Problem 1

==========length-3 frequent==========

< {2} {3} {4} >

< {2 5} {3} >

< {3} {4} {5} >

< {1} {2} {3} >

< {1} {2 5} >

< {1} {5} {3} >

< {5} {3 4} >

Joining:

------------------------------

< {2} {3} {4} > remove first item is < {3} {4} >

< {2} {3} {4} > remove last item is < {2} {3} >

< {2} {3} {4} > and < {2} {3} {4} > could not join

< {2} {3} {4} > remove first item is < {3} {4} >

< {2 5} {3} > remove last item is < {2 5} >

< {2} {3} {4} > and < {2 5} {3} > could not join

< {2} {3} {4} > remove first item is < {3} {4} >

< {3} {4} {5} > remove last item is < {3} {4} >

< {2} {3} {4} > and < {3} {4} {5} > could join

length-4 frequent < {2} {3} {4} {5} >

< {2} {3} {4} > remove first item is < {3} {4} >

< {1} {2} {3} > remove last item is < {1} {2} >

< {2} {3} {4} > and < {1} {2} {3} > could not join

< {2} {3} {4} > remove first item is < {3} {4} >

< {1} {2 5} > remove last item is < {1} {2} >

< {2} {3} {4} > and < {1} {2 5} > could not join

< {2} {3} {4} > remove first item is < {3} {4} >

< {1} {5} {3} > remove last item is < {1} {5} >

< {2} {3} {4} > and < {1} {5} {3} > could not join

< {2} {3} {4} > remove first item is < {3} {4} >

< {5} {3 4} > remove last item is < {5} {3} >

< {2} {3} {4} > and < {5} {3 4} > could not join

------------------------------

< {2 5} {3} > remove first item is < {5} {3} >

< {2} {3} {4} > remove last item is < {2} {3} >

< {2 5} {3} > and < {2} {3} {4} > could not join

< {2 5} {3} > remove first item is < {5} {3} >

< {2 5} {3} > remove last item is < {2 5} >

< {2 5} {3} > and < {2 5} {3} > could not join

< {2 5} {3} > remove first item is < {5} {3} >

< {3} {4} {5} > remove last item is < {3} {4} >

< {2 5} {3} > and < {3} {4} {5} > could not join

< {2 5} {3} > remove first item is < {5} {3} >

< {1} {2} {3} > remove last item is < {1} {2} >

< {2 5} {3} > and < {1} {2} {3} > could not join

< {2 5} {3} > remove first item is < {5} {3} >

< {1} {2 5} > remove last item is < {1} {2} >

< {2 5} {3} > and < {1} {2 5} > could not join

< {2 5} {3} > remove first item is < {5} {3} >

< {1} {5} {3} > remove last item is < {1} {5} >

< {2 5} {3} > and < {1} {5} {3} > could not join

< {2 5} {3} > remove first item is < {5} {3} >

< {5} {3 4} > remove last item is < {5} {3} >

< {2 5} {3} > and < {5} {3 4} > could join

length-4 frequent < {2 5} {3 4} >

------------------------------

< {3} {4} {5} > remove first item is < {4} {5} >

< {2} {3} {4} > remove last item is < {2} {3} >

< {3} {4} {5} > and < {2} {3} {4} > could not join

< {3} {4} {5} > remove first item is < {4} {5} >

< {2 5} {3} > remove last item is < {2 5} >

< {3} {4} {5} > and < {2 5} {3} > could not join

< {3} {4} {5} > remove first item is < {4} {5} >

< {3} {4} {5} > remove last item is < {3} {4} >

< {3} {4} {5} > and < {3} {4} {5} > could not join

< {3} {4} {5} > remove first item is < {4} {5} >

< {1} {2} {3} > remove last item is < {1} {2} >

< {3} {4} {5} > and < {1} {2} {3} > could not join

< {3} {4} {5} > remove first item is < {4} {5} >

< {1} {2 5} > remove last item is < {1} {2} >

< {3} {4} {5} > and < {1} {2 5} > could not join

< {3} {4} {5} > remove first item is < {4} {5} >

< {1} {5} {3} > remove last item is < {1} {5} >

< {3} {4} {5} > and < {1} {5} {3} > could not join

< {3} {4} {5} > remove first item is < {4} {5} >

< {5} {3 4} > remove last item is < {5} {3} >

< {3} {4} {5} > and < {5} {3 4} > could not join

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< {1} {2} {3} > remove first item is < {2} {3} >

< {2} {3} {4} > remove last item is < {2} {3} >

< {1} {2} {3} > and < {2} {3} {4} > could join

length-4 frequent < {1} {2} {3} {4} >

< {1} {2} {3} > remove first item is < {2} {3} >

< {2 5} {3} > remove last item is < {2 5} >

< {1} {2} {3} > and < {2 5} {3} > could not join

< {1} {2} {3} > remove first item is < {2} {3} >

< {3} {4} {5} > remove last item is < {3} {4} >

< {1} {2} {3} > and < {3} {4} {5} > could not join

< {1} {2} {3} > remove first item is < {2} {3} >

< {1} {2} {3} > remove last item is < {1} {2} >

< {1} {2} {3} > and < {1} {2} {3} > could not join

< {1} {2} {3} > remove first item is < {2} {3} >

< {1} {2 5} > remove last item is < {1} {2} >

< {1} {2} {3} > and < {1} {2 5} > could not join

< {1} {2} {3} > remove first item is < {2} {3} >

< {1} {5} {3} > remove last item is < {1} {5} >

< {1} {2} {3} > and < {1} {5} {3} > could not join

< {1} {2} {3} > remove first item is < {2} {3} >

< {5} {3 4} > remove last item is < {5} {3} >

< {1} {2} {3} > and < {5} {3 4} > could not join

------------------------------

< {1} {2 5} > remove first item is < {2 5} >

< {2} {3} {4} > remove last item is < {2} {3} >

< {1} {2 5} > and < {2} {3} {4} > could not join

< {1} {2 5} > remove first item is < {2 5} >

< {2 5} {3} > remove last item is < {2 5} >

< {1} {2 5} > and < {2 5} {3} > could join

length-4 frequent < {1} {2 5} {3} >

< {1} {2 5} > remove first item is < {2 5} >

< {3} {4} {5} > remove last item is < {3} {4} >

< {1} {2 5} > and < {3} {4} {5} > could not join

< {1} {2 5} > remove first item is < {2 5} >

< {1} {2} {3} > remove last item is < {1} {2} >

< {1} {2 5} > and < {1} {2} {3} > could not join

< {1} {2 5} > remove first item is < {2 5} >

< {1} {2 5} > remove last item is < {1} {2} >

< {1} {2 5} > and < {1} {2 5} > could not join

< {1} {2 5} > remove first item is < {2 5} >

< {1} {5} {3} > remove last item is < {1} {5} >

< {1} {2 5} > and < {1} {5} {3} > could not join

< {1} {2 5} > remove first item is < {2 5} >

< {5} {3 4} > remove last item is < {5} {3} >

< {1} {2 5} > and < {5} {3 4} > could not join

------------------------------

< {1} {5} {3} > remove first item is < {5} {3} >

< {2} {3} {4} > remove last item is < {2} {3} >

< {1} {5} {3} > and < {2} {3} {4} > could not join

< {1} {5} {3} > remove first item is < {5} {3} >

< {2 5} {3} > remove last item is < {2 5} >

< {1} {5} {3} > and < {2 5} {3} > could not join

< {1} {5} {3} > remove first item is < {5} {3} >

< {3} {4} {5} > remove last item is < {3} {4} >

< {1} {5} {3} > and < {3} {4} {5} > could not join

< {1} {5} {3} > remove first item is < {5} {3} >

< {1} {2} {3} > remove last item is < {1} {2} >

< {1} {5} {3} > and < {1} {2} {3} > could not join

< {1} {5} {3} > remove first item is < {5} {3} >

< {1} {2 5} > remove last item is < {1} {2} >

< {1} {5} {3} > and < {1} {2 5} > could not join

< {1} {5} {3} > remove first item is < {5} {3} >

< {1} {5} {3} > remove last item is < {1} {5} >

< {1} {5} {3} > and < {1} {5} {3} > could not join

< {1} {5} {3} > remove first item is < {5} {3} >

< {5} {3 4} > remove last item is < {5} {3} >

< {1} {5} {3} > and < {5} {3 4} > could join

length-4 frequent < {1} {5} {3 4} >

------------------------------

< {5} {3 4} > remove first item is < {3 4} >

< {2} {3} {4} > remove last item is < {2} {3} >

< {5} {3 4} > and < {2} {3} {4} > could not join

< {5} {3 4} > remove first item is < {3 4} >

< {2 5} {3} > remove last item is < {2 5} >

< {5} {3 4} > and < {2 5} {3} > could not join

< {5} {3 4} > remove first item is < {3 4} >

< {3} {4} {5} > remove last item is < {3} {4} >

< {5} {3 4} > and < {3} {4} {5} > could not join

< {5} {3 4} > remove first item is < {3 4} >

< {1} {2} {3} > remove last item is < {1} {2} >

< {5} {3 4} > and < {1} {2} {3} > could not join

< {5} {3 4} > remove first item is < {3 4} >

< {1} {2 5} > remove last item is < {1} {2} >

< {5} {3 4} > and < {1} {2 5} > could not join

< {5} {3 4} > remove first item is < {3 4} >

< {1} {5} {3} > remove last item is < {1} {5} >

< {5} {3 4} > and < {1} {5} {3} > could not join

< {5} {3 4} > remove first item is < {3 4} >

< {5} {3 4} > remove last item is < {5} {3} >

< {5} {3 4} > and < {5} {3 4} > could not join

==========length-4 frequent==========

< {2} {3} {4} {5} >

< {2 5} {3 4} >

< {1} {2} {3} {4} >

< {1} {2 5} {3} >

< {1} {5} {3 4} >

==========purning==========

all subsequences of < {2} {3} {4} {5} > are ["< {3} {4} {5} >", "< {2} {4} {5} >", "< {2} {3} {5} >", "< {2} {3} {4} >"]

< {3} {4} {5} > in length-3 frequent pattern set

< {2} {4} {5} > not in length-3 frequent pattern set

< {2} {3} {5} > not in length-3 frequent pattern set

< {2} {3} {4} > in length-3 frequent pattern set

all subsequences of < {2 5} {3 4} > are ["< {5} {3 4} >", "< {2} {3 4} >", "< {2 5} {4} >", "< {2 5} {3} >"]

< {5} {3 4} > in length-3 frequent pattern set

< {2} {3 4} > not in length-3 frequent pattern set

< {2 5} {4} > not in length-3 frequent pattern set

< {2 5} {3} > in length-3 frequent pattern set

all subsequences of < {1} {2} {3} {4} > are ["< {2} {3} {4} >", "< {1} {3} {4} >", "< {1} {2} {4} >", "< {1} {2} {3} >"]

< {2} {3} {4} > in length-3 frequent pattern set

< {1} {3} {4} > not in length-3 frequent pattern set

< {1} {2} {4} > not in length-3 frequent pattern set

< {1} {2} {3} > in length-3 frequent pattern set

all subsequences of < {1} {2 5} {3} > are ["< {2 5} {3} >", "< {1} {5} {3} >", "< {1} {2} {3} >", "< {1} {2 5} >"]

< {2 5} {3} > in length-3 frequent pattern set

< {1} {5} {3} > in length-3 frequent pattern set

< {1} {2} {3} > in length-3 frequent pattern set

< {1} {2 5} > in length-3 frequent pattern set

all subsequences of < {1} {5} {3 4} > are ["< {5} {3 4} >", "< {1} {3 4} >", "< {1} {5} {4} >", "< {1} {5} {3} >"]

< {5} {3 4} > in length-3 frequent pattern set

< {1} {3 4} > not in length-3 frequent pattern set

< {1} {5} {4} > not in length-3 frequent pattern set

< {1} {5} {3} > in length-3 frequent pattern set

==========length-4 frequent==========

< {1} {2 5} {3} >

Problem 2

<b> - projected database:

<(\_c)(ac)d(cf)>

<(\_c)(ae)>

<(df)(cb)>

<c>

items:

a:2

b:0

c:4

d:2

e:1

f:2

\_c:2

length-2 sequential pattern having prefix <b>:

<ba>

<bc>

<bd>

<(bc)>

<bf>

Problem 3

(1)

HMM

Alphabet: {g, r, b}

Set of states: {u1, u2}

Transition probability:

|  |  |
| --- | --- |
| 0.9 | 0.1 |
| 0.1 | 0.9 |

Emission probability：

|  |  |  |  |
| --- | --- | --- | --- |
|  | g | r | b |
| u1 | 1/3 | 1/3 | 1/3 |
| u2 | 1/2 | 1/4 | 1/4 |

Start probability:

[0.8, 0.2]

(2)

According to:

f(ggg) = fu1(ggg) + fu2(ggg)

fu1(ggg) = eu1(g) \* (fu1(gg) \* au1u1 + fu2(gg) \* au2u1)

fu2(ggg) = eu2(g) \* (fu1(gg) \* au1u2 + fu2(gg) \* au2u2)

fu1(gg) = eu1(g) \* (fu1(g) \* au1u1 + fu2(g) \* au2u1)

fu2(gg) = eu2(g) \* (fu1(g) \* au1u2 + fu2(g) \* au2u2)

fu1(g) = eu1(g) \* (f0(0) \* a0u1)

fu2(g) = eu2(g) \* (f0(0) \* a0u2)

f0(0) = 1

fu1(g) = eu1(g) \* (f0(0) \* a0u1) = 1/3 \* 1 \*0.8 = 0.2667

fu2(g) = eu2(g) \* (f0(0) \* a0u2) = 1/2 \* 1 \* 0.2 = 0.1000

fu1(g) = eu1(g) \* (f0(0) \* a0u1) = 1/3 \* (0.2667 \* 0.9 + 0.1 \* 0.1) = 0.0803

fu2(g) = eu2(g) \* (f0(0) \* a0u2) = 1/2 \* (0.2667 \* 0.1 + 0.1 \* 0.9) = 0.0583

fu1(ggg) = eu1(g) \* (fu1(gg) \* au1u1 + fu2(gg) \* au2u1) = 1/3 \* (0.0803 \* 0.9 + 0.0583 \* 0.1) = 0.0260

fu2(ggg) = eu2(g) \* (fu1(gg) \* au1u2 + fu2(gg) \* au2u2) = 1/2 \* (0.0803 \* 0.1 + 0.0583 \* 0.9) = 0.0303

f(ggg) = 0.0260 + 0.0303 = 0.0563

(3)

According to Viterbi algorithm:

Possibility matrix:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 0 | g | g | g |
| 0 | 1 | 0 | 0 | 0 |
| u1 | 0 | 0.2667 | 0.08 | 0.024 |
| u2 | 0 | 0.1 | 0.045 | 0.0203 |

Back pointer matrix:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 0 | g | g | g |
| 0 | null | null | null | null |
| u1 | null | (0,0) | (1,1) | (2,1) |
| u2 | null | (0,0) | (1,2) | (2,2) |

Termination :

(3,1)

Traceback:

(3,1) -> (2,1) -> (1,1)

All the states is u1 -> u1 -> u1

Problem 4

L1 norm = 20

DTW

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 15 | 18 | 20 | 6 | 11 | 12 | 9 | 11 |
| 14 | 19 | 17 | 5 | 12 | 10 | 8 | 12 |
| 14 | 15 | 13 | 5 | 12 | 9 | 8 | 12 |
| 14 | 10 | 9 | 5 | 12 | 8 | 8 | 12 |
| 14 | 5 | 5 | 9 | 7 | 13 | 18 | 16 |
| 9 | 5 | 4 | 5 | 10 | 13 | 15 | 17 |
| 7 | 2 | 3 | 8 | 10 | 16 | 21 | 22 |
| 2 | 9 | 15 | 17 | 26 | 27 | 29 | 35 |

Problem 5

Adjacency matrix

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 1 | 0 | 1 |
| 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 |

Column stochastic matrix

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0 | 0 | 0 | 1/2 | 1/2 | 0 |
| 1/2 | 1/3 | 1 | 0 | 0 | 1/2 |
| 0 | 0 | 0 | 1/2 | 0 | 1/2 |
| 0 | 1/3 | 0 | 0 | 1/2 | 0 |
| 1/2 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1/3 | 0 | 0 | 0 | 0 |

page rank score of each node:

[0.1627, 0.3599, 0.1472, 0.1605, 0.0789, 0.1270]T