1)

a)

|  |  |  |
| --- | --- | --- |
| G  +1000 | ←  847.65 | ←  732.35 |
| W  -1000 | ↑  570.67 | ↑  634.78 |
| →  288.44 | ↑  490.95 | ↑  612.32 |

Begin by solving for the two locations adjacent to our locations of known utility:

U([2,3]) = R([2,3]) + (0.9)\*[ (0.8)\*U([1,3]) + (0.1)\*U([2,3]) + (0.1)\*U([2,2]) ]

U([2,3]) = (-1) + (0.72)\*(1000) + (0.09)\*U([2,3]) + (0.09)\*U([2,2])

U([2,3]) = (720) + (0.09)\*U([2,3]) + (0.09)\*U([2,2])

0 = (720) + (-0.91)\*U([2,3]) + (0.09)\*U([2,2])

U([2,2]) = R([2,2]) + (0.9)\*[ (0.8)\*U([2,3]) + (0.1)\*U([2,2]) + (0.1)\*U([1,2]) ]

U([2,2]) = (-1) + (0.72)\*U([2,3]) + (0.09)\*U([2,2]) + (0.09)\*(-1000)

U([2,2]) = (-90.04) + (0.72)\*U([2,3]) + (0.09)\*U([2,2])

0 = (-91) + (0.72)\*U([2,3]) + (-0.91)\*U([2,2])

2 equations, 2 unknowns, set the two equal to each other, solve for one term, substitute that solution into one of the equations to solve for the second term, use that answer to solve the first term:

(720) + (-0.91)\*U([2,3]) + (0.09)\*U([2,2]) = (-91) + (0.72)\*U([2,3]) + (-0.91)\*U([2,2])

(720) + (-0.91)\*U([2,3]) + (0.09)\*U([2,2]) + (91) - (0.72)\*U([2,3]) + (0.91)\*U([2,2]) = 0

(811) + (-1.63)\*U([2,3]) + (1)\*U([2,2]) = 0

Solve for U([2,2]):

U([2,2]) = (-811) + (1.63)\*U([2,3])

Substitute into either of the equations to solve for U([2,3]):

0 = (720) + (-0.91)\*U([2,3]) + (0.09)\*[ (-811) + (1.63)\*U([2,3]) ]

0 = (720) + (-0.91)\*U([2,3]) + (-72.99) + (0.1467)\*U([2,3])

0 = (647.01) + (-0.7633)\*U([2,3])

(0.7633)\*U([2,3]) = (647.01)

U([2,3]) = (647.01) / (0.7633)

U([2,3]) = (847.648)

With U([2,3]) known, use either of the two original equations to solve for U([2,2]):

0 = (-91) + (0.72)\*(847.648) + (-0.91)\*U([2,2])

0 = (-91) + (610.307) + (-0.91)\*U([2,2])

0 = (519.307) + (-0.91)\*U([2,2])

(0.91)\*U([2,2]) = (519.307)

U([2,2]) = (519.307) / (0.91)

U([2,2]) = (570.667)

--

Next, use the next two adjacent locations to the two we have just calculated:

U([3,3]) = R([3,3]) + (0.9)\*[ (0.8)\*U([2,3]) + (0.1)\*U([3,3]) + (0.1)\*U([3,2]) ]

U([3,3]) = (-1) + (0.72)\*(847.648) + (0.09)\*U([3,3]) + (0.09)\*U([3,2])

U([3,3]) = (609.307) + (0.09)\*U([3,3]) + (0.09)\*U([3,2])

0 = (609.307) + (-0.91)\*U([3,3]) + (0.09)\*U([3,2])

U([3,2]) = R([3,2]) + (0.9)\*[ (0.8)\*U([3,3]) + (0.1)\*U([3,2]) + (0.1)\*U([2,2]) ]

U([3,2]) = (-1) + (0.72)\*U([3,3]) + (0.09)\*U([3,2]) + (0.09)\*(570.667)

U([3,2]) = (50.3603) + (0.72)\*U([3,3]) + (0.09)\*U([3,2])

0 = (50.3603) + (0.72)\*U([3,3]) + (-0.91)\*U([3,2])

(609.307) + (-0.91)\*U([3,3]) + (0.09)\*U([3,2]) = (50.3603) + (0.72)\*U([3,3]) + (-0.91)\*U([3,2])

(609.307) + (-0.91)\*U([3,3]) + (0.09)\*U([3,2]) + (-50.3603) - (0.72)\*U([3,3]) + (0.91)\*U([3,2]) = 0

(558.9467) + (-1.63)\*U([3,3]) + (1)\*U([3,2]) = 0

Solve for U([3,3]):

(1.63)\*U([3,3]) = (558.9467) + (1)\*U([3,2])

U([3,3]) = (558.9467) + (1)\*U([3,2]) / (1.63)

Substitute into either equation:

0 = (609.307) + (-0.91)\*[ (558.9467) + (1)\*U([3,2]) / (1.63) ] + (0.09)\*U([3,2])

0 = (609.307) + [ (-508.6415) + (-0.91)\*U([3,2]) / (1.63) ] + (0.09)\*U([3,2])

0 = (993.17) + (-508.6415) + (-0.91)\*U([3,2]) + (0.1467)\*U([3,2]) / (1.63)

0 = (993.17) + (-508.6415) + (-0.91)\*U([3,2]) + (0.1467)\*U([3,2])

0 = (484.52891) + (-0.7633)\*U([3,2])

(0.7633)\*U([3,2]) = (484.52891)

U([3,2]) = (484.52891) / (0.7633)

U([3,2]) = (634.782)

0 = (50.3603) + (0.72)\*U([3,3]) + (-0.91)\*(634.782)

0 = (-527.29) + (0.72)\*U([3,3])

(0.72)\*U([3,3]) = (527.29)

U([3,3]) = (527.29) / (0.72)

U([3,3]) = (732.349)

--

U([1,1]) = R([1,1]) + (0.9)\*[ (0.8)\*U([2,1]) + (0.1)\*U([1,1]) + (0.1)\*U([1,2]) ]

U([1,1]) = (-1) + (0.72)\*U([2,1]) + (0.09)\*U([1,1]) + (0.09)\*(-1000)

U([1,1]) = (-90.04) + (0.72)\*U([2,1]) + (0.09)\*U([1,1])

0 = (-91) + (0.72)\*U([2,1]) + (-0.91)\*U([1,1])

Neither U([2,1]) or U([1,1]) is known, solve for them first:

U([2,1]) = R([2,1]) + (0.9)\*[ (0.8)\*U([2,2]) + (0.1)\*U([1,1]) + (0.1)\*U([3,1]) ]

U([2,1]) = (-1) + (0.72)\*(570.667) + (0.09)\*U([1,1]) + (0.09)\*U([3,1])

U([2,1]) = (409.88) + (0.09)\*U([1,1]) + (0.09)\*U([3,1])

0 = (409.88) + (0.09)\*U([1,1]) + (0.09)\*U([3,1]) – (1)U([2,1])

Three unknowns

U([3,1]) = R([3,1]) + (0.9)\*[ (0.8)\*U([3,2]) + (0.1)\*U([3,1]) + (0.1)\*U([2,1]) ]

U([3,1]) = (-1) + (0.72)\*(634.782) + (0.09)\*U([3,1]) + (0.09)\*U([2,1])

U([3,1]) = (457.043) + (0.09)\*U([3,1]) + (0.09)\*U([2,1])

0 = (457.043) + (-0.91)\*U([3,1]) + (0.09)\*U([2,1])

2 unknowns, no complementary equation, use these three to solve for 3 equations, 3 unknowns:

Solve for U([1,1]):

(0.91)\*U([1,1]) = (-91) + (0.72)\*U([2,1])

U([1,1]) = (-91) + (0.72)\*U([2,1]) / (0.91)

Use to eliminate U([1,1]) in the only other equation that has it:

0 = (409.88) + (0.09)\*[ (-91) + (0.72)\*U([2,1]) / (0.91) ] + (0.09)\*U([3,1]) – (1)U([2,1])

0 = (409.88) + [ (-8.19) + (0.0648)\*U([2,1]) / (0.91) ] + (0.09)\*U([3,1]) – (1)U([2,1])

0 = [ (372.99) + (-8.19) + (0.0648)\*U([2,1]) + (0.0819)\*U([3,1]) – (0.91)U([2,1]) ] / (0.91)

0 = (364.8008) + (-0.8452)\*U([2,1]) + (0.0819)\*U([3,1])

We now have 2 equations with 2 complementary unknowns:

(457.043) + (-0.91)\*U([3,1]) + (0.09)\*U([2,1]) = (364.8008) + (-0.8452)\*U([2,1]) + (0.0819)\*U([3,1])

(457.043) + (-0.91)\*U([3,1]) + (0.09)\*U([2,1]) - (364.8008) + (0.8452)\*U([2,1]) - (0.0819)\*U([3,1]) = 0

(92.2422) + (-0.9919)\*U([3,1]) + (0.9352)\*U([2,1]) = 0

Solve for U([3,1]):

(0.9919)\*U([3,1]) = (92.2422) + (0.9352)\*U([2,1])

U([3,1]) = [ (92.2422) + (0.9352)\*U([2,1]) ] / (0.9919)

Substitute into either equation:

0 = (457.043) + (-0.91)\*([ (92.2422) + (0.9352)\*U([2,1]) ] / (0.9919) ) + (0.09)\*U([2,1])

0 = (458.043) + ([ (-83.94) + (-0.851)\*U([2,1]) ] / (0.9919) ) + (0.09)\*U([2,1])

0 = [ (454.878) + (-83.81956) + (-0.851)\*U([2,1]) + (0.089)\*U([2,1]) ] / (0.9919)

0 = (374.103) + (-0.762)\*U([2,1])

(0.762)\*U([2,1]) = (374.103)

U([2,1]) = (374.103) / (0.762)

U([2,1]) = (490.949)

Use to solve:

0 = (364.8008) + (-0.8452)\*U([2,1]) + (0.0819)\*U([3,1])

0 = (364.8008) + (-0.8452)\*(490.949) + (0.0819)\*U([3,1])

0 = (-50.149) + (0.0819)\*U([3,1])

U([3,1]) = (50.149) / (0.0819)

U([3,1]) = (612.32)

And:

0 = (-91) + (0.72)\*U([2,1]) + (-0.91)\*U([1,1])

0 = (-91) + (0.72)\*(490.949) + (-0.91)\*U([1,1])

0 = (262.483) + (-0.91)\*U([1,1])

(0.91)\*U([1,1]) = (262.483)

U([1,1]) = (262.483) / (0.91)

U([1,1]) = (288.443)

b)

Temporal difference Q-learning:

α = 1

γ = 0.9

5 executions of sequence: Right, Up, Up, Left (starting from [1,1] )

**Pass 1:**

[1,1]:

Uπ([1,1]) = Uπ([1,1]) + (1)( (-1) + (0.9)\* Uπ([2,1]) - Uπ([1,1]) )

Uπ([1,1]) = 0 + (1)( (-0.04) + (0.9)\* (0) – (0) )

Uπ([1,1]) = (-1)

[2,1]:

Uπ([2,1]) = Uπ([2,1]) + (1)( (-1) + (0.9)\* Uπ([2,2]) - Uπ([2,1]) )

Uπ([2,1]) = (0) + (1)( (-0.04) + (0.9)\*(0) - (0) )

Uπ([2,1]) = (-1)

[2,2]:

Uπ([2,2]) = Uπ([2,2]) + (1)( (-1) + (0.9)\* Uπ([2,3]) - Uπ([2,2]) )

Uπ([2,2]) = (0) + (1)( (-1) + (0.9)\*(0) - (0) )

Uπ([2,2]) = 0 + (1)( (-1) + (0.9)\* (0) – (0) )

Uπ([2,2]) = (-1)

[2,3]:

Uπ([2,3]) = Uπ([2,3]) + (1)( (-1) + (0.9)\* Uπ([3,3]) - Uπ([2,3]) )

Uπ([2,3]) = (0) + (1)( (-1) + (0.9)\*(1000) - (0) )

Uπ([2,3]) = 0 + (1)( (-1) + (900) – (0) )

Uπ([2,3]) = (899)

[1,3]:

Terminal state, U([3,3]) = 1000

Uπ[1,1] = -1

Uπ[2,1] = -1

Uπ[2,2] = -1

Uπ[2,3] = 899

Uπ[1,3] = 1000

**Pass 2:**

[1,1]:

Uπ([1,1]) = Uπ([1,1]) + (1)( (-1) + (0.9)\* Uπ([2,1]) - Uπ([1,1]) )

Uπ([1,1]) = (-1) + (1)( (-1) + (0.9)\* (-1) - (-1) )

Uπ([1,1]) = -1.9

[2,1]:

Uπ([2,1]) = Uπ([2,1]) + (1)( (-1) + (0.9)\* Uπ([2,2]) - Uπ([2,1]) )

Uπ([2,1]) = (-1) + (1)( (-1) + (0.9)\* (-1) - (-1) )

Uπ([2,1]) = -1.9

[2,2]:

Uπ([2,2]) = Uπ([2,2]) + (1)( (-1) + (0.9)\* Uπ([2,3]) - Uπ([2,2]) )

Uπ([2,2]) = (-1) + (1)( (-1) + (0.9)\* (899) - (-1) )

Uπ([2,2]) = 808.1

[2,3]:

Uπ([2,3]) = Uπ([2,3]) + (1)( (-1) + (0.9)\* Uπ([3,3]) - Uπ([2,3]) )

Uπ([2,3]) = (899) + (1)( (-1) + (0.9)\* (1000) - (899) )

Uπ([2,3]) = (899)

[1,3]:

Terminal state, U([3,3]) = 1000

Uπ[1,1] = -1.9

Uπ[2,1] = -1.9

Uπ[2,2] = 808.1

Uπ[2,3] = 899

Uπ[1,3] = 1000

**Pass 3:**

[1,1]:

Uπ([1,1]) = Uπ([1,1]) + (1)( (-1) + (0.9)\* Uπ([2,1]) - Uπ([1,1]) )

Uπ([1,1]) = (-1.9) + (1)( (-1) + (0.9)\* (-1.9) - (-1.9) )

Uπ([1,1]) = -2.71

[2,1]:

Uπ([2,1]) = Uπ([2,1]) + (1)( (-1) + (0.9)\* Uπ([2,2]) - Uπ([2,1]) )

Uπ([2,1]) = (-1.9) + (1)( (-1) + (0.9)\* (808.1) - (-1.9) )

Uπ([2,1]) = 726.29

[2,2]:

Uπ([2,2]) = Uπ([2,2]) + (1)( (-1) + (0.9)\* Uπ([2,3]) - Uπ([2,2]) )

Uπ([2,2]) = (808.1) + (1)( (-1) + (0.9)\* (899) - (808.1) )

Uπ([2,2]) = 808.1

[2,3]:

Uπ([2,3]) = Uπ([2,3]) + (1)( (-1) + (0.9)\* Uπ([3,3]) - Uπ([2,3]) )

Uπ([2,3]) = (899) + (1)( (-1) + (0.9)\* (1000) - (899) )

Uπ([2,3]) = 899

[1,3]:

Terminal state, U([3,3]) = 1000

Uπ[1,1] = -2.71

Uπ[2,1] = 726.29

Uπ[2,2] = 808.1

Uπ[2,3] = 899

Uπ[1,3] = 1000

**Pass 4:**

[1,1]:

Uπ([1,1]) = Uπ([1,1]) + (1)( (-1) + (0.9)\* Uπ([2,1]) - Uπ([1,1]) )

Uπ([1,1]) = (-2.71) + (1)( (-1) + (0.9)\* (726.29) - (-2.71) )

Uπ([1,1]) = 652.661

[2,1]:

Uπ([2,1]) = Uπ([2,1]) + (1)( (-1) + (0.9)\* Uπ([2,2]) - Uπ([2,1]) )

Uπ([2,1]) = (726.29) + (1)( (-1) + (0.9)\* (808.1) - (726.29) )

Uπ([2,1]) = 726.29

[2,2]:

Uπ([2,2]) = Uπ([2,2]) + (1)( (-1) + (0.9)\* Uπ([2,3]) - Uπ([2,2]) )

Uπ([2,2]) = (808.1) + (1)( (-1) + (0.9)\* (899) - (808.1) )

Uπ([2,2]) = 808.1

[2,3]:

Uπ([2,3]) = Uπ([2,3]) + (1)( (-1) + (0.9)\* Uπ([3,3]) - Uπ([2,3]) )

Uπ([2,3]) = (899) + (1)( (-1) + (0.9)\* (1000) - (899) )

Uπ([2,3]) = 899

[1,3]:

Terminal state, U([3,3]) = 1000

Uπ[1,1] = 652.661

Uπ[2,1] = 726.29

Uπ[2,2] = 808.1

Uπ[2,3] = 899

Uπ[1,3] = 1000

**Pass 5:**

[1,1]:

Uπ([1,1]) = Uπ([1,1]) + (1)( (-1) + (0.9)\* Uπ([2,1]) - Uπ([1,1]) )

Uπ([1,1]) = (652.661) + (1)( (-1) + (0.9)\* (726.29) - (652.661) )

Uπ([1,1]) = 652.661

[2,1]:

Uπ([2,1]) = Uπ([2,1]) + (1)( (-1) + (0.9)\* Uπ([2,2]) - Uπ([2,1]) )

Uπ([2,1]) = (726.29) + (1)( (-1) + (0.9)\* (808.1) - (726.29) )

Uπ([2,1]) = 726.29

[2,2]:

Uπ([2,2]) = Uπ([2,2]) + (1)( (-1) + (0.9)\* Uπ([2,3]) - Uπ([2,2]) )

Uπ([2,2]) = (808.1) + (1)( (-1) + (0.9)\* (899) - (808.1) )

Uπ([2,2]) = 808.1

[2,3]:

Uπ([2,3]) = Uπ([2,3]) + (1)( (-1) + (0.9)\* Uπ([3,3]) - Uπ([2,3]) )

Uπ([2,3]) = (899) + (1)( (-1) + (0.9)\* (1000) - (899) )

Uπ([2,3]) = 899

[1,3]:

Terminal state, U([3,3]) = 1000

Uπ[1,1] = -0.13756

Uπ[2,1] = -0.13756

Uπ[2,2] = 809.924

Uπ[2,3] = 899.96

Uπ[1,3] = 1000

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Cell | Pass 1 | Pass 2 | Pass 3 | Pass 4 | Pass 5 |
| [1,1] | -1 | -1.9 | -2.71 | 652.66 | 652.66 |
| [2,1] | -1 | -1.9 | 726.29 | 726.29 | 726.29 |
| [2,2] | -1 | 808.1 | 808.1 | 808.1 | 808.1 |
| [2,3] | 899 | 899 | 899 | 899 | 899 |
| [3,3] | 1000 | 1000 | 1000 | 1000 | 1000 |

2)

a)

P(Class) = # times hungry/not hungry appears as the classification out of the total number of classifications:

P(Class = hungry) = 600/1000 = 0.6

P(Class = not hungry) = 400/1000 = 0.4

b)

m = “the wumpus is not hungry”

**bigrams:**

the wumpus

wumpus is

is not

not hungry

By Bayes rule:

P(Class = hungry | Message = m) = P(Message = m | Class = hungry) / P(Class = hungry)

= P(P(wumpus|the) | class = hungry \* P(is|wumpus) | class = hungry \* P(not|is) | class = hungry \* P(hungry|not) | class = hungry ) / P(Class = hungry)

P(wumpus|the) = 300/1000 = 0.3

P(is|wumpus) = 90/1000 = 0.09

P(not|is) = 60/1000 = 0.06

P(hungry|not) = 100/1000 = 0.1

0.3 \* 0.09 \* 0.06 \* 0.1 = 0.000162

P(message = m | class = hungry) = 0.000162

P(class = hungry) = 0.6

0.000162 / 0.6 = 0.00027

P(class = hungry | message = m) = 0.00027

c)

P(Class = not hungry | Message = m) = P(Message = m | Class = not hungry) / P(Class = not hungry)

= P(P(wumpus|the) | class = not hungry \* P(is|wumpus) | class = not hungry \* P(not|is) | class = not hungry \* P(hungry|not) | class = not hungry ) / P(Class = not hungry)

P(wumpus|the) = 150/1000 = 0.15

P(is|wumpus) = 40/1000 = 0.04

P(not|is) = 60/1000 = 0.06

P(hungry|not) = 200/1000 = 0.2

0.15 \* 0.04 \* 0.06 \* 0.2 = 0.000072

P(message = m | class = not hungry ) = 0.000072

P(class = not hungry) = 0.4

0.000072 / 0.4 = 0.00018

P(class = not hungry | message = m) = 0.00018

d)

P(class = hungry | message = m) = 0.00027 > P(class = not hungry | message = m) = 0.00018

The more likely class, given this corpus, is the classification is “not hungry” for message m.

2)

a)

S

/ \

NP VP

/ | / |

article noun verb adjective

| | | |

“the agent is alive”

b)

S

/ \

/ VP

/ / | X X X

NP VP | NP | NP

/ | | | / | | / |

article noun verb adverb article noun conjunction article noun

| | | | | | | | |

“the agent is near the wumpus and the gold”

Sentence cannot be parsed, it is not consistent with (accepted) by the grammar.

c)

S

/ \

/ VP

/ / \

/ VP PP

/ / \ / \

NP VP NP / NP

/ | | / | / / \

article noun verb article noun preposition digit digit

| | | | | | | |

“the agent shoots the wumpus in 1 3”

and:

S S

/ | / \

/ | / VP

/ | / \

/ | / PP

/ | / / \

NP VP NP / NP

/ | | / | / / \

article noun verb article noun preposition digit digit

| | | | | | | |

“the agent shoots the wumpus in 1 3”

d)

S

/

NP \

/ \ \

/ RelativeClause VP

/ / | / \

NP / VP VP \

/ | / | | \

article noun relativePronoun verb verb adjective

| | | | | |

“the wumpus who stinks is dead”

4)

input sequence: [C2, C3, C3, C4, C5, C6, C7]

V1, onset = P(C2|onset)P(onset)

= (0.5)(1.0) = 0.5

V1, mid = P(C2|mid) = 0

V1, end = P(C2|end) = 0

V1, final = 0

-

V2, onset = P(C3|onset)max{[P(onset|onset)V1, onset], 0,0,0}

= (0.3)[(0.6)(0.5)] = 0.09

V2, mid = P(C3|mid)max{[P(mid|onset)V1, onset, P(mid|mid)V1, mid, 0,0]}

= (0.3){[(0.4)(0.5)], [(0.5)(0)]} = {0.06, 0}

V2, end = P(C3|end) = 0

V2, final = 0

-

V3, onset = P(C3|onset)max{[P(onset|onset)V2, onset, 0, 0, 0]}

= (0.3)[(0.6)(0.09)] = 0.0162

V3, mid = P(C3|mid)max {[P(mid|onset)V2, onset, P(mid|mid)V2, mid], 0, 0}

= (0.3){[(0.4)(0.09)], [(0.5)(0.06)]} = {0.0108, 0.009}

V3, end = P(C3|end) = 0

V3, final = 0

-

V4, onset = P(C4|onset) = 0

V4, mid = P(C4|mid)max{[P(mid|onset)V3, onset, P(mid|mid)V3, mid], 0, 0}

= (0.3){[(0.4)(0.0162)], [(0.5)(0.0108)]} = {0.00243, 0.00162}

V4, end = P(C4|end)max{[P(end|mid)V3, mid, P(end|end)V3, end], 0}

= (0){[()()], [()()]} {0, 0}

V4, final = 0

-

V5, onset = P(C5|onset) = 0

V5, mid = P(C5|mid)max{[P(mid|onset)V4, onset, P(mid|mid)V4, mid], 0,0}

= (0.4){[(0.4)(0)], [(0.5)(0.00243)]} = {0, 0.000486}

V5, end = P(C5|end)max{[P([end|mid]V4, mid), P(end|end)V4, end, 0}

= (0.2){[(0.5)(0.00243)], [(0.3)(0)]} = {0.000243, 0}

V5, final = 0

-

V6, onset = P(C6|onset) = 0

V6, mid = P(C6|mid) = 0

V6, end = P(C6|end)max{[P(end|mid)V5, mid, P(end|end)V5, end], 0}

= (0.4){[(0.5)(0.000486)], [(0.3)(0.000243)]} = {0.0000972, 0.00002916}

V6, final = 0

-

V7, onset = P(C7|onset) = 0

V7, mid = P(C7|mid) = 0

V7, end = P(C7|end)max{[P(end|mid)V6, mid, P(end|end)V6, end], 0}

= (0.4){[(0.5)(0)], [(0.3)(0.0000972)]} = {0, 0.000011664}

V7, final = 0

P(final|end)V7, end

= (0.7)(0.000011664)

= 0.0000081648

= 8.16 x 10-6

P(HMM) = 8.16 x 10-6

Most probable path:

Onset, onset, onset, mid, mid, end, end, final