2 A D2 F2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 D2 A E/2 C2 A B/2 A2)  10.8
3     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 F/2 G2 D/2 D/2 E/2 G/2 E2 B/2 B D2 D2
F)  16.4
4     (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 G2 F D E/2)  16.0
5     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A B/2 B/2 E2 E2 D/2 F/2 G/2 C2
C)  13.3
6     (A2 F D2 G2 A/2 B D2 F D A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  12.1
7     (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2)  14.7



----------------------------------------------------------------------the sample of individuals ...
50    (C E2 C A/2 G/2 A E/2 A2 F/2 G/2 E E2 B/2 B E C A C B/2 B C/2 C/2 A2 C/2 E C2)  9.7
41    (B/2 C G2 G G B/2 F/2 G G G B/2 G2 E/2 A B/2 D2 D2 E C/2 A F E F2 C2 C A/2)  12.800001
90    (E2 D G/2 A E F/2 A2 F2 D G F/2 A C/2 D2 F C E B F D/2 C2 G/2 A/2 F/2 C C/2)  11.8
32    (E2 A2 A/2 B/2 F2 B2 F/2 F A2 D2 F2 A F/2 F2 C/2 B F/2 F2 B2 C2 C2 G B/2 C2 A/2 A/2)
8.3
23    (G2 B/2 F E/2 D2 G D2 D C/2 F B2 F/2 C2 F E/2 F C/2 G/2 E/2 G/2 F/2 E/2 F2 E/2 C F)
11.8
29    (G2 C2 D/2 G2 E G2 E/2 B/2 B B/2 C2 D/2 A2 E/2 E F2 A D E F2 F/2 C/2 G E/2 C/2 E/2)
11.700001
10    (E2 D/2 D D2 G B E2 A2 B/2 C2 C A D/2 F2 E2 D C2 A B/2 C2 E/2 C G2 D D/2 A2)  11.200001
97    (E/2 D2 G G/2 E2 A2 A2 G D/2 F/2 A2 D2 G2 G/2 B2 B C2 F/2 D/2 E/2 C2 D/2 B2 A2 C2 G)
11.200001

the most fit of the sample ...
41    (B/2 C G2 G G B/2 F/2 G G G B/2 G2 E/2 A B/2 D2 D2 E C/2 A F E F2 C2 C A/2)  12.800001
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the sample of individuals ...
36    (C F D/2 G2 F/2 F/2 E2 A B A2 E2 D/2 E F D/2 F B2 D A2 E2 B2 G2 G2 D/2 D/2 B/2)
11.400001
73    (E C A2 A2 B E/2 C2 A2 B2 A G/2 E2 F F/2 B B E2 B A/2 D/2 A/2 F F C/2 F F)  12.0
15    (E B2 E E2 A/2 B/2 B2 B C C2 E F2 B2 D/2 G2 A F/2 D/2 G/2 F/2 B/2 E/2 F2 F/2 G2 B2)
12.000001
79    (B D2 A F/2 D/2 F2 G2 E2 C2 F C/2 F/2 E F B2 D2 C2 E/2 C/2 C C A2 B/2 A2 A2 B/2)  12.9
62    (D2 E/2 F2 G/2 F2 D/2 B/2 F2 B F C/2 G C E2 B/2 C2 D2 B D E2 C/2 E E/2 C2 G2 F2)  10.3
6     (A A2 E2 C2 G/2 G2 D/2 C2 E A2 E G2 F E B G/2 G2 B/2 F/2 E2 A/2 F/2 D/2 D2 A2 D2)
10.700001
98    (F2 C/2 C2 C/2 D2 A A/2 E C/2 E E A E2 C2 E2 A2 C2 E2 E D/2 D/2 A/2 C2 D D C2)
12.100001
85    (A C G2 C B/2 D2 E/2 D/2 G/2 C E2 A F C B E/2 C2 A G2 B/2 A/2 A C2 G F/2 D)  8.3

the most fit of the sample ...
79    (B D2 A F/2 D/2 F2 G2 E2 C2 F C/2 F/2 E F B2 D2 C2 E/2 C/2 C C A2 B/2 A2 A2 B/2)  12.9

Selected mother =
41    (B/2 C G2 G G B/2 F/2 G G G B/2 G2 E/2 A B/2 D2 D2 E C/2 A F E F2 C2 C A/2)  12.800001
Selected father =
79    (B D2 A F/2 D/2 F2 G2 E2 C2 F C/2 F/2 E F B2 D2 C2 E/2 C/2 C C A2 B/2 A2 A2 B/2)  12.9
the crossover =
0     (B/2 C G2 G G B/2 F/2 G G G B/2 G2 E/2 A B2 D2 C2 E/2 C/2 C C A2 B/2 A2 A2 B/2)  14.6
the possibly mutated individual =
0     (B/2 C G2 G G B/2 F/2 G G G B/2 G2 E/2 E/2 B2 D2 C2 E/2 C/2 C C A2 B/2 A2 A2 B/2)
14.400001
the renumbered individual =
8     (B/2 C G2 G G B/2 F/2 G G G B/2 G2 E/2 E/2 B2 D2 C2 E/2 C/2 C C A2 B/2 A2 A2 B/2)
14.400001
----------------------------------------------------------------------

Generation 1 population ...

1     (A2 G B2 A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  14.1
2     (E/2 G/2 A D2 F2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 D2 A E/2 C2 A B/2 A2)  10.8
3     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 F/2 G2 D/2 D/2 E/2 G/2 E2 B/2 B D2 D2
F)  16.4
4     (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 G2 F D E/2)  16.0
5     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A B/2 B/2 E2 E2 D/2 F/2 G/2 C2
C)  13.3
6     (A2 F D2 G2 A/2 B D2 F D A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  12.1
7     (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2)  14.7
8     (B/2 C G2 G G B/2 F/2 G G G B/2 G2 E/2 E/2 B2 D2 C2 E/2 C/2 C C A2 B/2 A2 A2 B/2)
14.400001



----------------------------------------------------------------the sample of individuals ...
44    (D2 E F/2 C E2 G/2 G2 C2 G/2 E A/2 E2 E D/2 D D2 A/2 F2 A2 D A F G2 E B2 B2)  11.5
23    (G2 B/2 F E/2 D2 G D2 D C/2 F B2 F/2 C2 F E/2 F C/2 G/2 E/2 G/2 F/2 E/2 F2 E/2 C F)
11.8
33    (D E2 F E/2 G2 A2 F2 F/2 E/2 D2 G F2 E2 F/2 D2 G2 G2 G/2 B D F/2 D/2 C E2 G2 B/2)
16.900002
63    (C/2 F A A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  12.900001
82    (E F/2 E F/2 C2 B2 D D2 D E/2 G2 A/2 F2 D2 F2 D2 A/2 E C D2 E E/2 E/2 C/2 E2 G2)
14.700001
48    (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2)  14.7
38    (E G C D/2 C2 F/2 B D/2 A2 A F D2 E A D C B/2 E/2 A2 E2 C2 D A/2 F C/2 C)  9.1
85    (A C G2 C B/2 D2 E/2 D/2 G/2 C E2 A F C B E/2 C2 A G2 B/2 A/2 A C2 G F/2 D)  8.3

the most fit of the sample ...
```

```
33    (D E2 F E/2 G2 A2 F2 F/2 E/2 D2 G F2 E2 F/2 D2 G2 G2 G/2 B D F/2 D/2 C E2 G2 B/2)
16.900002

the sample of individuals ...
13    (A/2 A F D2 F/2 F D/2 A A/2 B F E2 F/2 G/2 D C/2 F/2 C/2 F D/2 C/2 A C G2 E/2 D2)
12.400001
48    (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2)  14.7
6     (A A2 E2 C2 G/2 G2 D/2 C2 E A2 E G2 F E B G/2 G2 B/2 F/2 E2 A/2 F/2 D/2 D2 A2 D2)
10.700001
93    (C2 G2 B2 D/2 G A2 E D/2 G/2 D2 A/2 D2 E F C G F2 G/2 E B/2 A D2 C2 G F2 A/2)  10.5
93    (C2 G2 B2 D/2 G A2 E D/2 G/2 D2 A/2 D2 E F C G F2 G/2 E B/2 A D2 C2 G F2 A/2)  10.5
33    (D E2 F E/2 G2 A2 F2 F/2 E/2 D2 G F2 E2 F/2 D2 G2 G2 G/2 B D F/2 D/2 C E2 G2 B/2)
16.900002
58    (F A F2 C/2 C E C F D2 B B2 D D B C2 A2 D/2 G A/2 A/2 F/2 D/2 C2 A2 F/2 G/2)  10.200001
13    (A/2 A F D2 F/2 F D/2 A A/2 B F E2 F/2 G/2 D C/2 F/2 C/2 F D/2 C/2 A C G2 E/2 D2)
12.400001

the most fit of the sample ...
33    (D E2 F E/2 G2 A2 F2 F/2 E/2 D2 G F2 E2 F/2 D2 G2 G2 G/2 B D F/2 D/2 C E2 G2 B/2)
16.900002

Selected mother =
33    (D E2 F E/2 G2 A2 F2 F/2 E/2 D2 G F2 E2 F/2 D2 G2 G2 G/2 B D F/2 D/2 C E2 G2 B/2)
16.900002
Selected father =
33    (D E2 F E/2 G2 A2 F2 F/2 E/2 D2 G F2 E2 F/2 D2 G2 G2 G/2 B D F/2 D/2 C E2 G2 B/2)
16.900002
the crossover =
0     (D E2 F E/2 G2 A2 F2 F/2 E/2 D2 G F2 E2 F/2 D2 G2 G2 G/2 B D F/2 D/2 C E2 G2 B/2)
16.900002
the possibly mutated individual =
0     (D E2 F E/2 G2 A2 F2 F/2 E/2 D2 G F2 E2 F/2 D2 G2 A G/2 B D F/2 D/2 C E2 G2 B/2)  17.3
the renumbered individual =
9     (D E2 F E/2 G2 A2 F2 F/2 E/2 D2 G F2 E2 F/2 D2 G2 A G/2 B D F/2 D/2 C E2 G2 B/2)  17.3
----------------------------------------------------------------------

Generation 1 population ...

1     (A2 G B2 A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  14.1
2     (E/2 G/2 A D2 F2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 D2 A E/2 C2 A B/2 A2)  10.8
3     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 F/2 G2 D/2 D/2 E/2 G/2 E2 B/2 B D2 D2
F)  16.4
4     (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 G2 F D E/2)  16.0
5     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A B/2 B/2 E2 E2 D/2 F/2 G/2 C2
C)  13.3
6     (A2 F D2 G2 A/2 B D2 F D A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  12.1
7     (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2)  14.7
8     (B/2 C G2 G G B/2 F/2 G G G B/2 G2 E/2 E/2 B2 D2 C2 E/2 C/2 C C A2 B/2 A2 A2 B/2)
14.400001
9     (D E2 F E/2 G2 A2 F2 F/2 E/2 D2 G F2 E2 F/2 D2 G2 A G/2 B D F/2 D/2 C E2 G2 B/2)  17.3



----------------------------------------------------------------------the sample of individuals ...
20    (G2 B G2 F/2 B B2 G A/2 E2 A/2 G2 G2 E/2 A E A2 C/2 E G/2 E/2 G/2 D2 B/2 A/2 B2 B/2)
11.400001
13    (A/2 A F D2 F/2 F D/2 A A/2 B F E2 F/2 G/2 D C/2 F/2 C/2 F D/2 C/2 A C G2 E/2 D2)
12.400001
69    (A2 F D2 G2 A/2 B D2 F D E/2 B/2 F/2 A/2 G/2 E/2 C/2 D2 G/2 G2 A/2 G/2 G/2 G/2 A2 E/2
A/2)  13.9
67    (A/2 E/2 B/2 G/2 B/2 A F/2 A2 G B A E2 B A/2 G B/2 D/2 D/2 G C2 G/2 D D2 C2 A/2 D2)
10.6
```

```
42    (A2 F A/2 F E B G2 A/2 B2 D/2 C/2 A2 B2 B F2 F2 C2 D/2 F2 F B/2 D/2 B2 C/2 F2 E/2)  11.9
9     (C2 B C2 B/2 G/2 D/2 A C C D E2 F/2 F C2 E/2 B/2 E E/2 G/2 D2 F E/2 B G/2 F2 D)
10.400001
81    (E/2 D F/2 F B/2 E C2 B2 E/2 B/2 E2 D/2 E A/2 G/2 B/2 F/2 G2 B/2 E2 C A/2 F2 D/2 F/2 C2)
9.8
16    (D2 G2 G2 G G A A2 F2 D2 E/2 F D D2 B2 D A2 E2 C/2 D/2 G F2 B/2 D/2 B2 G E)  12.000001

the most fit of the sample ...
69    (A2 F D2 G2 A/2 B D2 F D E/2 B/2 F/2 A/2 G/2 E/2 C/2 D2 G/2 G2 A/2 G/2 G/2 G/2 A2 E/2
A/2)  13.9

the sample of individuals ...
23    (G2 B/2 F E/2 D2 G D2 D C/2 F B2 F/2 C2 F E/2 F C/2 G/2 E/2 G/2 F/2 E/2 F2 E/2 C F)
11.8
97    (E/2 D2 G G/2 E2 A2 A2 G D/2 F/2 A2 D2 G2 G/2 B2 B C2 F/2 D/2 E/2 C2 D/2 B2 A2 C2 G)
11.200001
90    (E2 D G/2 A E F/2 A2 F2 D G F/2 A C/2 D2 F C E B F D/2 C2 G/2 A/2 F/2 C C/2)  11.8
99    (G2 B/2 B2 G2 F C/2 C F C/2 C/2 F C2 C A D/2 A/2 G2 F2 D F2 C2 C2 B/2 C/2 B/2 G/2)
9.500001
55    (G/2 B/2 B C B2 E/2 F/2 F/2 C2 D A C B2 E B C/2 B F F/2 D2 F2 A2 G/2 E2 A C2)  7.9000006
20    (G2 B G2 F/2 B B2 G A/2 E2 A/2 G2 G2 E/2 A E A2 C/2 E G/2 E/2 G/2 D2 B/2 A/2 B2 B/2)
11.400001
97    (E/2 D2 G G/2 E2 A2 A2 G D/2 F/2 A2 D2 G2 G/2 B2 B C2 F/2 D/2 E/2 C2 D/2 B2 A2 C2 G)
11.200001
26    (F C/2 D/2 E/2 C2 D2 A2 D2 F2 D G/2 D/2 C B F2 D/2 D2 C/2 A/2 G/2 E/2 F/2 A A C2 C/2)
12.4

the most fit of the sample ...
26    (F C/2 D/2 E/2 C2 D2 A2 D2 F2 D G/2 D/2 C B F2 D/2 D2 C/2 A/2 G/2 E/2 F/2 A A C2 C/2)
12.4

Selected mother =
69    (A2 F D2 G2 A/2 B D2 F D E/2 B/2 F/2 A/2 G/2 E/2 C/2 D2 G/2 G2 A/2 G/2 G/2 G/2 A2 E/2
A/2)  13.9
Selected father =
26    (F C/2 D/2 E/2 C2 D2 A2 D2 F2 D G/2 D/2 C B F2 D/2 D2 C/2 A/2 G/2 E/2 F/2 A A C2 C/2)
12.4
the crossover =
0     (A2 F D2 G2 A/2 B D2 F D E/2 B/2 F/2 A/2 G/2 E/2 C/2 D2 G/2 G2 A/2 G/2 G/2 A A C2 C/2)
14.7
the possibly mutated individual =
0     (A2 F D2 G2 A/2 B D2 F D E/2 B/2 F/2 A/2 G/2 E/2 C/2 D2 G/2 G2 A/2 G/2 G/2 A A C2 C/2)
14.7
the renumbered individual =
10    (A2 F D2 G2 A/2 B D2 F D E/2 B/2 F/2 A/2 G/2 E/2 C/2 D2 G/2 G2 A/2 G/2 G/2 A A C2 C/2)
14.7
---------------------------------------------------------------------

Generation 1 population ...

1     (A2 G B2 A2 G B F2 D G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B)  14.1
2     (E/2 G/2 A D2 F2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 D2 A E/2 C2 A B/2 A2)  10.8
3     (B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2 F/2 G2 D/2 D/2 E/2 G/2 E2 B/2 B D2 D2
F)  16.4
4     (A2 G B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2 G2 F D E/2)  16.0
5     (G F/2 A/2 B/2 F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A B/2 B/2 E2 E2 D/2 F/2 G/2 C2
C)  13.3
6     (A2 F D2 G2 A/2 B D2 F D A2 B/2 F2 D/2 E/2 G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2 C)  12.1
7     (A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2 G G F F/2 E D2 C2 C/2)  14.7
8     (B/2 C G2 G G B/2 F/2 G G G B/2 G2 E/2 E/2 B2 D2 C2 E/2 C/2 C C A2 B/2 A2 A2 B/2)
14.400001
9     (D E2 F E/2 G2 A2 F2 F/2 E/2 D2 G F2 E2 F/2 D2 G2 A G/2 B D F/2 D/2 C E2 G2 B/2)  17.3
```

```
10    (A2 F D2 G2 A/2 B D2 F D E/2 B/2 F/2 A/2 G/2 E/2 C/2 D2 G/2 G2 A/2 G/2 G/2 A A C2 C/2)
14.7


------------------------------------------------------------
NIL
[3]>
```

Task 11: The GA

Note: The *limit* was changed to 20 for this section for better results. More on that in the behavior section :)

1. The Lisp code task …

```
;; THE NEXT GENERATION METHOD FOR THE GA
; Create an empty population -> perform copies -> perform-crossovers ->
return new
; generation
( defmethod next-generation ( ( cp population ) &aux np )
    ( setf np ( empty-population cp ) )
    ( perform-copies cp np )
    ( perform-crossovers cp np )
    np
)

;; THE GA!
; Number of generations
( defconstant *nr-generations* 25 )

; The Genetic algorithm :) -- runs 5 fitnes methods
( defmethod ga ( &aux p )

    ( format t "STEPWISE MOTION MELODIES! ~%~%" )
    ( setf *fitness* #'fitness-stepwise-motion )
    ( setf p ( initial-population ) )
    ( terpri )
    ( summarize p )
    ( dotimes ( i *nr-generations* )
        ( setf p ( next-generation p ) )
        ( check-average p )
    )
```

```
    ( terpri )
    ( summarize p )
    ( setf stepwise-melody-f  ( most-fit-individual (
population-individuals p )  ) )
    ( format t "PAIR-WISE MELODIES! ~%~%" )
    ( setf *fitness* #'fitness-pairs )
    ( dotimes ( i *nr-generations* )
        ( setf p ( next-generation p ) )
        ( check-average p )
    )
    ( terpri )
    ( summarize p )
    ( setf pairwise-melody-f ( most-fit-individual (
population-individuals p ) ) )
    ( format t "ASCENDING JUMPS AND STEPWISE DECLINES MELODIES! ~%~%" )
    ( setf *fitness* #'fitness-ascending-jumps )
    ( dotimes ( i *nr-generations* )
        ( setf p ( next-generation p ) )
        ( check-average p )
    )
    ( terpri )
    ( summarize p )
    ( setf ascending-jumps-melody-f ( most-fit-individual (
population-individuals p ) ) )
    ( format t "STEPWISE SLASHING MELODIES! ~%~%" )
    ( setf *fitness* #'fitness-stepwise-slashing )
    ( dotimes ( i *nr-generations* )
        ( setf p ( next-generation p ) )
        ( check-average p )
    )
    ( terpri )
    ( summarize p )
    ( setf stepwise-slashing-melody-f ( most-fit-individual (
population-individuals p ) ) )
    ( format t "ZIG-ZAG MELODIES! ~%~%" )
    ( setf *fitness* #'fitness-zig-zag )
    ( dotimes ( i *nr-generations* )
        ( setf p ( next-generation p ) )
        ( check-average p )
    )
```

```
    ( terpri )
    ( summarize p )
    ( setf zig-zag-melody-f ( most-fit-individual ( population-individuals
p ) ) )

    ( format t "~%Most fit stepwise melody: " )
    ( display stepwise-melody-f )

    ( format t "~%Most fit pairwise melody: " )
    ( display pairwise-melody-f )

    ( format t "~%Most fit ascending jumps/stepwise decline melody: " )
    ( display ascending-jumps-melody-f )

    ( format t "~%Most fit stepwise slashing melody: " )
    ( display stepwise-slashing-melody-f )

    ( format t "~%Most fit zig zag melody: " )
    ( display zig-zag-melody-f )

)

;; METHODS TO PROVIDE INFORMATION ON "PROGRESS"

; Methods that display the population averages for each generation
( defmethod summarize ( ( p population ) )
    ( display p )
    ( check-average p )
    ( terpri )
)

( defmethod check-average ( ( p population ) )
    ( format t "average fitness of population ~A = ~A~%"
        ( population-generation p )
        ( average p )
    )
)
```

2. The enter/run/observe task …

```
[1]> ( load "D:\\Programming Projects\\Lisp Projects\\Final Assignment\\wildcardga.lisp" )
;; Loading file D:\Programming Projects\Lisp Projects\Final Assignment\wildcardga.lisp ...
;; Loaded file D:\Programming Projects\Lisp Projects\Final Assignment\wildcardga.lisp
T
[2]> ( ga )
STEPWISE MOTION MELODIES!



Generation 0 population ...

1     (G B/2 G D B/2 A2 B/2 A2 C/2 B E/2 D/2 B F/2 B G2 A/2 G/2 A2 D/2)  8.5
2     (C2 F/2 G2 B2 B2 A B/2 A/2 B/2 G/2 F/2 E/2 D F/2 E A2 B/2 F2 D/2 E/2)  13.8
3     (G F/2 B2 D/2 G/2 G A D/2 F/2 G/2 C2 C B/2 G G2 E G B/2 E2 F/2)  8.9
4     (F A/2 F/2 B2 F/2 F2 E F2 A C2 G/2 F/2 A E/2 G2 C B E C2 B2)  6.8
5     (A2 A2 A/2 D/2 D E2 G2 C2 E/2 D2 G F/2 B2 C/2 D G/2 G/2 G/2 B2 G2)  10.0
6     (E F/2 B2 A G A F2 E/2 E/2 D A/2 G2 A2 B/2 E/2 B2 B F/2 G2 G/2)  12.9
7     (B/2 G A A2 C/2 G2 C/2 E/2 E/2 F2 A A2 E2 C2 G/2 G2 D/2 C2 E A2)  8.700001
8     (E G2 F E B G/2 G2 B/2 F/2 E2 A/2 F/2 D/2 D2 A2 D2 G F/2 A/2 B/2)  9.6
9     (F/2 B2 B/2 A F/2 B/2 D/2 D B A/2 A/2 D/2 A B/2 D2 E2 E2 A2 G A)  9.700001
10    (B C2 G2 D/2 E G2 F2 B C/2 E G/2 F/2 D G2 D2 B2 E/2 G G F)  7.3
11    (B A/2 A/2 D/2 G2 C G C2 C2 B C2 B/2 G/2 D/2 A C C D E2 F/2)  6.9000006
12    (F C2 E/2 B/2 E E/2 G/2 D2 F E/2 B G/2 F2 D E2 D/2 D D2 G B)  9.400001
13    (E2 A2 B/2 C2 C A D/2 F2 E2 D C2 A B/2 C2 E/2 C G2 D D/2 A2)  8.1
14    (C B/2 D B2 D D/2 E2 C F E2 E B/2 A F/2 C2 G E2 E/2 G D)  7.4
15    (C2 B2 B2 B2 D2 G E2 D/2 A2 A2 A/2 G/2 F/2 D/2 F/2 B F F/2 C A)  8.5
16    (F C2 D/2 G C2 A2 F/2 G2 F A B F/2 A/2 A F D2 F/2 F D/2 A)  9.1
17    (A/2 B F E2 F/2 G/2 D C/2 F/2 C/2 F D/2 C/2 A C G2 E/2 D2 G2 G/2)  8.8
18    (D2 C G/2 F2 E/2 C A/2 A/2 F/2 D D/2 B/2 G/2 C C/2 B2 C C/2 B2 E2)  8.2
19    (G/2 C B2 G E B2 E E2 A/2 B/2 B2 B C C2 E F2 B2 D/2 G2 A)  7.7000003
20    (F/2 D/2 G/2 F/2 B/2 E/2 F2 F/2 G2 B2 D2 G2 G2 G G A A2 F2 D2 E/2)  11.0
21    (F D D2 B2 D A2 E2 C/2 D/2 G F2 B/2 D/2 B2 G E C2 A B2 A)  7.3
22    (G/2 G2 B A F/2 B/2 G2 F/2 D C D2 C2 E E2 G2 B/2 E2 D/2 E2 C)  12.6
23    (C B/2 E G/2 B2 B E G/2 D E F/2 D2 C/2 D G/2 A F/2 B2 D F2)  8.8
24    (E F/2 F2 F A/2 G2 D2 D D2 D2 D2 E/2 C2 D/2 A/2 B E/2 C/2 A C/2)  11.300001
25    (E/2 F2 F2 D B/2 D B G/2 E2 B2 G2 F A2 E/2 G2 B G2 F/2 B B2)  8.6
26    (G A/2 E2 A/2 G2 G2 E/2 A E A2 C/2 E G/2 E/2 G/2 D2 B/2 A/2 B2 B/2)  8.1
27    (A/2 A B2 F/2 A2 D/2 B G C/2 B A/2 D C2 A2 B A/2 A2 F2 D/2 D/2)  9.400001
28    (C/2 E F2 E2 D/2 B E2 C2 G C A/2 G/2 C E2 A F D2 D2 E/2 F/2)  9.3
29    (E D/2 F2 A2 A2 D2 A E/2 C2 A B/2 A2 G2 B/2 F E/2 D2 G D2 D)  9.6
30    (C/2 F B2 F/2 C2 F E/2 F C/2 G/2 E/2 G/2 F/2 E/2 F2 E/2 C F G/2 B/2)  9.0
31    (C2 E/2 A/2 F2 G2 A/2 E2 E/2 D/2 D/2 G G2 E E/2 E/2 C G G/2 A C)  10.8
32    (G2 F D E/2 F G2 G2 B C G/2 E/2 E F/2 A2 C/2 G/2 C2 A E2 B)  8.6
33    (F2 C F2 B E G G F/2 F/2 G2 F C/2 D/2 E/2 C2 D2 A2 D2 F2 D)  9.6
34    (G/2 D/2 C B F2 D/2 D2 C/2 A/2 G/2 E/2 F/2 A A C2 C/2 E/2 G/2 A D2)  9.9
35    (F/2 A C/2 G2 G/2 D/2 A2 C G2 A F E/2 D F2 G/2 A/2 F/2 A/2 A D/2)  9.1
36    (E F/2 D/2 F G/2 D/2 E2 E2 F D/2 G E2 B2 G C2 G/2 B E F2 E2)  9.8
37    (C2 D/2 E B2 E/2 A/2 B2 E/2 G2 C2 D/2 G2 E G2 E/2 B/2 B B/2 C2 D/2)  8.6
38    (A2 E/2 E F2 A D E F2 F/2 C/2 G E/2 C/2 E/2 F/2 F2 C2 B/2 E F/2)  9.400001
39    (B C2 C2 B A C A G2 F A2 F F2 F2 C C/2 B2 B/2 A/2 D E2)  10.000001
40    (B/2 B/2 C2 D2 G2 E2 B/2 F2 A2 G E/2 D/2 D/2 A2 F C/2 E2 C B/2 D/2)  7.6000004
41    (A/2 D2 D2 G G A E2 A2 A/2 B/2 F2 B2 F/2 F A2 D2 F2 A F/2 F2)  8.0
42    (C/2 B F/2 F2 B2 C2 C2 G B/2 C2 A/2 A/2 D E2 F E/2 G2 A2 F2 F/2)  8.700001
43    (E/2 D2 G F2 E2 F/2 D2 G2 G2 G/2 B D F/2 D/2 C E2 G2 B/2 G E2)  11.1
44    (A/2 G/2 A2 F/2 C/2 D E2 G/2 C/2 B2 G2 E/2 B2 G2 D C E F2 E2 E2)  10.8
45    (F2 E2 A2 A/2 E G G/2 D2 D/2 D F/2 F2 A2 F A/2 C/2 B A E F/2)  9.500001
46    (B/2 C2 F G B G2 F F/2 B C/2 C F D/2 G2 F/2 F/2 E2 A B A2)  9.900001
47    (E2 D/2 E F D/2 F B2 D A2 E2 B2 G2 G2 D/2 D/2 B/2 B D/2 D2 E/2)  8.7
48    (C A/2 G/2 E2 D/2 B/2 C/2 F E/2 A2 C2 G2 A2 F2 A C/2 G2 B/2 D2 C2)  7.0
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49    (D D2 E G C D/2 C2 F/2 B D/2 A2 A F D2 E A D C B/2 E/2)  8.1
50    (A2 E2 C2 D A/2 F C/2 C C E2 E/2 B2 B B2 G/2 C/2 C/2 E D/2 G/2)  9.300001
51    (C/2 F/2 E G/2 E E2 G/2 A/2 G2 B D D G2 A D2 F F2 C/2 G/2 G2)  9.7
52    (G2 G/2 D/2 B2 A2 G/2 D/2 E F2 E G G/2 A2 A E2 F/2 D/2 A/2 G2 C)  11.400001
53    (B/2 C G2 G G B/2 F/2 G G G B/2 G2 E/2 A B/2 D2 D2 E C/2 A)  9.500001
54    (F E F2 C2 C A/2 A2 F A/2 F E B G2 A/2 B2 D/2 C/2 A2 B2 B)  11.400001
55    (F2 F2 C2 D/2 F2 F B/2 D/2 B2 C/2 F2 E/2 G/2 E2 B A2 D2 B D2 E/2)  7.1000004
56    (D C/2 C/2 E C/2 A2 D/2 E G/2 D/2 B B E D2 F2 E F2 D2 D2 E)  10.900001
57    (F/2 C E2 G/2 G2 C2 G/2 E A/2 E2 E D/2 D D2 A/2 F2 A2 D A F)  7.2000003
58    (G2 E B2 B2 G/2 B2 G2 A/2 D B B2 E/2 A A2 D B F/2 C/2 G2 D2)  5.4
59    (B/2 C2 B2 D2 F D2 G2 D/2 F F B2 E D2 E/2 C2 F/2 C G2 A B)  6.8
60    (E A A2 A/2 B2 A2 C/2 D2 A B2 E F F/2 A2 E2 B C/2 E B A/2)  9.400001
61    (D/2 G B2 E/2 D2 D B C2 F D C B D/2 B B2 A2 D2 E C G)  7.1000004
62    (G2 G2 A F2 E/2 B2 A2 F D E/2 C/2 E/2 E A C G B A2 F C2)  10.1
63    (G G F F/2 E D2 C2 C/2 C G E2 F/2 E/2 E/2 D2 E2 C2 E2 E/2 C/2)  14.800001
64    (D/2 E2 G2 D2 D E2 C E E/2 E/2 F/2 C2 A2 D2 C E2 C A/2 G/2 A)  10.900001
65    (E/2 A2 F/2 G/2 E E2 B/2 B E C A C B/2 B C/2 C/2 A2 C/2 E C2)  6.7
66    (F/2 B A2 C/2 D/2 A B2 B B2 D2 C/2 A2 F2 A2 B2 B B/2 A/2 F/2 B/2)  10.700001
67    (D/2 E C B2 B2 E G/2 C2 B B D A/2 A F2 G2 C2 A B E/2 B2)  6.9
68    (D/2 A G/2 E E2 E D F2 G2 B C F D/2 B F F/2 F/2 F/2 F/2 C/2)  9.8
69    (G G A/2 B2 A/2 G2 F2 A E A/2 G/2 A E2 E/2 G2 E/2 A G/2 G2 A2)  12.900001
70    (G/2 D E B B2 E/2 E/2 D F/2 A D F B/2 A E E/2 B/2 F/2 E C)  8.400001
71    (D2 G/2 E2 A2 G/2 B/2 B C B2 E/2 F/2 F/2 C2 D A C B2 E B C/2)  5.6
72    (B F F/2 D2 F2 A2 G/2 E2 A C2 A/2 C G2 C D E2 C/2 A/2 A C2)  7.1000004
73    (E A/2 E/2 E/2 F2 F E/2 C F/2 C2 G A2 E2 D/2 A2 G C/2 D/2 C/2 E2)  9.6
74    (A/2 E2 C B/2 C2 A A2 B2 B2 E2 C D2 B2 E2 C2 A/2 F/2 B2 A C/2)  6.6000004
75    (E2 A F A F2 C/2 C E C F D2 B B2 D D B C2 A2 D/2 G)  5.3999996
76    (A/2 A/2 F/2 D/2 C2 A2 F/2 G/2 G2 C/2 F E B/2 B2 F F2 G A/2 D D/2)  10.500001
77    (E2 A2 E2 D2 F2 E2 E/2 C B C/2 B F2 C2 D2 B/2 B E G/2 D C2)  7.1
78    (F/2 C2 D2 C/2 D G B/2 B D/2 E E F/2 E2 D2 A2 E/2 B/2 F2 C2 G)  9.1
79    (E/2 D B/2 A/2 D B2 B C/2 B C2 F/2 C C/2 B D/2 A2 B C C2 B2)  5.3999996
80    (C C B B2 F/2 E/2 D2 E/2 F2 G/2 F2 D/2 B/2 F2 B F C/2 G C E2)  8.6
81    (B/2 C2 D2 B D E2 C/2 E E/2 C2 G2 F2 C/2 F A A2 G B F2 D)  8.6
82    (G/2 D G/2 F A/2 G E2 C F/2 E D/2 D/2 E D A/2 F/2 F B A2 G)  11.6
83    (B/2 F F G/2 F/2 E/2 F2 D/2 F B/2 B2 C2 C2 B/2 D D2 E2 D/2 D2 C/2)  12.000001
84    (F D/2 F G/2 A/2 E2 F/2 A/2 F A E/2 B G/2 C/2 G/2 B2 D2 G/2 C2 D)  7.5
85    (C/2 F/2 G B2 G/2 B/2 E/2 D B/2 E2 B2 C/2 G/2 G D D E D2 B2 B)  7.9
86    (D C2 E2 D E2 A2 C2 A G C/2 E/2 G A2 F/2 D D2 A/2 E/2 B/2 G/2)  8.8
87    (B/2 A F/2 A2 G B A E2 B A/2 G B/2 D/2 D/2 G C2 G/2 D D2 C2)  9.6
88    (A/2 D2 A2 D E E/2 C/2 G C/2 F/2 E F G/2 C2 E/2 F2 B/2 F2 F G/2)  8.6
89    (F2 C A/2 B/2 E G E C/2 A2 F D2 G2 A/2 B D2 F D E/2 B/2 F/2)  7.5
90    (A/2 G/2 E/2 C/2 D2 G/2 G2 A/2 G/2 G/2 G/2 A2 E/2 A/2 D/2 G/2 G A D D2)  11.0
91    (G B G F/2 A D2 F2 C/2 C/2 B/2 E2 F2 F2 D2 A/2 E2 D F/2 E/2 C)  9.1
92    (F2 A2 B2 C/2 A B/2 G2 C E2 D E/2 C F D2 G/2 G/2 E2 D2 D2 F/2)  10.1
93    (A2 A E2 G2 C2 F2 A2 C/2 B2 D C A2 D A F2 E2 C2 F/2 E/2 F)  6.8
94    (G B/2 A E F/2 C2 B2 D/2 C G D/2 B2 E C A2 A2 B E/2 C2 A2)  6.3
95    (B2 A G/2 E2 F F/2 B B E2 B A/2 D/2 A/2 F F C/2 F F A2 E/2)  8.700001
96    (A C/2 E B/2 F2 D/2 G2 A C/2 C2 E2 C2 B2 D C/2 D2 F C2 D F2)  7.8
97    (E2 B2 A E2 A/2 F2 C2 G/2 A2 F A/2 D/2 F2 F E2 C2 B F/2 F2 G2)  8.1
98    (B E G E A/2 A G2 A2 G2 F/2 D C2 F/2 A C/2 F2 C A2 B2 F)  8.8
99    (C/2 B2 D F/2 E F/2 B2 E/2 G G/2 A/2 F/2 D2 F2 B2 G/2 D/2 D/2 B B)  8.4
100   (E/2 E/2 G2 G E E2 A C/2 F/2 D G2 C B/2 D/2 D D2 B/2 C/2 E2 G2)  6.5

average fitness of population 0 = 8.955998

average fitness of population 1 = 11.375999
average fitness of population 2 = 13.067
average fitness of population 3 = 14.147999
average fitness of population 4 = 14.779
average fitness of population 5 = 15.341002
average fitness of population 6 = 16.074
average fitness of population 7 = 16.606005
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average fitness of population 8 = 16.932003
average fitness of population 9 = 17.22599
average fitness of population 10 = 17.398993
average fitness of population 11 = 17.746998
average fitness of population 12 = 17.727
average fitness of population 13 = 17.867992
average fitness of population 14 = 18.181988
average fitness of population 15 = 18.008987
average fitness of population 16 = 18.115988
average fitness of population 17 = 18.111988
average fitness of population 18 = 18.170988
average fitness of population 19 = 17.979988
average fitness of population 20 = 18.11399
average fitness of population 21 = 18.046991
average fitness of population 22 = 18.08699
average fitness of population 23 = 17.987988
average fitness of population 24 = 18.23099
average fitness of population 25 = 18.059988



Generation 25 population ...

1     (A2 G A/2 B2 A/2 G2 G/2 A/2 A G F/2 E/2 F E/2 F2 E2 D2 C/2 D E/2)  18.6
2     (A2 G A/2 B2 A/2 G2 G/2 A/2 A G F/2 E/2 F2 E/2 F E2 D2 C/2 D E/2)  18.6
3     (F G A/2 B2 A/2 G2 G/2 A/2 A G F/2 E/2 F E/2 D2 E2 D2 C/2 D E/2)  18.6
4     (A2 G A/2 B2 A/2 G2 G/2 A/2 G/2 G F/2 E/2 F E/2 D2 E2 D2 C2 D E/2)  18.6
5     (F G A/2 B2 A/2 G2 D A/2 A G/2 F/2 G/2 F E/2 D2 E2 D C/2 D E/2)  16.8
6     (A2 G A/2 B2 A/2 A G/2 A/2 A2 G F/2 E/2 F2 E/2 D2 E2 D C/2 D E/2)  18.6
7     (F G A/2 B2 F G2 G/2 A/2 G G F/2 E/2 F E/2 D2 E/2 D2 C2 D/2 E/2)  17.6
8     (B/2 G A/2 B2 A/2 A G/2 A/2 A2 G F/2 E/2 F2 E/2 D2 E2 D C/2 D E/2)  18.1
9     (A2 G A/2 G/2 A/2 G2 G/2 A/2 A G F/2 G F E/2 D2 E/2 D2 E/2 D E/2)  18.6
10    (E G A/2 G/2 A/2 G2 G/2 A/2 A G F/2 G F E/2 D2 E/2 D2 E/2 D E/2)  18.1
11    (F G A/2 B2 A/2 G2 G/2 A/2 A G/2 F/2 E/2 F2 E/2 D2 E2 D2 C/2 D E/2)  18.6
12    (F G A/2 B2 A2 G2 G/2 D A G F2 E/2 D/2 E/2 D2 E2 D C/2 D E/2)  16.8
13    (F G A/2 B2 A/2 G2 G/2 A/2 G G F/2 E/2 A2 E/2 D2 E/2 D2 C2 D E/2)  16.6
14    (A2 G A/2 B2 E/2 G2 G/2 A/2 G G F/2 E/2 F E/2 D2 E/2 D2 C2 D E/2)  17.1
15    (A2 G A/2 A A/2 G2 G/2 A/2 A G F/2 E/2 F E/2 F2 E2 D2 C/2 D E/2)  18.2
16    (A2 G A/2 B2 A/2 G2 G/2 A/2 G G F/2 D F E/2 D2 E/2 D2 C2 D E/2)  17.6
17    (A2 G A/2 B2 A/2 A G/2 A/2 A2 G F/2 E/2 F E/2 D2 E2 D2 C/2 D E/2)  18.6
18    (F G A/2 G/2 A/2 G2 A2 A/2 A D2 F/2 E/2 F E/2 D2 E2 D2 C/2 D E/2)  17.1
19    (F G A/2 D2 A/2 G2 A2 A/2 A G/2 F/2 E/2 F E/2 D2 E2 D2 C/2 D E/2)  16.6
20    (A2 G A/2 B2 A/2 A G/2 A/2 A2 G F/2 E/2 F2 E/2 D2 C/2 D C/2 D E/2)  18.6
21    (F G A/2 B2 A/2 G2 G/2 B A G F/2 E/2 F E/2 D2 E2 D2 C/2 D E/2)  18.3
22    (F G A/2 B2 A/2 G2 G/2 G/2 A G/2 F/2 E/2 F2 E/2 D2 E2 D/2 C/2 D E/2)  18.6
23    (A/2 G A/2 B2 A/2 A2 G/2 A/2 A G/2 F/2 E F E/2 D2 E2 D2 C D E/2)  18.6
24    (A2 G A/2 B2 A/2 G2 G/2 A/2 G/2 G F/2 E/2 F E/2 D2 E2 D2 C D C)  18.6
25    (A2 G A/2 B2 A/2 A G/2 A/2 A2 G F/2 E/2 F E/2 D2 E2 D2 C/2 D E/2)  18.6
26    (A/2 G A/2 B2 B A2 G/2 G/2 A G F/2 E F E/2 D2 E2 D2 C/2 D E/2)  18.6
27    (F G A/2 B2 A2 G2 G/2 G/2 A G F/2 E/2 F2 E/2 D2 E2 D2 C/2 D F2)  18.1
28    (G2 G A/2 B2 A/2 G2 G/2 A/2 A G F/2 E/2 F E/2 D2 E2 D2 C/2 D E/2)  18.4
29    (A2 G A/2 B2 A/2 G2 G/2 F2 G/2 G F/2 E/2 F E/2 D2 E2 D2 C2 D E/2)  18.6
30    (F G A/2 G/2 A/2 G2 G/2 A/2 A G F/2 E/2 F2 E/2 D2 E2 D2 C2 D E/2)  18.6
31    (F B/2 A/2 B2 A/2 G2 G/2 A/2 A G/2 F/2 E/2 F E/2 D2 E2 D2 C2 D E/2)  17.6
32    (A2 G A/2 B2 A/2 G2 G/2 A/2 G/2 G F/2 E/2 F E/2 D2 E2 D2 C2 D E/2)  18.6
33    (A2 G A/2 B2 A/2 G2 G/2 A/2 G G F/2 E/2 G E/2 D2 E/2 D2 C2 D E/2)  17.6
34    (F G A/2 B2 A/2 F/2 G/2 A/2 A G/2 F/2 G/2 F E/2 D2 E2 D C/2 D E/2)  18.3
35    (F G A/2 B A/2 G2 G/2 A/2 G G F/2 E/2 F A/2 F2 E2 D2 C/2 D E)  17.6
36    (A/2 G A/2 B2 A/2 G2 G/2 G/2 A G F/2 E/2 F2 E/2 D2 E2 D C/2 D E/2)  18.6
37    (A2 G A/2 B2 A/2 A G/2 A/2 A2 G F/2 E/2 F2 E/2 D2 E2 D C/2 A/2 E/2)  16.6
38    (A2 G A/2 B2 A/2 A G/2 A/2 A G F/2 E/2 F E/2 D2 E2 D2 C/2 D E)  18.6
39    (F G A/2 G/2 A/2 G2 G/2 A/2 A G F/2 E/2 F2 E/2 F E2 D2 C/2 D E/2)  18.6
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40 (F G B2 B2 A/2 G2 G/2 A/2 A G/2 F/2 E/2 F2 E/2 D2 E2 D2 C/2 D E/2) 17.9
41 (F G A/2 B2 A/2 G2 G/2 G/2 A G F/2 E/2 F2 E/2 E2 E2 D C/2 D E/2) 18.2
42 (A2 G A/2 G/2 B G2 G/2 A/2 A G F/2 G F E/2 D2 E/2 D2 E/2 D E/2) 17.6
43 (F G A/2 B2 A/2 G2 G/2 A/2 A G/2 F/2 E/2 F E/2 D2 E2 D2 C2 D E/2) 18.6
44 (A2 G A/2 B2 A/2 A G/2 A/2 A2 G F/2 E/2 B/2 E/2 D2 E2 D2 C/2 D E) 16.6
45 (A2 G A/2 B2 A/2 G2 G/2 A/2 G G F/2 E/2 F E/2 D2 E2 D2 C/2 D E/2) 18.6
46 (F G A/2 B2 D G2 G/2 G/2 A G F/2 E/2 F E/2 D2 E2 D C2 D E/2) 16.6
47 (F G A/2 B2 A/2 G2 G/2 A/2 G G D/2 E/2 D2 E/2 D2 E2 D2 C/2 D E/2) 17.6
48 (F G A/2 B A/2 G2 G/2 A/2 A G F/2 E F E/2 D2 E2 D C/2 D E/2) 18.6
49 (A2 G A/2 B2 F2 G2 G/2 A/2 G/2 G F/2 E/2 F E/2 F/2 E2 D2 C2 D E/2) 17.6
50 (A2 G A/2 A A/2 A G/2 A/2 A G F/2 E/2 F E/2 D2 E2 D2 C/2 D E/2) 18.2
51 (A2 G A/2 B2 A/2 A G/2 A/2 A2 G F/2 E/2 G/2 E/2 D2 E2 D2 C/2 D E/2) 17.6
52 (F G A/2 B2 A/2 G2 G/2 G/2 A G/2 F/2 E/2 F2 E/2 D2 E2 D/2 C/2 D E/2) 18.6
53 (F G A B2 A/2 G2 G/2 A/2 A G F/2 E/2 F E/2 D2 E2 D2 C2 D E/2) 18.6
54 (A/2 G A/2 B2 A/2 B/2 G/2 A/2 A G/2 F/2 E F E/2 D2 E2 D2 C D E/2) 18.3
55 (A/2 G A/2 B2 A/2 G2 G/2 G/2 A G F/2 E/2 F2 E/2 D2 E2 D C/2 D E/2) 18.6
56 (A2 G A/2 B2 A/2 G2 G/2 A/2 A2 G/2 F/2 G/2 F E/2 D2 E2 D C/2 D E/2) 18.6
57 (A2 G A/2 B2 A/2 A G/2 A/2 A2 G F/2 E/2 F E/2 D2 E/2 D2 C2 D E/2) 18.6
58 (F G A/2 B2 A/2 G2 G/2 A/2 A G/2 F/2 E/2 F2 E/2 D/2 E2 D/2 C/2 B E2) 16.6
59 (A2 G A B2 A/2 G2 G/2 A/2 A G/2 F/2 E/2 F E/2 D2 E2 D2 C/2 D E/2) 18.6
60 (F G A/2 B2 A/2 G2 G/2 A/2 A G F/2 E/2 F2 E/2 F E2 D2 C/2 D E/2) 18.6
61 (F G A/2 G/2 A/2 G2 G/2 A/2 A G F/2 E/2 F2 E/2 F E2 D2 C/2 D E/2) 18.6
62 (A2 G A/2 B2 A/2 G2 G/2 A/2 A G/2 F/2 E/2 F2 E/2 D2 E2 D2 C/2 D E/2) 18.6
63 (A2 G A/2 B2 A/2 G2 G/2 A/2 G/2 G F/2 E/2 F E/2 D2 E2 D2 C2 D E/2) 18.6
64 (F G A/2 B2 A/2 G2 G/2 A/2 A G/2 F/2 E/2 D2 E/2 D2 E2 D2 C/2 D E/2) 18.6
65 (F G A/2 B2 A2 G2 G/2 G/2 A G F/2 E/2 F2 E/2 D2 E2 D2 C/2 D E/2) 18.6
66 (F G A B2 A/2 G2 G/2 A/2 A G/2 F/2 E/2 F2 E/2 D2 E2 D2 C/2 D E/2) 18.6
67 (F G A/2 B2 A/2 G2 G/2 A/2 A G/2 F/2 E F E/2 G/2 E2 D2 C D E/2) 17.6
68 (A2 G C2 B2 A/2 A G/2 G/2 A G F/2 E/2 F E/2 F2 E2 D2 C/2 D E) 16.6
69 (F G A/2 A A/2 G2 G/2 G/2 A G F/2 E/2 F2 E/2 F2 E2 D2 C/2 D E) 18.2
70 (A/2 G A/2 B2 B A2 G/2 G/2 A G F/2 E F E/2 D2 E2 D2 C/2 D E/2) 18.6
71 (D2 G A/2 B2 A/2 G2 G/2 A/2 G G F/2 E F E/2 D2 E2 D2 C/2 D E/2) 17.6
72 (F G D B2 A/2 G2 G/2 G/2 A G F/2 E/2 F E/2 D2 E2 D2 C/2 D E/2) 16.6
73 (A2 G A/2 B2 A/2 G2 G/2 G/2 A G F/2 E/2 D/2 E/2 D2 E2 D C/2 D E/2) 18.6
74 (F G A/2 B2 A/2 G2 B G/2 A G/2 F/2 E/2 F2 E/2 D/2 E2 D2 C2 D E/2) 18.0
75 (F G A/2 B2 A/2 G2 G/2 A/2 G/2 G F/2 E/2 F E/2 D2 C2 D2 C2 D E/2) 18.6
76 (A2 G A/2 B2 A/2 G2 E/2 A/2 A G/2 F/2 E/2 F E/2 D2 E2 D2 C/2 D E/2) 17.3
77 (A2 G A/2 B2 A/2 G2 G/2 G/2 A G F/2 E/2 D/2 E/2 F E2 D2 C/2 D E/2) 18.6
78 (A2 G A/2 B2 A/2 G2 G/2 A/2 A G F/2 E/2 E E/2 D2 E2 D2 C/2 D E) 18.2
79 (F G A/2 B2 A/2 G2 G/2 A/2 A G/2 F/2 E/2 F E/2 D2 E2 D2 C/2 D E/2) 18.6
80 (F G A/2 B2 A2 G2 G/2 G/2 A G F2 E/2 F E/2 D2 E2 D2 G D E/2) 16.6
81 (A2 G A/2 B2 A/2 G2 G/2 A/2 A2 G F/2 E/2 F E/2 D2 E2 D C/2 D E/2) 18.6
82 (F G A/2 B2 A/2 G2 G/2 A/2 A G/2 F/2 G/2 F E/2 D2 F D2 C/2 D E/2) 17.6
83 (C/2 G A/2 B2 A2 G2 G/2 A/2 A G/2 F/2 E F E/2 D2 E/2 D2 C2 D E/2) 17.6
84 (F G A/2 B2 A/2 G2 G/2 A/2 A G F/2 E/2 F E/2 F2 E2 D2 C/2 D E/2) 18.6
85 (A2 G A/2 B2 B A2 G/2 G/2 A G F/2 E F E/2 D2 E2 D2 C/2 D E/2) 18.6
86 (A2 G A/2 B2 A/2 G2 G/2 A/2 A G/2 F/2 E/2 F E/2 D2 E2 D2 C/2 D D) 18.400002
87 (F G A/2 B2 A/2 G2 G/2 A/2 A G/2 F/2 E/2 F E/2 D2 E2 F C D C) 17.6
88 (F G A/2 B2 A/2 G2 G/2 G/2 A G F/2 E/2 F2 E/2 D2 E2 D2 C/2 D E/2) 18.6
89 (F G A/2 B2 A2 G2 G/2 G/2 A G F/2 E/2 F D2 D2 E2 D2 C2 D E/2) 17.900002
90 (A2 G A/2 B2 A/2 G2 C A/2 A2 G F/2 E/2 F E/2 D2 E2 D2 C2 D E/2) 16.8
91 (F G A B2 A/2 G2 G/2 A/2 A G/2 F/2 E/2 F E/2 D2 E2 D C/2 D E/2) 18.6
92 (F G A/2 B2 A/2 G2 G/2 A/2 A G F/2 E/2 F E/2 F2 E2 D2 C/2 D G) 17.6
93 (F G A/2 B2 A2 G2 G/2 G/2 A G F2 E/2 F2 E/2 D2 E2 D2 C/2 D E/2) 18.6
94 (A2 G A/2 B2 A/2 G2 G/2 A/2 G G F/2 E/2 F E/2 D2 E/2 D2 C2 D/2 E/2) 18.6
95 (A2 G A/2 B2 A/2 A G/2 A/2 A2 G F/2 E/2 F2 C/2 D2 E2 D2 C/2 D E/2) 17.6
96 (A2 G A/2 B2 A/2 G2 G/2 A/2 A G F/2 E/2 F E/2 F2 E2 D2 C/2 D E/2) 18.6
97 (F G A/2 B2 A/2 G2 G/2 A/2 A G/2 F/2 G/2 F E/2 C/2 E2 D2 C/2 D E/2) 17.6
98 (F G A/2 G/2 A/2 G2 D A/2 A G/2 F/2 E/2 F E/2 D2 E2 D2 C/2 D E/2) 16.8
99 (F G G2 B A/2 G2 G/2 A/2 G G F/2 E F E/2 D2 E2 D2 C/2 D E/2) 17.9
100 (F G A/2 B2 A/2 G2 G/2 A/2 A G F/2 E/2 F E/2 F2 E2 D2 C/2 D2 E/2) 18.6

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average fitness of population 25 = 18.059988

PAIR-WISE MELODIES!

average fitness of population 26 = 0.36
average fitness of population 27 = 1.01
average fitness of population 28 = 1.42
average fitness of population 29 = 1.93
average fitness of population 30 = 2.11
average fitness of population 31 = 2.55
average fitness of population 32 = 3.47
average fitness of population 33 = 4.29
average fitness of population 34 = 5.1
average fitness of population 35 = 5.84
average fitness of population 36 = 6.37
average fitness of population 37 = 6.56
average fitness of population 38 = 7.0
average fitness of population 39 = 7.48
average fitness of population 40 = 7.54
average fitness of population 41 = 7.56
average fitness of population 42 = 7.5
average fitness of population 43 = 7.43
average fitness of population 44 = 7.68
average fitness of population 45 = 8.13
average fitness of population 46 = 8.47
average fitness of population 47 = 8.31
average fitness of population 48 = 8.5
average fitness of population 49 = 8.51
average fitness of population 50 = 8.63



Generation 50 population ...

1     (A2 A2 B2 B2 A/2 D G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
2     (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G E/2 E/2 D/2 D/2 F2 F C/2 C/2 D2 D2)  8
3     (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  10
4     (A2 A2 B2 B2 A/2 A/2 D/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
5     (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  10
6     (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
7     (B A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
8     (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 D F C/2 C/2 E/2 E/2)  7
9     (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
10    (A2 A2 B2 B2 A/2 D2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
11    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G E/2 E/2 D/2 D/2 F C2 C/2 C/2 E/2 E/2)  8
12    (A2 A2 B2 B2 B A/2 G/2 G/2 F G F/2 F/2 D/2 D/2 F F C/2 C/2 D2 D2)  7
13    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
14    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 G/2 G F/2 F/2 D/2 D/2 F F C/2 C/2 D2 D2)  8
15    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
16    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  10
17    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A C2 F/2 F/2 D/2 D/2 F F C/2 C/2 D2 D2)  9
18    (A2 A2 B2 B2 A/2 C2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
19    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
20    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  10
21    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 B F C/2 C/2 E/2 E/2)  9
22    (A2 A2 B2 B2 A/2 A/2 F/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
23    (A2 A2 B2 B2 A/2 C/2 G/2 G/2 F G F/2 F/2 D/2 D/2 F F C/2 C/2 D2 D2)  8
24    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 E/2 B/2 E/2 G D/2 D/2 F F C/2 C/2 E/2 E/2)  8
25    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 D2 D2)  9
26    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F A2 C/2 C/2 E/2 E/2)  9
27    (A2 A2 B2 B2 A/2 A/2 G/2 E E/2 B/2 E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
28    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  10
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29    (A2 B B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
30    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  10
31    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F G2 C/2 E/2 E/2)  8
32    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
33    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  10
34    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 B/2 D/2 F F C/2 C/2 E/2 E/2)  8
35    (A2 C B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
36    (G A2 B2 B2 A/2 A/2 G/2 G/2 A G E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
37    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A D2 E/2 E/2 B2 D/2 F F C/2 C/2 E/2 E/2)  8
38    (A2 A2 C/2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
39    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
40    (A2 A2 B2 B2 A/2 A/2 G G/2 E/2 B/2 E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
41    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
42    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A B/2 F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
43    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
44    (A2 A2 B2 B2 A/2 D/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
45    (A2 A2 B2 B2 A/2 A/2 G/2 E/2 A G E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
46    (A2 A2 B2 B2 D A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
47    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
48    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
49    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 D2 D2)  9
50    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F E2 C/2 C/2 E/2 D2)  8
51    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A C2 B/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
52    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A D F/2 F/2 D/2 D/2 F F C/2 C/2 D2 D2)  9
53    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
54    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 F G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
55    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 E/2 B/2 E/2 E/2 D/2 D/2 F F C/2 C/2 D2 D2)  9
56    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A C2 F/2 F/2 D/2 D/2 F F C/2 C/2 D D2)  8
57    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 C/2 B/2 E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
58    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 D2 D2)  9
59    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
60    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
61    (D/2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  7
62    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 D2 D2)  9
63    (C2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
64    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 F F F C/2 C/2 E/2 E/2)  8
65    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 D2 D2)  9
66    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
67    (A2 A2 B2 D2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
68    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 E/2 D/2 A2 F F C/2 C/2 E/2 E/2)  7
69    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  10
70    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 E/2 F F C/2 C/2 E/2 E/2)  9
71    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 E2 F C/2 C/2 E/2 E/2)  8
72    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A B/2 E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
73    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F B2 C/2 D2 D2)  8
74    (A2 A2 B2 B2 A/2 G/2 G/2 G/2 A A E/2 E/2 F/2 D/2 F F C/2 C/2 E/2 E/2)  8
75    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 B2 F C/2 C/2 E/2 E/2)  9
76    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 E/2 B/2 E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
77    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 B2 C F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
78    (A2 A2 E/2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
79    (A2 A2 B2 B2 A/2 G2 G/2 G/2 A D2 E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
80    (A2 A2 B2 B2 F2 A/2 G/2 G/2 E/2 B/2 E/2 E/2 D/2 D/2 F F C/2 C/2 D2 D2)  8
81    (A2 A2 B2 F A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
82    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 G2 D2 D2)  8
83    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
84    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
85    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A B F/2 F/2 D/2 D/2 F F C/2 D E/2 E/2)  8
86    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 G/2 E/2 E/2)  9
87    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 B2 A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
88    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
89    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
90    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 E/2 B/2 E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
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91    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 E/2 D/2 F F C/2 C/2 E/2 E/2)  8
92    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F G2 C/2 C/2 E/2 E/2)  9
93    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 E2 F F C/2 C/2 E/2 E/2)  8
94    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 B E/2)  9
95    (A2 A2 B2 B2 A/2 A/2 G/2 F/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
96    (A2 A2 A B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
97    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  9
98    (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A G F/2 E/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
99    (A2 A2 B2 A A/2 A/2 G/2 G/2 A G F/2 F/2 D/2 D/2 F F C/2 C/2 E/2 E/2)  8
100   (A2 A2 B2 B2 A/2 A/2 G/2 G/2 F G F/2 F/2 D/2 D/2 F F C/2 C/2 D2 D2)  9

average fitness of population 50 = 8.63

ASCENDING JUMPS AND STEPWISE DECLINES MELODIES!

average fitness of population 51 = 5.49
average fitness of population 52 = 6.78
average fitness of population 53 = 8.11
average fitness of population 54 = 9.51
average fitness of population 55 = 10.72
average fitness of population 56 = 11.98
average fitness of population 57 = 13.03
average fitness of population 58 = 13.79
average fitness of population 59 = 14.56
average fitness of population 60 = 15.17
average fitness of population 61 = 15.58
average fitness of population 62 = 15.97
average fitness of population 63 = 16.53
average fitness of population 64 = 16.62
average fitness of population 65 = 17.15
average fitness of population 66 = 17.41
average fitness of population 67 = 17.67
average fitness of population 68 = 17.93
average fitness of population 69 = 18.46
average fitness of population 70 = 18.47
average fitness of population 71 = 18.5
average fitness of population 72 = 18.51
average fitness of population 73 = 18.36
average fitness of population 74 = 18.55
average fitness of population 75 = 18.56



Generation 75 population ...

1     (C A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E2 D F2 E/2 G)  19
2     (D/2 A2 G2 F/2 E D G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D C E/2 G)  19
3     (E2 A2 G2 F/2 D/2 D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G)  17
4     (C A2 G2 F/2 B2 A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F A/2 G F2 E/2 G/2)  19
5     (D/2 A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D C E/2 G)  19
6     (E2 A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G/2)  19
7     (C A2 G2 F/2 B2 A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G/2)  19
8     (C A2 G2 F/2 E A/2 G/2 B A G F/2 E/2 D/2 C/2 F E2 D F2 E/2 G)  19
9     (D2 A2 G2 F/2 E2 A/2 G/2 F A G F/2 E/2 D/2 C/2 F E/2 D F2 A/2 G)  19
10    (C A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G/2)  19
11    (E2 A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G)  19
12    (C A2 G2 F/2 E D2 G/2 B/2 A2 G F/2 E/2 D/2 C/2 F E2 D F2 E/2 G)  19
13    (C A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D2 F2 E/2 G)  19
14    (F/2 A2 G2 B2 E D2 F/2 B/2 A G F/2 E/2 D C/2 F E/2 D F2 A/2 G)  18
15    (E2 A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G/2)  19
16    (F/2 A2 G2 F/2 E A/2 G2 B/2 A G/2 F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G)  19
17    (C E/2 G2 F/2 E D2 G/2 B/2 A2 G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G)  19
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18 (F/2 A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E2 D F2 E/2 G) 19
19 (E2 A2 G2 F/2 E A/2 G/2 B/2 B/2 G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G/2) 17
20 (C A2 G2 F/2 E A/2 G/2 B A G F/2 E/2 D/2 C/2 F E2 D F2 E/2 G) 19
21 (F/2 A2 C2 F/2 E D2 F/2 B/2 A G F/2 E/2 D C/2 F E/2 D F2 A/2 G) 18
22 (E2 A2 G2 F/2 E A/2 C B/2 A G F/2 E/2 D/2 C/2 F2 E/2 D F2 E/2 G) 18
23 (C A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G) 19
24 (C A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D2 F2 E/2 G/2) 19
25 (F/2 A2 G2 F/2 E A/2 G2 B/2 A G/2 F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G) 19
26 (C A2 G2 F/2 F2 D2 G/2 F A2 G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G) 17
27 (C A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D2 F2 E/2 G) 19
28 (C A2 G2 G/2 E D2 G/2 B A2 G F/2 E/2 D/2 C/2 F E/2 G F2 E/2 G) 17
29 (C A2 G2 F/2 E F G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 A/2 G) 17
30 (F/2 A2 G2 F/2 E D G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G) 19
31 (C E/2 G2 F/2 E D2 G/2 B/2 A2 G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 B2) 19
32 (F/2 A2 G2 F/2 E F G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G) 17
33 (C A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 A G) 19
34 (C G G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 A/2 G) 18
35 (C A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C2 F E2 D F2 E/2 G) 19
36 (C A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 G2 F2 E/2 A2) 19
37 (F/2 A2 G2 F/2 E D2 F/2 E A G F/2 E/2 D C/2 F E/2 D F2 A/2 G) 19
38 (D/2 B G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D C E/2 G) 18
39 (F/2 A2 G2 F/2 E D2 D/2 B/2 A G F/2 E/2 D/2 C/2 F E2 D F2 E/2 G) 18
40 (E2 D2 G2 F/2 E A/2 G2 B/2 A G/2 F/2 E/2 D/2 C/2 F E/2 D C E/2 G) 19
41 (C A2 G2 F/2 E D2 G/2 E2 A G F/2 E/2 D/2 C/2 F E/2 D F2 A G) 18
42 (C A2 G2 F/2 E A/2 G B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 A2) 19
43 (C A2 G2 F/2 B2 A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D E/2 E/2 A2) 17
44 (C E/2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E2 D F2 E/2 G) 19
45 (E2 A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F2 E/2 G2 F2 E/2 G) 19
46 (E2 D/2 G2 F/2 E A/2 G/2 F2 A G F E/2 D/2 C/2 F E/2 D F2 E/2 A2) 19
47 (C A2 G2 F/2 E A/2 G B A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G/2) 19
48 (C A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G) 19
49 (E2 A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G/2) 19
50 (C A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G) 19
51 (C A2 G2 F/2 A/2 A/2 G/2 B A G F/2 E/2 D/2 C/2 F E2 D F2 E/2 G) 18
52 (F/2 A2 G2 F/2 E D G/2 F2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G) 19
53 (F/2 A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G) 19
54 (E2 D/2 G2 F/2 E A/2 G/2 F2 A G F E/2 D/2 E F E/2 D F2 E/2 A2) 17
55 (D/2 A2 G2 F/2 A A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D2 F2 E/2 G) 18
56 (E2 D/2 G2 F/2 E A/2 G/2 F2 E/2 G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G) 19
57 (E2 A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G) 19
58 (E2 A2 G2 F/2 E D/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F2 E/2 D F2 E/2 G/2) 19
59 (C A2 G2 F/2 E D2 G/2 B/2 D/2 G F/2 E/2 D/2 C/2 F E/2 D F2 A G) 18
60 (E2 B2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E2 D F2 E/2 G) 18
61 (C A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E2 D F2 E/2 A2) 19
62 (E2 A2 G2 F/2 E A/2 G/2 D/2 A G F/2 E/2 D/2 C/2 F E/2 D2 F2 E/2 G/2) 18
63 (C A2 G2 F/2 E D2 G/2 B A2 G F/2 E/2 D/2 C/2 F E/2 D C E/2 G) 19
64 (C A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 D F E/2 D F2 A/2 G) 18
65 (B2 A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G) 19
66 (C A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 A/2 G) 19
67 (C A2 G2 F/2 B2 A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G) 19
68 (E2 A2 G2 F/2 D2 A/2 G/2 B/2 A2 G F/2 E/2 D/2 C/2 F E/2 G F2 E/2 G) 18
69 (E2 A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G) 19
70 (F/2 A2 G2 F/2 E A/2 G/2 B/2 A2 G F/2 E/2 D/2 C/2 F2 E/2 D F2 E/2 G/2) 19
71 (D2 A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G/2) 19
72 (C A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G) 19
73 (C A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D C E/2 G) 19
74 (D/2 A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D C/2 F E/2 D F2 A/2 G) 19
75 (F/2 A2 G2 F/2 E D2 G/2 B/2 A G/2 F/2 E/2 D/2 C/2 D E/2 D F2 E/2 G) 17
76 (C A2 G2 F/2 B2 A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E2 D F2 E/2 G) 19
77 (D A2 G2 F/2 E D2 G B/2 A G F/2 E/2 D/2 C/2 F E/2 C F2 A/2 G) 18
78 (F/2 A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G/2) 19
79 (C A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G) 19

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80    (F/2 A2 G2 F/2 E D/2 G/2 B/2 A2 G F/2 E/2 D/2 C/2 F E/2 D F2 A/2 G/2)  19
81    (C A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D A2 E/2 B)  18
82    (D/2 A2 G2 F/2 E D2 G/2 B/2 A G F/2 D/2 D/2 C/2 F E/2 D F2 A/2 G)  17
83    (C A2 G2 F/2 E A/2 G2 B/2 A G/2 F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G)  19
84    (C A2 G2 F/2 B2 A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 A/2 F2 E/2 G)  18
85    (C A2 G2 F/2 E D/2 G/2 D/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G)  18
86    (E2 D2 G2 F/2 A/2 A/2 G/2 F A G F/2 E/2 D/2 C/2 F E/2 D F2 A/2 G)  18
87    (F/2 A2 G2 F/2 E2 A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 A/2 G)  19
88    (C A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 A/2 F2 E/2 G)  18
89    (C A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 A/2 G)  19
90    (C A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E2 D F2 E/2 G)  19
91    (C A2 G2 F/2 E E2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G/2)  18
92    (E2 A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G)  19
93    (E2 A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G)  19
94    (C A2 G2 F/2 B2 A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E G F2 E/2 G/2)  19
95    (C A2 G2 F/2 E A/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D C E/2 G)  19
96    (B2 A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D A/2 E/2 G)  18
97    (C E/2 G2 F/2 E D2 G/2 B/2 A2 G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G)  19
98    (C A2 G2 F/2 E D2 G/2 B/2 A2 G F/2 E/2 D/2 C/2 F E/2 D F2 A/2 G)  19
99    (F/2 A2 G2 F/2 E D2 F/2 B/2 A G F/2 E/2 C C/2 F E G F2 E/2 G/2)  17
100   (C A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 G)  19

average fitness of population 75 = 18.56

STEPWISE SLASHING MELODIES!

average fitness of population 76 = 11.13
average fitness of population 77 = 11.51
average fitness of population 78 = 11.63
average fitness of population 79 = 11.84
average fitness of population 80 = 12.28
average fitness of population 81 = 12.52
average fitness of population 82 = 12.43
average fitness of population 83 = 12.64
average fitness of population 84 = 12.56
average fitness of population 85 = 12.43
average fitness of population 86 = 12.45
average fitness of population 87 = 12.53
average fitness of population 88 = 12.46
average fitness of population 89 = 12.42
average fitness of population 90 = 12.47
average fitness of population 91 = 12.4
average fitness of population 92 = 12.48
average fitness of population 93 = 12.36
average fitness of population 94 = 12.58
average fitness of population 95 = 12.46
average fitness of population 96 = 12.53
average fitness of population 97 = 12.56
average fitness of population 98 = 12.65
average fitness of population 99 = 12.97
average fitness of population 100 = 13.41



Generation 100 population ...

1     (C2 D2 E2 F/2 E F/2 G/2 A A G F/2 E/2 D/2 C/2 F E/2 D F/2 E/2 D)  14
2     (C2 D2 E2 F/2 E F/2 G/2 A2 A G F/2 E/2 D/2 G2 F E/2 D F2 E D)  14
3     (C2 D2 E2 F/2 B/2 A/2 G/2 F/2 F G F/2 E/2 D/2 C/2 F E/2 D F/2 E/2 D)  14
4     (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E D)  14
5     (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D)  14
6     (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E D/2 G2 F E/2 D F2 E/2 D)  14
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7 (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E D F2 E/2 D) 14
8 (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E D/2 G2 F E/2 D F2 E/2 D) 14
9 (G/2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 13
10 (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E D) 14
11 (C2 D2 E2 F/2 B/2 F2 G/2 F/2 F G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 12
12 (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 14
13 (C2 D2 E2 F/2 B/2 A/2 G/2 F/2 F G F/2 E/2 D/2 C/2 F E/2 D B2 E/2 D) 13
14 (C2 D2 E2 F/2 E F/2 G/2 B/2 D/2 G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 13
15 (C2 D2 E2 F/2 E F/2 A/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 13
16 (E2 A2 G2 F/2 E/2 A/2 G/2 B/2 A G F/2 E D/2 G2 F E/2 D F2 E/2 B/2) 12
17 (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E D) 14
18 (C2 D2 E2 F E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 14
19 (C2 D2 E2 F/2 B/2 A/2 G/2 F/2 F G F/2 E/2 D/2 C/2 F E/2 D F/2 E/2 D) 14
20 (C D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 14
21 (C2 D2 E2 F/2 E F/2 G F A G F2 E/2 D/2 C/2 F E/2 D F2 E D) 13
22 (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 14
23 (C2 D2 E2 F/2 E F/2 G B/2 A G F E/2 D/2 G2 F E/2 D F2 E D) 14
24 (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 14
25 (C2 D2 E2 F/2 E F/2 G B/2 A G F2 E/2 D/2 C/2 F E/2 D F2 E D) 14
26 (E2 A2 G2 F/2 E/2 A/2 G2 F2 F/2 G F/2 E/2 D/2 C/2 F E D C E/2 D) 13
27 (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 C/2 F E/2 D F/2 E/2 D) 14
28 (C2 D2 E2 F/2 B/2 A/2 G/2 F/2 F G F/2 E/2 D/2 C/2 G E/2 D F/2 E/2 D) 13
29 (C2 D2 E2 F/2 B/2 A/2 G/2 F/2 F G F/2 E/2 D/2 C/2 F E/2 D A E/2 D) 13
30 (C2 D2 E2 F/2 E F/2 G/2 A2 A G F/2 E/2 D/2 E2 F E/2 D F2 E/2 D) 14
31 (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 B2 D) 12
32 (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 C/2 F E/2 D F/2 E/2 B2) 13
33 (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 B2 F E/2 D F2 E/2 D) 13
34 (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 C/2 F E/2 D F/2 E/2 D) 14
35 (B/2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 13
36 (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 14
37 (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 G G2 F E/2 D F2 E/2 D) 13
38 (C2 D2 E2 F/2 B/2 A/2 G/2 F/2 F G F/2 E/2 D/2 C/2 F E/2 D F/2 E/2 D) 14
39 (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 C/2 E/2 D F2 E/2 D) 12
40 (C2 D2 E2 F/2 F F/2 G/2 D2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 12
41 (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 F2 C/2 F E/2 D F/2 E/2 D) 13
42 (C2 D2 E2 F/2 E F/2 A A2 A G F/2 E/2 D/2 E2 F E/2 D F2 E/2 D) 12
43 (C2 D2 E2 F/2 G2 F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 13
44 (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 14
45 (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E A/2) 13
46 (C2 D2 E2 F/2 E F/2 F/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 13
47 (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 14
48 (C2 D2 E2 F/2 E F/2 G/2 A A G F/2 E/2 D/2 C/2 F E/2 D D E/2 D) 13
49 (C2 D2 E2 B2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E D) 13
50 (C2 D2 E2 F/2 E F/2 G/2 A2 A G F/2 E/2 A G2 F E/2 D F/2 E/2 D) 14
51 (C2 D2 E2 F/2 E A/2 G/2 F/2 F G F/2 E/2 D/2 C/2 F E/2 D F/2 C/2 D) 12
52 (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 G/2 D) 13
53 (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 14
54 (C2 A2 G2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 F) 12
55 (C2 D2 E2 F/2 B/2 A/2 G/2 F/2 F G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 14
56 (C2 D2 E2 F/2 B/2 F/2 G/2 A A G F/2 E/2 D/2 C/2 F E/2 D F/2 E/2 D) 13
57 (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E D) 14
58 (C2 D2 E2 F/2 B/2 A/2 G/2 F/2 F G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 14
59 (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E D) 14
60 (C2 D2 E2 F/2 E F/2 G/2 A2 A G F/2 E/2 D/2 G2 F E/2 D E E/2 D) 13
61 (C2 G2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 12
62 (C2 D2 E2 F/2 E/2 A/2 G/2 F2 F/2 G F/2 E/2 D/2 C/2 F E D C B D) 12
63 (C2 D2 E2 F/2 E F/2 G B/2 A G F2 E/2 C C/2 F E/2 D F2 E D) 12
64 (C2 D2 E2 F/2 E F/2 G/2 A A G F/2 E/2 D/2 C/2 F E/2 D F/2 E/2 D) 14
65 (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 F/2 G2 F E/2 D F2 E/2 D) 14
66 (C2 D2 E2 F/2 E C/2 G B/2 A G F/2 E D/2 G2 F E/2 D F2 E/2 D) 12
67 (C2 D2 E2 F/2 E F/2 G/2 B/2 G/2 G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D) 13
68 (C2 D2 E2 F/2 E F/2 G B/2 A G F2 E/2 D/2 C/2 F E/2 D F2 E D) 14

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69    (C2 D2 E2 F/2 E F/2 G/2 A2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D)  14
70    (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D)  14
71    (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E D)  14
72    (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D)  14
73    (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D)  14
74    (C2 D2 E2 F/2 E F/2 G B/2 A G F2 E/2 D/2 C/2 F A D F2 E D)  12
75    (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D)  14
76    (C2 D2 C2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E B)  11
77    (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D)  14
78    (C2 D2 E2 F/2 E2 F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D)  14
79    (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D)  14
80    (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E D/2 G2 F E/2 D F2 E/2 D)  14
81    (C2 D2 E2 F/2 E F/2 G/2 A2 A G F/2 E/2 D/2 E2 F E/2 D F2 E/2 D)  14
82    (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E D)  14
83    (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F B/2 D F2 E/2 D)  12
84    (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F/2 E/2 D/2)  14
85    (C2 A E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 D)  12
86    (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D)  14
87    (C2 D2 E2 F/2 B/2 A/2 G/2 F/2 F G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D)  14
88    (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F/2 C2 D)  13
89    (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E D)  14
90    (C2 D2 E2 F/2 B/2 A/2 G/2 F/2 F G F/2 E/2 D/2 C/2 F E/2 D F/2 E/2 D)  14
91    (C D/2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D)  14
92    (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 C/2 F E/2 D F2 E/2 D)  14
93    (C2 D2 E2 F/2 E F/2 G B/2 A G F2 E/2 D/2 G2 F E/2 D F2 E/2 D)  14
94    (C/2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D)  14
95    (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D)  14
96    (C2 D2 E2 F/2 E F/2 G/2 A2 A G F/2 E/2 F G2 F E/2 D F/2 E/2 D)  14
97    (C2 D2 E2 F/2 E A/2 G/2 B/2 A G B/2 E/2 D/2 C/2 F E/2 D C/2 E/2 D)  12
98    (C2 D2 E2 F/2 B/2 A/2 G/2 F/2 F G F/2 E/2 D/2 G2 F E/2 D F2 E/2 D)  14
99    (C2 D2 E2 F/2 E F/2 G B/2 A G F/2 E/2 D/2 G2 F E/2 D F2 E D)  14
100   (C2 D2 E2 F/2 E F/2 G/2 B/2 A G F/2 E/2 D/2 G2 F E/2 D B/2 E/2 D)  13

average fitness of population 100 = 13.41

ZIG-ZAG MELODIES!

average fitness of population 101 = 10.325997
average fitness of population 102 = 10.613999
average fitness of population 103 = 11.087998
average fitness of population 104 = 11.498996
average fitness of population 105 = 11.826997
average fitness of population 106 = 11.965002
average fitness of population 107 = 12.091999
average fitness of population 108 = 12.094
average fitness of population 109 = 12.097998
average fitness of population 110 = 12.181994
average fitness of population 111 = 12.126997
average fitness of population 112 = 12.158993
average fitness of population 113 = 12.282992
average fitness of population 114 = 12.146992
average fitness of population 115 = 12.136994
average fitness of population 116 = 12.155993
average fitness of population 117 = 12.249991
average fitness of population 118 = 12.2219925
average fitness of population 119 = 12.029994
average fitness of population 120 = 12.200993
average fitness of population 121 = 12.147996
average fitness of population 122 = 12.226994
average fitness of population 123 = 12.286996
average fitness of population 124 = 12.527999
average fitness of population 125 = 12.678004
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Generation 125 population ...

1 (B2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 C D E/2 D) 12.700001
2 (C2 D/2 E F/2 E F/2 G F F/2 G2 F/2 E/2 F E2 F2 E/2 C D E/2 D) 13.300001
3 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 A/2 G2 F E/2 C D C2 D) 11.900002
4 (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F E/2 F2 D E/2 D) 13.300001
5 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F E F2 E/2 C D E/2 D) 13.300001
6 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F C F2 E/2 F2 D E/2 D) 11.700002
7 (C/2 D2 E2 F/2 E F/2 G F F2 G C/2 E/2 F G2 F2 E/2 C D E/2 D) 11.300001
8 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 C D C2 D) 13.300001
9 (C2 D/2 E2 F/2 E F/2 G F F/2 G2 F/2 E/2 F G2 F2 E/2 C D E/2 D) 13.300001
10 (C/2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 C D E/2 D) 13.300001
11 (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E2 F G2 F E/2 C D C2 D) 13.300001
12 (C2 D/2 E2 F/2 E F/2 G F A2 G2 F/2 E/2 F G2 F2 E/2 C D E/2 D) 12.600001
13 (C2 D2 E2 F/2 E F/2 E F F2 G F/2 E/2 F G2 F E/2 C D C2 D) 13.300001
14 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 F2 D E/2 D) 13.300001
15 (C/2 D2 E2 F/2 E F/2 G F D/2 G F/2 E/2 F G2 F2 E/2 C D E/2 D) 12.400002
16 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F G/2 C D C2 D) 13.300001
17 (C2 D/2 E2 F/2 E B/2 G F F/2 G2 F/2 E/2 F E2 F2 E/2 C D E/2 D) 11.300001
18 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 F2 D E/2 D) 13.300001
19 (C2 D/2 E2 F/2 E F/2 G F F/2 G2 F/2 E/2 F G2 F2 E/2 C D E/2 D) 13.300001
20 (C2 D/2 E2 F/2 E F/2 G F F/2 G/2 F/2 E/2 F G2 F2 E/2 C B2 E/2 D) 11.300001
21 (C2 D/2 E2 F/2 E F/2 G F F/2 G2 B E/2 F E2 F2 E/2 C D E/2 D) 11.700002
22 (C2 D2 E F/2 E F/2 G F F/2 G2 F/2 E/2 F G2 F2 E/2 E/2 D E/2 D) 13.200002
23 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 F2 D E/2 D) 13.300001
24 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 F2 D E/2 D) 13.300001
25 (C2 D/2 E2 F/2 E F/2 G F F2 A/2 F/2 E/2 F G2 F2 E/2 C D E/2 D) 11.700002
26 (C2 D/2 E2 F/2 E F/2 E2 G F2 G F/2 E/2 F G2 F2 E/2 F2 D E/2 D) 13.000002
27 (C2 D/2 E2 F/2 E F/2 G F F/2 G2 F/2 E/2 F G2 F2 G/2 C D E/2 D) 13.300001
28 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 C D E/2 B/2) 12.300002
29 (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F E/2 C D C2 D) 13.300001
30 (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 C D E/2 D/2) 13.300001
31 (C/2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 C D E/2 D) 13.300001
32 (C2 D/2 E2 F/2 E F/2 G F F/2 G/2 F/2 E/2 F G2 F2 E/2 C D E/2 D) 13.300001
33 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F C F E/2 C D C2 D) 11.700002
34 (C2 D/2 E2 F/2 E F/2 G F F/2 G2 F/2 E/2 F G2 F2 E/2 C D E/2 D) 13.300001
35 (C2 D/2 E2 F/2 E F/2 G F F/2 G/2 F/2 E/2 F G2 F2 E/2 C D E/2 D) 13.300001
36 (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F E/2 F2 D E/2 D) 13.300001
37 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F E/2 C D C2 D) 13.300001
38 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 C2 F G2 F2 E/2 F2 D E/2 D) 11.700002
39 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 A2 G2 F E/2 C D C2 D/2) 11.900002
40 (C2 D/2 E2 C2 E F/2 G F F2 G F/2 E/2 F G2 F E C D C2 D) 11.700001
41 (C2 F/2 E2 F/2 E F/2 G F F/2 G2 F/2 E/2 F G2 F2 E/2 C D E/2 D) 13.1
42 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 F2 D E/2 D) 13.300001
43 (C2 C/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 C D E/2 D) 12.400001
44 (C2 D2 E F/2 E F/2 G F F/2 G2 F/2 E/2 F G2 F2 E/2 C D E/2 D) 13.300001
45 (C2 D/2 E2 F/2 E G/2 G F F2 G F/2 E/2 F G2 F2 E/2 F2 D E/2 D) 11.600001
46 (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F A2 F2 D E/2 D) 11.700002
47 (C2 D2 E2 A2 E F/2 G F F/2 G2 F/2 E/2 F E2 F2 E/2 C D E/2 D) 12.1
48 (C2 D2 E2 F/2 E F/2 G F F2 G C/2 E/2 F G2 F2 E/2 F2 D E/2 D) 11.300001
49 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 D2 F G2 F2 E/2 C D E/2 D) 11.700002
50 (C2 D/2 E2 F/2 E F/2 G F F/2 G2 F/2 E/2 F E2 F2 E/2 C D E/2 D) 13.300001
51 (C2 D/2 E2 F/2 E F/2 G F F/2 G/2 F/2 E/2 F G2 F2 E/2 A2 D C2 D) 12.300002
52 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F E C F2 C2 D) 11.700002
53 (C2 D/2 E2 F/2 E F/2 G F F/2 G2 F/2 G F G2 F2 E/2 C D E/2 D) 13.300001
54 (C2 D/2 E2 F/2 E F/2 G F F/2 G/2 F/2 E/2 F G2 F2 E/2 C D E/2 D) 13.300001
55 (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F E/2 C D E/2 D) 13.300001
56 (C2 D2 E2 F/2 G2 F/2 G F F2 G F/2 E/2 F G2 F G D2 D E/2 D) 12.600002
57 (C2 A2 E2 F/2 E F/2 G F F/2 G2 F/2 E/2 F G2 F E/2 C D C2 D) 12.5

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58    (C2 D2 E F/2 E F/2 G F F/2 G/2 F/2 E/2 F G2 F2 E/2 B/2 D E/2 D)  12.300002
59    (C2 D/2 E2 F/2 E F/2 G F F/2 G2 F/2 G F G2 F2 E/2 C D E/2 D)  13.300001
60    (C/2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 C D E/2 D)  13.300001
61    (C2 D/2 E2 F/2 E F/2 G F F/2 G2 F/2 E/2 F G2 F2 E/2 C D C2 D)  13.300001
62    (C2 D2 E2 E2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 C D E/2 D)  12.300001
63    (G2 D/2 E2 F/2 E F/2 G F F/2 G/2 F/2 E/2 F G2 F2 E/2 C D E/2 D)  12.700001
64    (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E2 F C/2 F E/2 C D C2 D)  11.700002
65    (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F E/2 F2 D E/2 D)  13.300001
66    (C2 D2 E F/2 E F/2 G F F2 G F/2 E2 F G2 F E/2 C D C2 D)  13.300001
67    (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 C D E/2 D)  13.300001
68    (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F E C D C2 D)  13.300001
69    (C2 E2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 F2 D E/2 D)  12.400001
70    (C2 D2 E2 F/2 E F/2 G F F2 G B2 E/2 F G2 F E/2 C D E/2 D)  11.700002
71    (C2 D2 E2 D E F/2 E2 B/2 A G2 F/2 E/2 F G2 F E/2 C D E/2 D)  12.600001
72    (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F E/2 F2 D E/2 D)  13.300001
73    (C2 D2 E2 F/2 E F/2 G F F2 G C2 E/2 F G2 F2 E/2 C D E/2 D)  11.300001
74    (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 B/2 F G2 F2 E/2 C D E/2 D)  11.700002
75    (C/2 D2 E2 F/2 E F/2 G F F/2 G/2 F/2 E/2 F G2 F2 E/2 C D F D)  11.700002
76    (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 C D E/2 D)  13.300001
77    (C2 D2 E2 F/2 E F/2 G F F2 G G2 E/2 F G2 F E/2 C D C2 D)  12.000002
78    (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F E/2 C B C2 D)  11.700002
79    (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 B G2 F2 E/2 C D E/2 D)  11.300001
80    (C2 D/2 E2 F/2 E F/2 G F F/2 G/2 F/2 E/2 F G2 F2 E/2 C D E/2 D)  13.300001
81    (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 C D E/2 F)  12.900002
82    (C2 D/2 E2 F/2 E F/2 G F F/2 G/2 F/2 E/2 F G2 F2 E/2 C D C2 D)  13.300001
83    (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 C D E/2 D)  13.300001
84    (C2 D2 E F/2 E F/2 G F F/2 G2 F/2 E/2 F G2 F2 E/2 C B/2 E/2 D)  11.300001
85    (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 C D E/2 D)  13.300001
86    (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E2 F G2 F E/2 C D E/2 D)  13.300001
87    (C2 D/2 E2 F/2 E F/2 G F F/2 G/2 F/2 E/2 F2 G2 F E/2 C D E/2 D)  13.300001
88    (C2 D/2 E2 D2 E F/2 G F F/2 G2 F/2 E/2 F G2 F2 E/2 C D E/2 D)  13.300001
89    (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 C D E/2 D)  13.300001
90    (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 F2 D E/2 D)  13.300001
91    (C2 D2 E2 F/2 E F/2 G F F2 G F/2 E/2 F2 G2 F E/2 C D C2 D/2)  13.300001
92    (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 F2 D E/2 D)  13.300001
93    (C2 D/2 E2 F/2 E F/2 G F F/2 G/2 F/2 E/2 F G2 F2 E/2 C D E/2 D)  13.300001
94    (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F F/2 F2 E/2 F2 D E/2 D)  12.300001
95    (C/2 D2 E2 F/2 E F/2 A2 F F/2 G2 F/2 E/2 F G2 F E/2 C D C2 D)  11.700001
96    (C2 D2 E2 F/2 E F/2 G F F2 E F/2 E/2 F G2 F E/2 C D E/2 D)  13.300001
97    (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F2 E/2 C D E/2 D)  13.300001
98    (C2 G/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F E C D C2 D)  12.5
99    (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F G2 F E/2 C B E/2 D)  11.300001
100   (C2 D/2 E2 F/2 E F/2 G F F2 G F/2 E/2 F C/2 F2 E/2 F2 D E/2 D)  11.700002

average fitness of population 125 = 12.678004


Most fit stepwise melody: 1     (A2 G A/2 B2 A/2 G2 G/2 A/2 A G F/2 E/2 F E/2 F2 E2 D2 C/2 D
E/2)  18.6

Most fit pairwise melody: 3     (A2 A2 B2 B2 A/2 A/2 G/2 G/2 A A E/2 E/2 D/2 D/2 F F C/2 C/2
E/2 E/2)  10

Most fit ascending jumps/stepwise decline melody: 1     (C A2 G2 F/2 E D2 G/2 B/2 A G F/2 E/2
D/2 C/2 F E2 D F2 E/2 G)  19

Most fit stepwise slashing melody: 1     (C2 D2 E2 F/2 E F/2 G/2 A A G F/2 E/2 D/2 C/2 F E/2 D
F/2 E/2 D)  14

Most fit zig zag melody: 2     (C2 D/2 E F/2 E F/2 G F F/2 G2 F/2 E/2 F E2 F2 E/2 C D E/2 D)
13.300001
NIL
```

Behavior of the GA

As mentioned previously, this genetic algorithm only composes melodies consisting of notes from C major. If I had more time, I would have added support for more keys. The infrastructure is in place for adding more keys with a *CURRENT-KEY* variable; it's just a matter of either hard-coding different keys or writing a program to generate keys.

The genetic algorithm begins by generating an initial population. Populations are made of individuals who have a melody, fitness, and number. The melody is a list of randomized notes from the C major scale. The C major scale implemented in the program has note representations for half notes, quarter notes, and eighth notes, a total of 21 possible notes to choose from. The fitness is calculated using one of five fitness metrics: stepwise motion, pair-wise, ascending jumps/stepwise descending, stepwise slashing, and zig zag.

The first fitness metric used is the stepwise motion melody metric. This fitness method works recursively with a list of pitches generated by the pitch-string method. The position of the first and second pitches in the list are calculated using the position of the note on the scale. This is calculated by getting the position of the note within the C major list and calculating modulo 7 since note durations repeat. The pitch-distance is calculated by subtracting the aforementioned positions of the pitches (pitch two - pitch one). The stepwise motion fitness metric rewards +1 point for pitch-distances of 1 and -1. The function operates recursively by removing the car of the list each iteration until one pitch remains.

The second fitness metric used is the fitness-pairs melody metric. Like the first fitness method, this one works recursively on a list of pitches generated by the pitch-string method. The caveat of this fitness metric is constraining the note sequence in such a way that the note pairs change throughout the piece, as playing the same note pairs throughout the piece, while valid by the original definition, is not particularly interesting. If I had more time, I would have rewritten the *pitch-string* method to create a list of pitch objects with note and duration fields. Instead, I have the following cases:

- Reward +1 if there are only 2 notes left in the list and they are equal in pitch in duration
- Reward +1 if the first and second notes are equal AND the pitch-distance between the third note and the first note is not equal to 0 → this ensures that the same note does note repeat every time

Instead of recursively passing the cdr of the list to the second fitness method each time, the first two elements are removed from the list thus passing the cddr into the recursion. As another note, the percent-mutation needs to be tweaked to produce better results – all pairs are rarely

generated. **Update 12/5/2022:** Changing the limit to a smaller size results in better results for the pairwise melody.

The third fitness metric used is the ascending jumps/stepwise decline melody metric. The same list melody input, first and second pitch position calculations, and pitch distance calculation from the first fitness method are used. This fitness metric rewards +1 point for pitch distances greater than 1 – jumps – and +1 point for pitch distances equal to -1 – stepwise decline. Like the first fitness metric, recursion is used until only one element remains in the list.

The fourth fitness metric used is the stepwise slashing melody metric. The same list melody input, first and second pitch position calculations, and pitch distance calculation from the first and third fitness methods are used. Unlike the previous fitness metrics, a helper method is utilized with an extra parameter storing the previous pitch distance observed, giving insight into the direction of the melody. Additionally, the *notes-num* parameter tracks the streak of consecutive notes traveling in one direction on the interval (up or down). A problem with the way this has been implemented is that repeated notes "break" the streak, as there is no account for direction prior to repeated notes. In some ways, this works out fine, as it restricts the number of repeated notes to produce a composition with more movement. Points are awarded as follows:

- +1 point for a *notes-num* streak of 1 (two consecutive notes) or 2 (three consecutive notes) AND the previous pitch-distance and current pitch-distance are both stepwise in one direction (both -1 or both 1)
- +1 point if the current pitch-distance is stepwise AND the *notes-num* streak is 0 (case for when there is no streak)

The metric above does limit the stepwise notes streaks to 2 or 3, which is promising. However, some tweaks need to be made to the point distribution, as the program seems less favoring of the defined note streaks and is too reminiscent of the stepwise motion algorithm. This could be fixed by lowering the point value for the second reward criteria above.

The final fitness metric used is the zig zag melody metric. The same list melody input, first and second pitch position calculations, and pitch distance calculation from the other fitness methods are used. Like the stepwise slashing melody metric, the previous pitch distance is tracked for determining the direction of the melody. The *fitness-zig-zag-p* predicate function returns true if the current pitch-distance equals 1 and the previous pitch-distance is negative OR the current pitch-distance equals 1 and the previous pitch-distance is positive. Essentially, the predicate checks whether a stepwise "turn" occurs. Points are rewarded in the following way:

- +1 for passing the predicate AND the first note is degree 1, 3, 5, or 7 of the scale
- +0.6 when the current pitch-distance is 1 or -1, indicating stepwise motion
- +0.3 when the current pitch-distance is 0, indicating equal note pitches (not necessarily equal duration)

This metric method took quite a bit of tweaking to get to a reasonable point where zig zags can be seen. As the possibility of reward increases, the precision of point values needs to increase to produce sought-after facets of the melody composition.

The same methodology for selection, mutation, copy, and crossover in the RBG genetic algorithm are used in this melodic composition program. There is not a need for special crossovers or mutations to preserve the integrity of the melody, as there are relatively few constraints on the possible notes used.