

# Bioinformatics - Tree Comparison

## Project 3

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December 8, 2015

### 1/4 Approximation - Results

#### hp-string 1

hhppppphhppphppphp  
flfr r flffr r flr r lf

```

      p - p      .   .   .
      |   |
      p   p      .   .   .
      |   |
h - H   p - H - h - p
      *       *       |
p - h - p   h - p - p
      |       |
      .   .   p - p   .   .

```

Score: 2

## hp-string 2

hphphhhppphhhpphh  
ffffffffrrffflrll

h	-	p	-	h	-	p	-	h	-	H	-	h	-	p
*				*				*		*				
H	-	h	*	H	-	h	-	H	-	h	-	p	-	p
.		p	-	p		.		.		.		.		.

Score: 5

## hp-string 3

phpphphhhphhphhhhh  
ffffffffffffrrffff

p	-	H	-	p	-	p	-	h	-	p	-	h	-	H	-	h	-	p	-	h
								*		*		*		*						
.		.		.		.		H	-	h	-	H	-	h	-	H	-	p	-	H

Score: 4

## hp-string 4

hphpphhphpphphhphph  
fflrrlffffrrfflrrlff

.		.		p	-	p		.		.		.		.
h	-	p	-	h	*	H	-	h	-	p	-	h	-	p
*				*				*		*		*		
H	-	p	-	H	-	p		H	-	p	-	H	-	p
.		.		.		p	-	h		.		.		.

Score: 5

## hp-string 5

hhhpphphphpphphpph  
flrrlffffrrffffffffff

.	.	.	h	-	p	.	.	.	.	.								
.	.	h	-	H	p	-	H	-	p	-	H	-	p	-	H			
				*			*		*									
H	-	p	-	p	-	h	-	p	-	h	-	p	-	h	-	p	-	p

Score: 3

## hp-string 6

hhpphpphpphpphpphpph  
lrrllfrrflfrrlfrrfllrrl

.	.	p	-	H	.	.			
H	-	p	p	p	.	.			
h	p	-	h	p	-	h	-	p	
*		*		*					
H	-	h	*	H	-	p	H	-	p
.	p	-	p	p	p	.			
.	.	.	h	-	p	.			

Score: 4

## hp-string 7

pphphhppppphhpppphhpppphh  
 ffffflfr r flfffr r fflfr r fl

.	.	.	.	.	.	p - p	.	.	.	.
.	.	.	.	.	.			.	.	.
.	.	.	.	.	.	h	p	.	.	.
.	.	.	.	.	.			.	.	.
p - p - h - p - p - H						p - H - h - p - p				
.	.	.	.	.	.	*	*	*		
.	.	.	.	.	.	h - H	*	h - H	p - p	
.	.	.	.	.	.					
.	.	.	.	.	.	p	p	.	.	.
.	.	.	.	.	.					
.	.	.	.	.	.	p - p	.	.	.	.

Score: 4

## hp-string 8

ppphhpphppppphhhhhhhpphphpppphhpphpp  
 ffflrrllffrrfflffrrfflrrllfr r flffff

.	.	.	.	.	.	.	.	p - p	.	.	.
.	.	.	.	.	.	.	.			.	.
.	.	.	.	.	.	.	.	p	p	.	.
.	.	.	.	.	.	h - p	h	p	.	.	.
.	.	.	.	.	.					.	.
.	.	p - p - p - H				p - H	*	h - H	h - H		
.	.	*	*	*	*						
p - p - H - p - p - h						p - h	p - h	H - h			
.	.	.	.	.	.						
.	.	.	.	.	.	H	p	H - p	.	.	.
.	.	.	.	.	.						
.	.	.	.	.	.	p - p	.	.	.	.	.

Score: 5

## hp-string 9

pphpphhpphhppppphhhhhhhhhpppppphhpphhpphphpphhhh  
f fl r r l l r r l l f r r f l f f f f r r f f l f f r r f l l r r l l f r r f l f f f

$$\begin{array}{cccccccccccccccc}
. & . & . & . & . & . & p - p & . & . & . & . & . & . & . \\
& & & & & & | & | & & & & & & \\
. & . & p - p & p - p & p - p & p & p & . & . & . & . & . & . & . \\
& & | & | & | & | & | & & & & & & & \\
p - p - h * H - h * H - h & p - h - H - h - H - h - H - h & & & & & & & & & & & & \\
& * & * & * & * & * & * & & * & * & * & * & & | \\
. & . & H - h - H - h - H & p - H & p - H & p - H - h - H & & & & & & & & \\
& & & & & | & | & | & | & | & & & & \\
. & . & . & . & . & . & p & p & h - p & h & p & . & . & . \\
& & & & & & | & | & & | & | & & & \\
. & . & . & . & . & . & p - h & . & . & p & p & . & . & . \\
& & & & & & & & & | & | & & & \\
. & . & . & . & . & . & . & . & . & p - p & . & . & . & .
\end{array}$$

Score: 11

## hp-string 10

# hhphphphphhhhphppphppphppphppphppphphhhhhphphphphhh ffffffffffffrr

$\begin{array}{ccc} \text{h} & - & \text{h} & - & \text{p} & - & \text{H} & - & \text{p} & - & \text{H} & - & \text{p} & - & \text{H} & - & \text{h} & - & \text{H} & - & \text{h} & - & \text{p} & - & \text{h} & - & \text{p} & - & \text{p} & - & \text{p} & - & \text{h} & - & \text{p} & - & \text{p} & - & \text{h} & - & \text{p} & - & \text{p} \\ * & & * & & & & * & & & & * & & & & * & & * & & * & & * & & & & * & & & & & & & & * & & & & & & & & & & & & * & & | \\ \text{H} & - & \text{h} & - & \text{p} & - & \text{h} & - & \text{p} & - & \text{h} & - & \text{p} & - & \text{h} & - & \text{H} & - & \text{h} & - & \text{H} & - & \text{p} & - & \text{H} & - & \text{p} & - & \text{p} & - & \text{p} & - & \text{H} & - & \text{p} & - & \text{p} & - & \text{p} & - & \text{H} & - & \text{p} & - & \text{p} \end{array}$

Score: 12

## hp-string 11

pphhhphhhhhhhhhppphhhhhhhhhhhphppphhhhhhhhhhhhhpppphhhhhhphhhphp  
ffflrlffffffflrlffffffrrffffffflfrflfffffflrlfff

```
. . . h - p . . . . . p - p . . . . . . . . . .
.
      | |
p - p - h - H * h - H - h - H - h - H - h - H p - H - h - H - h - H - h - H - h - H - h - p - h - p
      * * * * * * * * * * * * * * * *
|
. . . p - h - p - h - H * h - H - h - H - h - p h - H - h - H - h - H - h - H - h - H - h - p - p
      | |
. . . . . p - H . . . . . p H . . . . . . . . . .
.
      | |
. . . . . . . . . . . p - p . . . . . . . . . .
.
```

Score: 20

## hp-string 12

hhhhhhhhhhhhphphpphphpphphpphphpphphpphphpphphpphphhhhhhhhhhhhh  
ffffffffffffffffflrllrllfrflfrflfrflrllrllrllffffff

```
. . . . . . . . . . . . . . . . . . . . . p - h . . .
. . . . . . . . . . . . . . . . . . . . . . . . . . . | |
. . . . . . . . . . . . . . . . . . . . . . . . . . . p - p p - p P P . . .
. . . . . . . . . . . . . . . . . . . . . . . . . . . | | | | | |
h - H - h - H - h - H - h - H - h - H - h - H - p - H - p - H * h - H * h - H p - H - h - p
* * * * * * * * * * * * * * * * * * * * * * * * * * * |
H - h - H - h - H - h - H - h - H - h - H - h - p - h - p - h - p h - p h - p h - H - p
. . . . . . . . . . . . . . . . . . . . . . . . . . . p - H p - H P P . . .
. . . . . . . . . . . . . . . . . . . . . . . . . . . | |
. . . . . . . . . . . . . . . . . . . . . . . . . . . H - p . .
```

Score: 20

## hp-string 13

```
hhhhpppphhhhhhhhhhhhpppppphhhhhhhhhhhhppphhhhhhhhhhhppphhhhhhhhhhhppphpphphpphph
fffflrrflffffffffflrrflffffffffflrrlrrrffffflrrlffffffffflrrrflrrllrrlrf
```

[illegible]

Score: 25

## hp-string 14

[illegible][illegible]

Score: 25



## hp-string 15

```
ppphppphhhpphhpphhpphhpppppppphhhhhpphhhhhppppppppphphphhhhhhhhhhhpphhphhpapphphhhpppppphh  
ffflrllfllrllfffflrrllfffllfffrffllffflrllfffrfflfflrllffffffflrllffffflrfflfffflfrffl
```

[illegible]

Score: 24

## Our folding approach

Bruteforce for  $n < 20$

---

**Algorithm 1** BRUTEFORCE

---

```
1: for all possible foldings  $x$  do
2:   if  $x$  is valid folding then
3:     get score of folding
4:     if score is the best then
5:       store the path and score
6:     end if
7:   end if
8: end for
```

---

Sampling for  $n \geq 20$

---

**Algorithm 2** SAMPLING WITH DFS

---

```
1: while long time is not long anymore do
2:   generate valid random folding using DFS
3:   get score of folding
4:   if score is the best then
5:     store the path and score
6:   end if
7: end while
```

---

## hp-string 1

hhppppphhppphppphp  
nwsseeneenwnnsw

```

      p - p      .      .
      |      |
p - h      p      .      .
      *      |
p - H * h - p - p
|      |      *      |
p      h * H - h - p
|      |
p - p - p      .      .
```

Score: 4

## hp-string 2

hphphhhppphhhpphh  
nwnwswwssenessenn

```

.      .      h - p      .
          |      |
p - h - H * h - p
|      *      *      *      |
p      H - h * H * h
|      |      |      |
p - h * H * h      .
          |      |
.      .      p - p      .

```

Score: 8

## hp-string 3

phpphphhhphhhphhhhh  
nwneneneessswwnen

```

.      .      H - h - p
          |      *      |
.      p - h * H * h
          |      *      |      |
p - h * H - h * H
|      *      |      *      |
p - H * h - H - p
          |
.      p      .      .      .

```

Score: 9

## hp-string 4

hphpphhphpphphhpphph  
nwswseswssenenesesennw

```
p - h - p      .      .  
|   *   |  
p - H * h * H - p  
    |   *   *   |  
p - h * H - h * H  
|   *   |   |   |  
h * H - p   p - p  
|   |  
p - p      .      .      .
```

Score: 9

## hp-string 5

hhhpphphpphphpph  
nwwseseenwnwnnwse

```

p - h - p      .      .
|   *   |
p - H * h - p      .
    *   *   |
p - h - H * h - p
|   *   |   *   |
p - H * h * H - p
    |   *   |
.   p - H - p      .

```

Score: 10

## hp-string 6

hhpphpphpphpphpph  
ssenwnwnwnswsessennn

```

.   p - p      .      .      .
    |   |
p - H * h - p - p      .
|   *   *       |
p - h * H * h * H - p
    |   |   |   *   |
.   p   h * H * h - p
    |   |   |   |
.   p   p   p - p      .
    |   |
.   H - p      .      .      .

```

Score: 9

## hp-string 7

p p h p p h h p p p p h h p p p p h h p p p p h h  
e n w n e n w n e e s s s s e n n e e n n w s w

```

p - p - p      .      p - p
|           |      |      |
p - h * H * h - H      p
      |      |      *      *      |
p - H * h * H - h - p
|      *      |      |
p - h      p      p      .      .
      |      |      |
p - p      p - p      .      .

```

Score: 7

## hp-string 8

p p p h p p h h p p p p p h h h h h h p p h h p p p p h h p p h p p  
n w s w s e s w s s e n e s e n n w n e e s s e e s w w s s w n w s

```

.      .      p - p      .      .      .
      |      |
p - h - H      p      .      .      .
|      *      *
p - H * h - p - p      .      .
      |      |      |
p - h * H - h * H      .      .
|      *      |      |
p      p - h * H * h - p - p
|      |      |      |      *      |
p - p      H - h * H - p - p
                        *      |
.      .      p - H * h      .      .
      |      |      |
.      .      p      p - p      .      .

```

Score: 12

## hp-string 9

pphpphhphppppphhhhhhhhhhhpppppphphpphhpphphhhhh  
 nesseswseseseseeneenwnwnswnneneseseneseseneseswwwse

```

p - h      .      .      .      .      .      .      .      .      .
|      |
p      p      .      .      p - p      .      .      .      .      .
|      |      |      |
.      p - H      p - p      p - p      p - p      p - p      .
|      |      |      |      |      |      |      |
.      p - h * H * h - H * h - H * h - H * h - p
|      *      |      |      |      *      *      *      *      *      |
.      p - H * h - H * h - H - h * H - h - H - p
|      |      |      *      |      |      *
.      .      h - p      .      p - h - H * h - H      .      .
|      |
.      .      .      p - p - p      .      .      .      .      .

```

Score: 17

## hp-string 10

hhphphphphhhhhphppphppphpppphppphppphphhhhhphphphphh  
 swnnwnnwsswnnwnnennessennesseeeessesssswnnenwnwnwsse

```

.      h - p      p - p      .      .      .      .
|      |      |      |
.      p      p      p      p      .      .      .      .
|      |      |      |
p - p      p - h * H - p - p - p      .
|      *      *      |
h - p      p - H * h - p      .      H      .
|      |      |      |      |      |
.      h * H      p      p      h - p      p - p
|      |      |      |      *      |      |
.      H - h * H * h - H * h - p      p
|      *      *      *      |      |
.      .      .      p - H * h * H - h * H
|      |      |      *      |
.      .      .      .      p - H * h - H - p

```

Score: 17



## hp-string 11

pphhhphhhhhhhhhppphhhhhhhhhhhphppphhhhhhhhhhhhhpppphhhhhhphhhphp  
 wwnnnwwseswwnwsseeeseesswnwssseneseeeswwseeennnwnwswnnnese

```

.      .      H - h - p      .      .      .      .      .
      |      *      |
p - H * h - H * h      .      .      .      .      .
|      |      *      |      |
p      h - H - h * H      .      .      .      .      .
|      *      *      *      |
p - H - h - H * h - p - p      .      .      .
      |      *
.      .      .      h - H - h * H - h      .      .
      *      |      |      |
.      .      .      p - h * H      p      p - h - p
      |      |      |      |      *
.      .      .      h * H - h * H * h - H      .
      |      *      *      |      |      |
.      .      .      p      h - H * h - H * h - p
      |      |      |      *      *      *      |
.      .      .      p - p      h - H - h - H      p
      *      *      |      |
.      .      .      .      .      .      h - H - h      p
      |      *      *      |
.      .      .      .      .      .      H - h - H - p

```

Score: 28

## hp-string 12

hhhhhhhhhhhhhhphpphpphphpphphpphphpphphpphphpphphpphphpphphpphphpphphpphphpphphpphphpph  
nneeeswwsswnwwwnwswnwneeeeseenwneeeneseesesswseswswnnwsswswnw

.	.	.	.	.	.	.	.	.	p	-	p	.	.	.	.											
.	.	.	.	.		h	-	p	-	p	-	H	*	h	-	H	-	p	-	p	.					
												*	*	*												
p	-	p	-	h	-	p	-	p		H	-	p	.	h	-	H	-	h	-	H	*	h	.			
				*				*					*	*												
H	-	h	*	H	-	h	*	H	-	h	-	p	.	H	*	h	-	H	-	h	*	H	-	p		
								*								*	*	*	*	*						
.		p	-	p		p	-	p	-	H	-	p	-	H	*	h	*	H	*	h	-	H	*	h	-	p
														*												
.		.		.		.		.		p	-	H	-	h	*	H	*	h		p	-	h				
										*		*														
.		.		.		.		.		H	-	h	*	H	-	h	*	H	-	h	-	p				
.		.		.		.		.		H	-	h		.		.		.		.		.				

Score: 28

## hp-string 13

hhhhpppphhhhhhhhhhhhpppppphhhhhhhhhhhhpppphhhhhhhhhhhhpppphhhhhhhhhhhhpppphphpphphpph  
 nwnwnwseswseswnnnnwnwswsennesswssseneneennnesseswsseenwnennnnessseennwswnnnnwswnnw

```

.      p - p      .      p - p - p      .      h - p      .      .      .      .
|      |      |      |      |      |      *      |      *      |      |      |
p - p      H - h      p - h * H - h - H * h * H - h      .      .
|      |      *      |      |      |      *      |      |      |      |
p      H - h * H * h * h - H * h - H * h      p - p      p      .      .
|      |      |      |      |      |      *      |      |      |
p - h * H * h * H - h * H * h      .      h - H      p      .      .
*      |      |      *      |      |      |      |      |      |
.      H - h * H - h - H * h * H - h * H * h * H      p - H
|      *      |      |      |      |      *      |      |      |
.      h * H - p - p - p - H * h - H * h * H * h * h - p      p
|      |      |      |      |      |      *      |      |      *
.      H * h      .      .      .      .      H * h - H * h - H - p - p
|      |      |      |      |      |      |      |      *
.      h - H      .      .      .      .      h * H - h      .      .      .
|      |      |      |      |      |      |
.      .      .      .      .      .      p - p - p      .      .      .

```

Score: 39

## hp-string 14

pppppphphppppphhhphhhhhphhphpppphphhphhhhhphhhhhhhhhphhphhhhhhhpppppppppphhhhhhhhphhphhhhhppppppphhh  
 swnnneeneseeswwwssswswwwwneenwnwsswnnwneenwnneenwnwwwwneeeeesennwnnnwswnwsseeswwwwwwseswwwseeeeeee

```

. . . . . p - p p - p . . . . .
| | | |
. . . . . p p - p p . . . . .
| |
. . . . . h - H - h p . . . . .
* * | |
. . H - p - p - h - H - h - H p - p . . . . .
| * * * |
. . p - H * h - p - h - H - h - H * h . . . . .
| | * * * | |
p - p - H - h * H - p - H - h - H * h - H . . . . .
| * * * | * *
p - p - p - p - h - p - h - H * h - H - h . . . . .
* * |
. . . . . H - h - H . . . . .
|
. . . . . p - h . . . . . p - h . . .
| * | |
. . . . . h - H . . . . . p - p - h * H - p - p
* | | * |
. . . . . h - H - h . . . . . p p H - p - p - p
| * * | | |
. . . . . p - h * H - p - p p - p h . . . .
| | | |
. . . . . H * h . . . . . p - p . H . . . .
| | | |
. . . . . p - p p - H - h * H - p . . . .
| * * |
. . . . . H - h - H - h . . . . .

```

Score: 31

## hp-string 15

ppphhpphhhhpphhhhpphhhhpphhhhpppppppphhhhhhpphhhhhhppppppppphhphhhhhhhhhhhhhpphhhhpphhpphhpphhpppppphh  
sseneeeennwnnnneeswsesessennennwnnnnnwseswwwssswwwwswsswseneenwnneessswswseeswwnnnwnwsesess

[illegible]

Score: 31

## Results

## Approximation

	score	time	fold
1	-2	<1ms	flfrrflffrrflrrlf
2	-5	<1ms	ffffffrrfffflrrl
3	-4	<1ms	ffffffrrffff
4	-5	<1ms	flrrlffrrfflrrlff
5	-3	<1ms	flrrlffffrrfffffff
6	-4	<1ms	lrrllfrrflfrrlfrfllrrl
7	-4	<1ms	ffffflfrrflffrrfflfrfll
8	-5	<1ms	ffflrrllfrrfflffrrfflrrllfrrflffff
9	-11	<1ms	flrrllrrllfrrlffffffrrfflffrrfflrrllfrrlfff
10	-12	<1ms	ffffffffffffffffffffrrffffffffffffffffffff
11	-20	<1ms	ffflrrlfffffflrrlffffffffffffrrfffffffffflfrfllfffflrrlfff
12	-20	<1ms	ffffffffffffflrrllrrllfrrflffrrflfrrllrrllrrlffffffffffff
13	-25	<1ms	ffflfrrflffffffffflfrrfflffffffffflrrlfrffflrrlffffflfrrfflrrllrrlff
14	-25	<1ms	fffffffffflfrfllffffffflfrrflrrllrrllfllrrlfffrfrrflrrlffffflffffrrffflffffflfrrflffrrfflff
15	-24	<1ms	ffflrrllfllrrlfffflrrlfffflffrrfflfffflrrlfffrlfffrffflfllrrlffffflrrlfffflfrfllfffflffrrffl

## Bruteforce and Sampling

	score	time	fold
1	-4	55s	nwsseeneenwwnnsws
2	-8	1m10s	nwnswswssenesenn
3	-9	1m16s	nwneneneessswwnen
4	-9	6m50s	nwwseswssenenesennw
5	-10	6m55s	nwwseseenenwnwnwse
6	-9	1m53s	ssenenwnwnswsseennnn
7	-7	6m34s	enwnenwneesssenneennsw
8	-12	n/a	nswswseswssenenesennwneesseeeswsswnws
9	-17	n/a	nesseswseseseeeneenwnnwswnnenesesenenesesewwwse
10	-17	n/a	swnnnnnwsswnnwnnnessennnesseeessssswnnenwnwnwsse
11	-28	n/a	wnnnnwswseswnnwssseeseesswnssseneeeseeswweeennnwnswnnnese
12	-28	n/a	mneeeswssswwnwwwwnwswnwneeeeeseenwneeneseeesseswseswnnnwssswwnw
13	-39	n/a	nwnnwswseswswwnnnwnwswssenesessssenneeeennneseswsseenwnnnnesseeennwnnnnwswnnw
14	-30	n/a	swnneeneseswssswswwnneenwnwswwnnneenwnneenwnwwwneeeesennwnnwswnsseeswswswswseeeee
15	-31	n/a	sseneeeenwnnnneeeswsesessennnnwnnnnwswswswswswswswsseneenwneessswswseeswswnnnwswses