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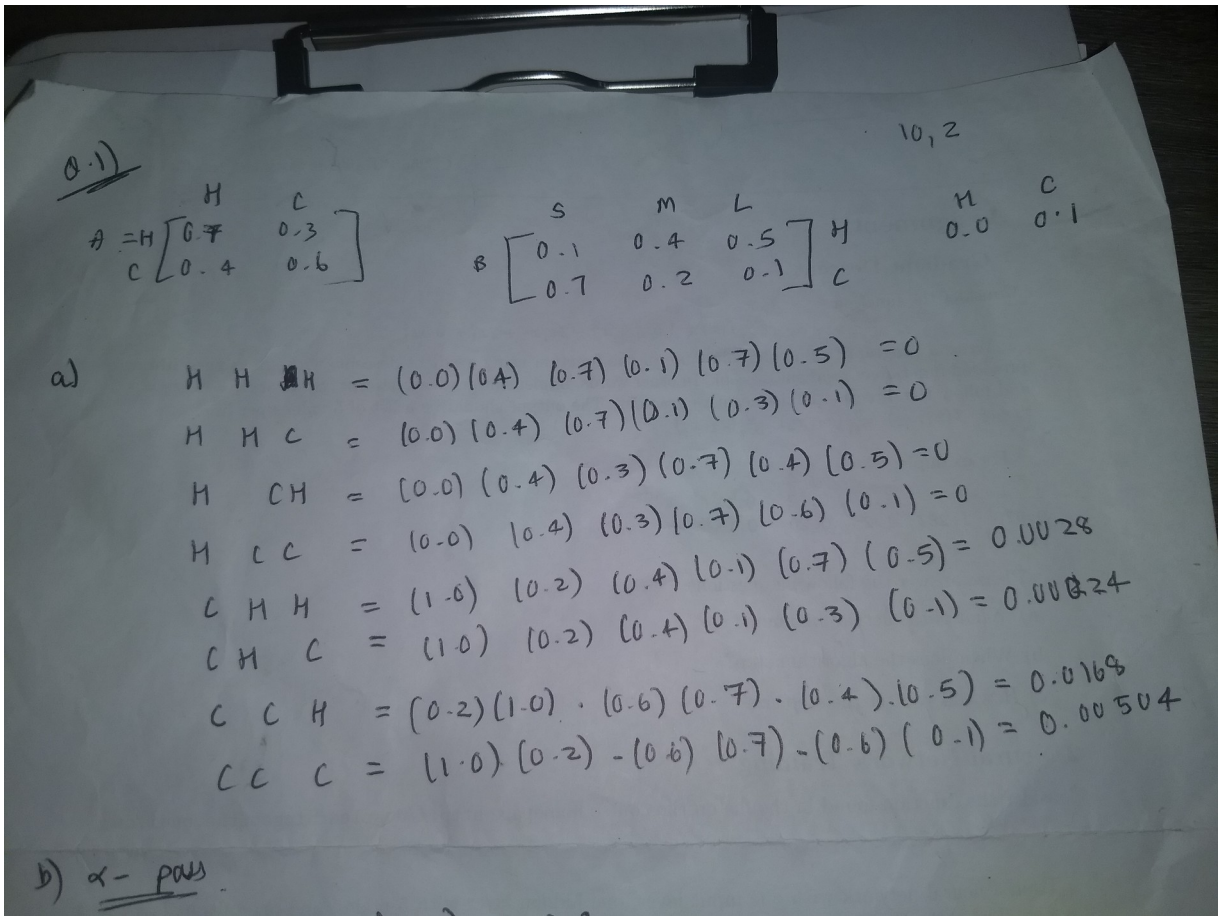
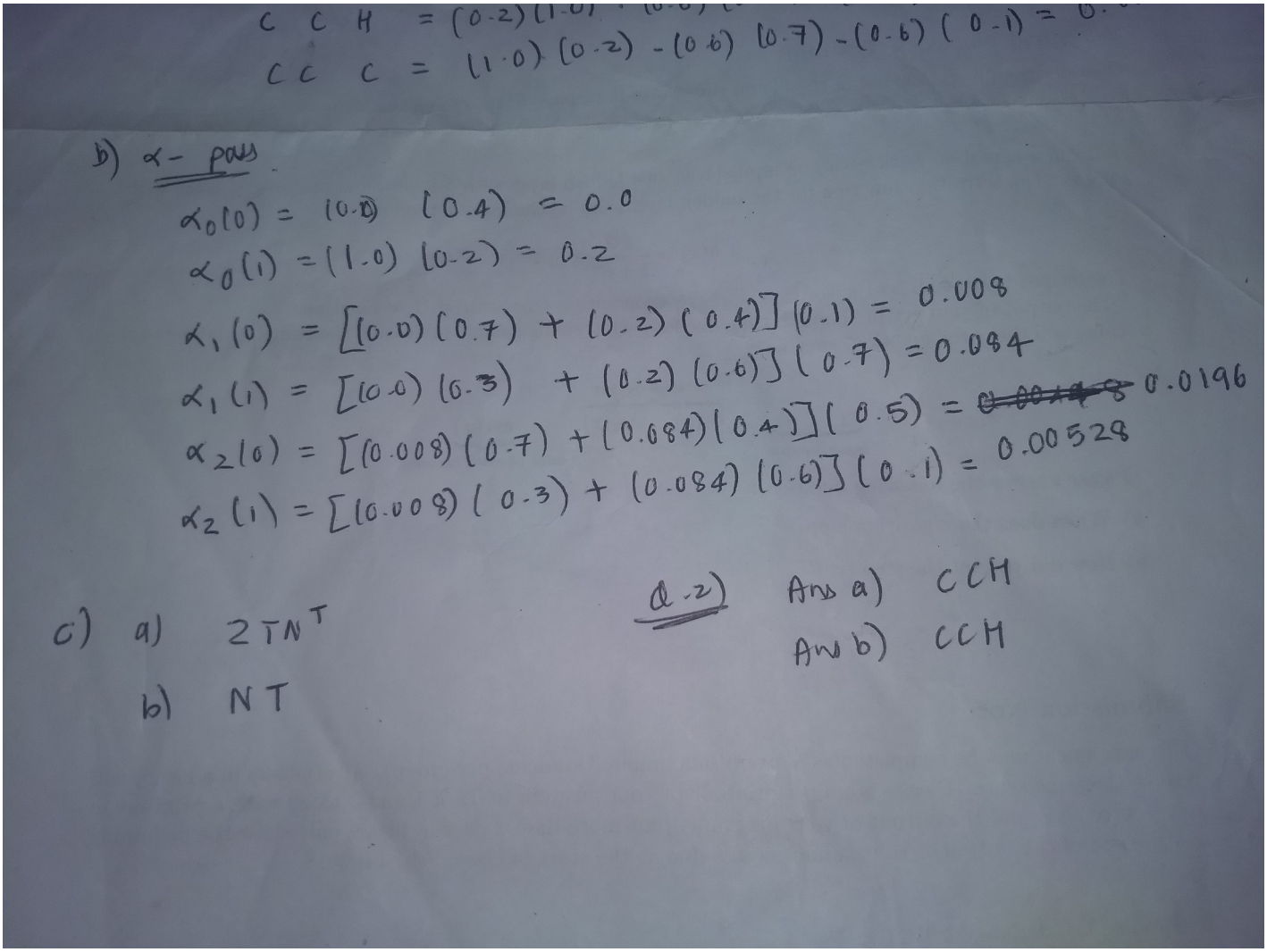
Assignment 1

Answer 1:

a)



b), c)



Answer 2)
a) CCH
b) CCH

Answer 10

a) When N = 2 hidden states

After 200 iterations, the State 1 starts detecting for vowels, and also State 0, we can see that values for vowels is much lower than the consonants (of the order of 10^-17).

```
Initial Matrix
[1. 0.]
1.0
Transition Matrix
[[8.15854252e-06 9.99991841e-01]
 [5.58873217e-01 4.41126783e-01]]
Observation Matrix
[[-3.56533688e-17  1.42004295e-01]
 [ 5.95757591e-02  3.44340975e-04]
 [ 2.81452479e-02  6.76201881e-03]
 [ 7.57731219e-03  3.32241528e-02]
 [-3.36216172e-17  1.60670877e-01]
 [ 2.81384266e-02  6.76584234e-03]
 [ 9.60502147e-03  5.95435344e-03]
 [ 1.52964434e-01  2.63965321e-04]
 [-3.44955118e-17  6.73379667e-02]
 [ 1.31828923e-02  2.15546399e-04]
 [-3.57717272e-17  2.25381696e-02]
 [ 4.62523594e-02  4.14123044e-02]
 [ 3.97789522e-02  2.41021925e-04]
 [ 1.26239002e-01  3.11006793e-04]
 [ 1.49834524e-02  6.64059809e-02]
 [ 2.86019341e-02  6.50603417e-03]
 [-4.11193713e-17  1.38270979e-04]
 [ 6.64148651e-02  2.44158828e-04]
 [ 1.37101784e-01  5.02218781e-02]
 [ 1.80286849e-02  9.45655796e-02]
 [-3.54614370e-17  1.88048531e-02]
 [ 1.99213910e-02  1.71757333e-04]
 [ 4.32320961e-02  5.77207696e-03]
 [ 1.99020646e-02  1.82590262e-04]
 [ 1.92862350e-03  1.77238090e-02]
 [ 6.59078065e-03  1.77281732e-04]
 [ 1.31834916e-01  2.51039867e-01]]

Process finished with exit code 0
```

b) **When n = 3, the HMM may be is looking for combinations of alphabets with each other.**

```
Transition Matrix
[[3.16007906e-03 1.46449005e-01 8.50390916e-01]
 [3.97634220e-13 6.22411105e-01 3.77588895e-01]
 [7.63440904e-01 7.03771997e-06 2.36552058e-01]]

 Checking Row Stochastic Properties for Matrix A :
[1. 1. 1.]

Observation Matrix
[[1.14829849e-001 2.29051592e-001 3.04818509e-002]
 [4.80805442e-002 1.05708122e-025 8.05315861e-003]
 [6.09730636e-027 1.60822922e-002 2.48304581e-002]
 [5.57993752e-002 6.70725444e-071 7.13687906e-003]
 [1.78622251e-013 9.02451975e-015 2.13535464e-001]
 [1.19312958e-014 4.10508225e-002 1.71217653e-002]
 [1.95493823e-002 3.08158335e-065 3.37828941e-030]
 [1.49878598e-001 1.30715700e-027 2.03506526e-021]
 [5.69822142e-003 1.11640720e-014 8.50445457e-002]
 [1.30329215e-002 4.74268342e-136 1.62027039e-100]
 [3.90987646e-002 4.87089368e-066 1.56610082e-060]
 [5.90534829e-018 2.89525158e-001 3.03311911e-020]
 [3.90987646e-002 5.03514266e-051 4.99394941e-037]
 [1.94047001e-002 2.01872203e-056 8.45312540e-002]
 [7.50820257e-002 2.50784638e-002 3.43590989e-002]
 [1.74175183e-002 5.35163224e-002 1.51510638e-013]
 [0.00000000e+000 0.00000000e+000 0.00000000e+000]
 [3.74311625e-002 8.27980982e-014 2.11345787e-002]
 [1.48673955e-001 9.48251322e-002 2.62673981e-002]
 [2.45260325e-002 3.47146716e-012 1.20356014e-001]
 [5.23125825e-045 8.04236549e-002 1.24297011e-031]
 [1.95493823e-002 2.04419685e-057 1.75566762e-085]
 [1.91418124e-002 5.97214544e-002 6.70211489e-003]
 [1.95493823e-002 1.69602859e-220 1.90508546e-097]
 [2.67364690e-156 8.04236549e-002 9.38747647e-036]
 [1.38815940e-179 1.60847310e-002 7.63731841e-283]
 [1.34157608e-001 1.42167215e-002 3.20445420e-001]]

 Checking Row Stochastic Properties for Matrix B :
[1. 1. 1.]

Process finished with exit code 0
```

c) When n = 4, the HMM may be is looking for formation of words.

```
Initial Matrix
[0. 0. 0. 1.]

 Checking Row Stochastic Properties for Initial Matrix (Pi) :
1.0

Transition Matrix
[[1.32004743e-01 4.02869496e-02 5.70219600e-01 2.57488707e-01]
 [3.49572003e-04 1.26558680e-02 1.16114106e-02 9.75383149e-01]
 [2.54866132e-14 8.52290253e-01 1.47709745e-01 1.99470908e-09]
 [6.76716571e-01 4.88187967e-02 2.74464633e-01 2.76771695e-10]]

 Checking Row Stochastic Properties for Matrix A :
[1. 1. 1. 1.]

Observation Matrix
[[1.14312612e-001 1.03644852e-029 1.64686628e-014 2.24516220e-001]
 [5.39361654e-112 2.07936018e-002 8.77677077e-118 5.72219518e-002]
 [5.15435312e-002 3.77233241e-028 6.83532440e-045 9.53994067e-003]
 [6.31650572e-059 1.05764042e-002 7.73526767e-002 8.16411807e-003]
 [1.76442058e-001 9.14718091e-012 2.56639495e-001 1.50759005e-027]
 [2.34591838e-002 1.56268068e-017 1.75877929e-002 1.63505118e-002]
 [3.02106712e-099 3.44156816e-144 9.30529454e-003 1.68152135e-002]
 [9.60748829e-002 1.69463834e-002 9.82334154e-009 1.01323174e-001]
 [7.91668075e-002 1.44768811e-029 1.48928407e-025 8.69961235e-002]
 [1.33184362e-220 5.35288017e-288 1.05543004e-242 1.64707734e-002]
 [4.73616387e-085 1.27353772e-139 4.83652394e-002 8.39830189e-003]
 [1.21783864e-001 2.22328874e-020 2.10707156e-002 3.61608753e-002]
 [1.67322717e-031 2.54344628e-047 4.63482660e-002 1.01087077e-002]
 [1.16911273e-001 3.03500382e-055 7.72597066e-002 8.75231773e-003]
 [1.22631398e-001 5.09342762e-003 2.45801827e-002 4.48611420e-002]
 [1.25199805e-002 7.51792658e-008 9.50889204e-003 3.16636157e-002]
 [0.00000000e+000 0.00000000e+000 0.00000000e+000 0.00000000e+000]
 [4.90019113e-002 2.91282815e-077 4.23674573e-002 8.51973859e-003]
 [1.46034012e-002 1.75349354e-002 2.46647326e-001 4.52994077e-002]
 [6.01787289e-006 2.31745316e-046 6.60052957e-002 1.74613279e-001]
 [1.08970894e-002 2.70557889e-002 3.31835382e-038 1.07622281e-002]
 [4.85833819e-020 1.24776770e-103 2.57129927e-022 2.47061601e-002]
 [2.61754484e-056 1.67948398e-077 8.40429944e-003 5.87561964e-002]
 [4.93465069e-061 3.04044736e-002 7.83711421e-068 1.19362831e-081]
 [1.72842646e-026 7.52230799e-090 4.85573506e-002 3.74130538e-009]
 [1.06459889e-002 4.78572115e-025 1.00234516e-013 1.34796203e-031]
 [1.48691155e-021 8.71594910e-001 4.43825904e-019 9.59021509e-067]]

 Checking Row Stochastic Properties for Matrix B :
[1. 1. 1. 1.]

Process finished with exit code 0
```

d) When n = 27, the HMM should look for each character. But the result is not as expected.

```
Observation Matrix
[[0.00000000e+000 5.74675932e-106 0.00000000e+000 0.00000000e+000
  0.00000000e+000 6.68474759e-171 5.95434596e-191 0.00000000e+000
  0.00000000e+000 0.00000000e+000 1.34065964e-212 1.59835655e-222
  0.00000000e+000 3.69629515e-155 3.58210511e-001 0.00000000e+000
  0.00000000e+000 0.00000000e+000 7.59412581e-001 0.00000000e+000
  0.00000000e+000 0.00000000e+000 0.00000000e+000 2.21937041e-198
  4.45053769e-083 1.89908267e-232 4.72973111e-001]
 [0.00000000e+000 0.00000000e+000 2.43454487e-105 4.99999993e-001
  0.00000000e+000 0.00000000e+000 0.00000000e+000 0.00000000e+000
  0.00000000e+000 1.10962871e-001 3.02983841e-123 0.00000000e+000
  0.00000000e+000 0.00000000e+000 0.00000000e+000 0.00000000e+000
  0.00000000e+000 0.00000000e+000 8.45362093e-083 0.00000000e+000
  0.00000000e+000 0.00000000e+000 0.00000000e+000 0.00000000e+000
  0.00000000e+000 0.00000000e+000 0.00000000e+000]
 [0.00000000e+000 0.00000000e+000 9.95506488e-296 0.00000000e+000
  0.00000000e+000 0.00000000e+000 0.00000000e+000 0.00000000e+000
  0.00000000e+000 0.00000000e+000 0.00000000e+000 0.00000000e+000
  0.00000000e+000 0.00000000e+000 0.00000000e+000 4.16666667e-001
  0.00000000e+000 0.00000000e+000 3.32794615e-002 0.00000000e+000
  0.00000000e+000 0.00000000e+000 0.00000000e+000 4.35373070e-073
  0.00000000e+000 0.00000000e+000 0.00000000e+000]
 [0.00000000e+000 0.00000000e+000 0.00000000e+000 0.00000000e+000
  0.00000000e+000 3.65565782e-066 7.59558833e-294 0.00000000e+000
  2.26153089e-233 1.84938118e-002 0.00000000e+000 5.83488871e-071
  0.00000000e+000 6.65145165e-002 0.00000000e+000 0.00000000e+000
  2.57863068e-115 0.00000000e+000 0.00000000e+000 0.00000000e+000
  0.00000000e+000 4.71498592e-001 0.00000000e+000 0.00000000e+000
  0.00000000e+000 0.00000000e+000 0.00000000e+000]
 [0.00000000e+000 4.88938885e-001 0.00000000e+000 0.00000000e+000
  0.00000000e+000 1.00000000e+000 3.69287019e-163 0.00000000e+000
  6.28748695e-021 0.00000000e+000 0.00000000e+000 1.00000000e+000
  9.42761690e-116 8.11274781e-210 2.50034727e-094 0.00000000e+000
  0.00000000e+000 0.00000000e+000 0.00000000e+000 7.49999418e-001
  0.00000000e+000 2.48653940e-029 3.60340634e-009 2.52876253e-108
  9.77827593e-049 0.00000000e+000 5.91259018e-006]
 [1.17887706e-001 0.00000000e+000 0.00000000e+000 0.00000000e+000
  0.00000000e+000 0.00000000e+000 0.00000000e+000 0.00000000e+000
  0.00000000e+000 0.00000000e+000 0.00000000e+000 0.00000000e+000
  0.00000000e+000 0.00000000e+000 1.21142629e-047 1.66666667e-001
  0.00000000e+000 0.00000000e+000 6.65589230e-002 0.00000000e+000
```