Assignment 1

Problem - 2.1:

a).

P(O, X=HHH) = (0.0).(0.4).(0.7).(0.1).(0.7).(0.5) = 0.0

P(O, X= HHC) = (0.0).(0.4).(0.7).(0.1).(0.3).(0.1) = 0.0

P(O, X = HCH) = (0.0).(0.4).(0.3).(0.7).(0.4).(0.5) = 0.0

P(O, X = HCC) = (0.0).(0.4).(0.3).(0.7).(0.6).(0.1) = 0.0

P(O, X= CHC) = (1.0).(0.2).(0.4).(0.1).(0.3).(0.1) = 0.00024

P(O, X = CHH) = (1.0).(0.2).(0.4).(0.1).(0.7).(0.5) = 0.0028

P(O, X = CCH) = (1.0).(0.2).(0.6).(0.7).(0.4).(0.5) = 0.0168

P(O, X = CCC) = (1.0).(0.2).(0.6).(0.7).(0.6).(0.1) = 0.00504

Final = 0.0+0.0+0.0+0.0+0.00024+0.0028+0.0168+0.00504=0.02488

b). Considering state 0 as H, state 1 as C, Computing P(o|λ)

= 0.0*0.4=0.0
=1.0*0.2=0.2
=[(0.0*0.7)+(0.2*0.4)]*0.1=0.008
=[(0.0.0.3)+(0.2.0.6)]*0.7=0.084
=[(0.008*0.7)+(0.084*0.4)]*0.5=0.0196
=[(0.008*0.3)+(0084*0.6)]*0.1=0.00528
=0.0196+0.00528=0.02488

c). work factor for the method in part a) – For Direct Computation, O(N^T.T) -> Exponential
For Example T=3 Observations, N=2 Hidden States
then number of hidden paths =2^3*3=24 path evaluations
To multiply 6 numbers, we need 5 multiplication steps = 8*5=40 Multiplications (N^T×(2T−1) multiplications)

work factor for the method in part b) – For Forward algorithm, O(N^2*T) -> Polynomial
2^2*3=12 multiplications

Problem - 2.3:

a) observation sequence $\mathcal{O}$ = ($\mathcal{O}$0, $\mathcal{O}$1, $\mathcal{O}$2, $\mathcal{O}$3), where $\mathcal{O}i$ ∈ {0, 1, 2}. Verify that $\sum P(\mathcal{O} \mid \lambda) = 1$, the sum is over the observation sequences of length four

I wrote a Python program to calculate the probability and included the code in the assignment folder. I started by setting up the A, B, and π matrices with the given values. Then, using itertools, I

generated all possible observation sequences of length 4 along with their state transitions. The program outputs the probability for each sequence, and when I add them all together, the total comes out to 1.

Below are 81 observation sequences of length 4:

for (0, 0, 0, 0) observation sequence is 0.02840236

for (0, 0, 0, 1) observation sequence is 0.01835428

for (0, 0, 0, 2) observation sequence is 0.01744736

for (0, 0, 1, 0) observation sequence is 0.0146524

for (0, 0, 1, 1) observation sequence is 0.0131824

for (0, 0, 1, 2) observation sequence is 0.0138572

for (0, 0, 2, 0) observation sequence is 0.01260644

for (0, 0, 2, 1) observation sequence is 0.01300292

for (0, 0, 2, 2) observation sequence is 0.01409464

for (0, 1, 0, 0) observation sequence is 0.0147616

for (0, 1, 0, 1) observation sequence is 0.0099688

for (0, 1, 0, 2) observation sequence is 0.0096296

for (0, 1, 1, 0) observation sequence is 0.0102496

for (0, 1, 1, 1) observation sequence is 0.0101728

for (0, 1, 1, 2) observation sequence is 0.0109376

for (0, 1, 2, 0) observation sequence is 0.0099968

for (0, 1, 2, 1) observation sequence is 0.0110024

for (0, 1, 2, 2) observation sequence is 0.0120808

for (0, 2, 0, 0) observation sequence is 0.01274924

for (0, 2, 0, 1) observation sequence is 0.00880052

for (0, 2, 0, 2) observation sequence is 0.00856624

for (0, 2, 1, 0) observation sequence is 0.010022

for (0, 2, 1, 1) observation sequence is 0.0102608

for (0, 2, 1, 2) observation sequence is 0.0111052

for (0, 2, 2, 0) observation sequence is 0.01016356

for (0, 2, 2, 1) observation sequence is 0.01138708

for (0, 2, 2, 2) observation sequence is 0.01254536

for (1, 0, 0, 0) observation sequence is 0.0194936

for (1, 0, 0, 1) observation sequence is 0.0126728

for (1, 0, 0, 2) observation sequence is 0.0120736

for (1, 0, 1, 0) observation sequence is 0.01052

for (1, 0, 1, 1) observation sequence is 0.009632

for (1, 0, 1, 2) observation sequence is 0.010168

for (1, 0, 2, 0) observation sequence is 0.0092584

for (1, 0, 2, 1) observation sequence is 0.0096712

for (1, 0, 2, 2) observation sequence is 0.0105104

for (1, 1, 0, 0) observation sequence is 0.0142016

for (1, 1, 0, 1) observation sequence is 0.0097568

for (1, 1, 0, 2) observation sequence is 0.0094816

for (1, 1, 1, 0) observation sequence is 0.01088

for (1, 1, 1, 1) observation sequence is 0.011072

for (1, 1, 1, 2) observation sequence is 0.011968

for (1, 1, 2, 0) observation sequence is 0.0109504

for (1, 1, 2, 1) observation sequence is 0.0122272

for (1, 1, 2, 2) observation sequence is 0.0134624

for (1, 2, 0, 0) observation sequence is 0.0140728

for (1, 2, 0, 1) observation sequence is 0.0098344

for (1, 2, 0, 2) observation sequence is 0.0096128

for (1, 2, 1, 0) observation sequence is 0.0118

for (1, 2, 1, 1) observation sequence is 0.012256

for (1, 2, 1, 2) observation sequence is 0.013304

for (1, 2, 2, 0) observation sequence is 0.0121832

for (1, 2, 2, 1) observation sequence is 0.0137576

for (1, 2, 2, 2) observation sequence is 0.0151792

for (2, 0, 0, 0) observation sequence is 0.01893724

for (2, 0, 0, 1) observation sequence is 0.01233652

for (2, 0, 0, 2) observation sequence is 0.01176224

for (2, 0, 1, 0) observation sequence is 0.0103756

for (2, 0, 1, 1) observation sequence is 0.0095536

for (2, 0, 1, 2) observation sequence is 0.0100988

for (2, 0, 2, 0) observation sequence is 0.00919796

for (2, 0, 2, 1) observation sequence is 0.00964628

for (2, 0, 2, 2) observation sequence is 0.01049176

for (2, 1, 0, 0) observation sequence is 0.0151648

for (2, 1, 0, 1) observation sequence is 0.0104584

for (2, 1, 0, 2) observation sequence is 0.0101768

for (2, 1, 1, 0) observation sequence is 0.0118624

for (2, 1, 1, 1) observation sequence is 0.0121312

for (2, 1, 1, 2) observation sequence is 0.0131264

for (2, 1, 2, 0) observation sequence is 0.0120128

for (2, 1, 2, 1) observation sequence is 0.0134504

for (2, 1, 2, 2) observation sequence is 0.0148168

for (2, 2, 0, 0) observation sequence is 0.01546076

for (2, 2, 0, 1) observation sequence is 0.01082948

for (2, 2, 0, 2) observation sequence is 0.01059376

for (2, 2, 1, 0) observation sequence is 0.013118

for (2, 2, 1, 1) observation sequence is 0.0136592

for (2, 2, 1, 2) observation sequence is 0.0148348

for (2, 2, 2, 0) observation sequence is 0.01358644

for (2, 2, 2, 1) observation sequence is 0.01536292

for (2, 2, 2, 2) observation sequence is 0.01695464

Sum of all the above probabilities are equals to $0.9999999999999997 \approx 1.0$

By executing the code snippet provided in the folder, it gives above output. Hence is verified

b). Using Forward algorithm:

I wrote a Python program to calculate the probability and included the code in the assignment folder. I started by setting up the A, B, and π matrices with the given values. Then, using itertools, I generated all possible observation sequences of length 4 along with their state transitions. The program outputs the probability for each sequence, and when I add them all together, the total comes out to 1.

Observation sequence (0, 0, 0, 0), Probability is 0.028409

Observation sequence (0, 0, 0, 1), Probability is 0.01836

Observation sequence (0, 0, 0, 2), Probability is 0.01745

Observation sequence (0, 0, 1, 0), Probability is 0.01465

Observation sequence (0, 0, 1, 1), Probability is 0.01318

Observation sequence (0, 0, 1, 2), Probability is 0.013859

Observation sequence (0, 0, 2, 0), Probability is 0.0126

Observation sequence (0, 0, 2, 1), Probability is 0.01300

Observation sequence (0, 0, 2, 2), Probability is 0.01409

Observation sequence (0, 1, 0, 0), Probability is 0.01477

Observation sequence (0, 1, 0, 1), Probability is 0.00997

Observation sequence (0, 1, 0, 2), Probability is 0.00963

Observation sequence (0, 1, 1, 0), Probability is 0.01025

Observation sequence (0, 1, 1, 1), Probability is 0.01017

Observation sequence (0, 1, 1, 2), Probability is 0.01094

Observation sequence (0, 1, 2, 0), Probability is 0.009989

Observation sequence (0, 1, 2, 1), Probability is 0.011

Observation sequence (0, 1, 2, 2), Probability is 0.0120799

Observation sequence (0, 2, 0, 0), Probability is 0.012750

Observation sequence (0, 2, 0, 1), Probability is 0.0088

Observation sequence (0, 2, 0, 2), Probability is 0.00856

Observation sequence (0, 2, 1, 0), Probability is 0.010020

Observation sequence (0, 2, 1, 1), Probability is 0.01026

Observation sequence (0, 2, 1, 2), Probability is 0.01111

Observation sequence (0, 2, 2, 0), Probability is 0.010159

Observation sequence (0, 2, 2, 1), Probability is 0.01139

Observation sequence (0, 2, 2, 2), Probability is 0.012549

Observation sequence (1, 0, 0, 0), Probability is 0.019489

Observation sequence (1, 0, 0, 1), Probability is 0.01267

Observation sequence (1, 0, 0, 2), Probability is 0.01207

Observation sequence (1, 0, 1, 0), Probability is 0.01052

Observation sequence (1, 0, 1, 1), Probability is 0.00964

Observation sequence (1, 0, 1, 2), Probability is 0.01017

Observation sequence (1, 0, 2, 0), Probability is 0.00925

Observation sequence (1, 0, 2, 1), Probability is 0.00967

Observation sequence (1, 0, 2, 2), Probability is 0.01051

Observation sequence (1, 1, 0, 0), Probability is 0.0142

Observation sequence (1, 1, 0, 1), Probability is 0.00976

Observation sequence (1, 1, 0, 2), Probability is 0.009479

Observation sequence (1, 1, 1, 0), Probability is 0.010879

Observation sequence (1, 1, 1, 1), Probability is 0.011080

Observation sequence (1, 1, 1, 2), Probability is 0.01197

Observation sequence (1, 1, 2, 0), Probability is 0.0109500

Observation sequence (1, 1, 2, 1), Probability is 0.01223

Observation sequence (1, 1, 2, 2), Probability is 0.01346

Observation sequence (1, 2, 0, 0), Probability is 0.0140700

Observation sequence (1, 2, 0, 1), Probability is 0.00983

Observation sequence (1, 2, 0, 2), Probability is 0.00962

Observation sequence (1, 2, 1, 0), Probability is 0.0118

Observation sequence (1, 2, 1, 1), Probability is 0.01226

Observation sequence (1, 2, 1, 2), Probability is 0.0133

Observation sequence (1, 2, 2, 0), Probability is 0.01218

Observation sequence (1, 2, 2, 1), Probability is 0.01376

Observation sequence (1, 2, 2, 2), Probability is 0.01519

Observation sequence (2, 0, 0, 0), Probability is 0.01893

Observation sequence (2, 0, 0, 1), Probability is 0.01234

Observation sequence (2, 0, 0, 2), Probability is 0.01176

Observation sequence (2, 0, 1, 0), Probability is 0.01037

Observation sequence (2, 0, 1, 1), Probability is 0.00956

Observation sequence (2, 0, 1, 2), Probability is 0.0101

Observation sequence (2, 0, 2, 0), Probability is 0.0092

Observation sequence (2, 0, 2, 1), Probability is 0.00964999

Observation sequence (2, 0, 2, 2), Probability is 0.01049

Observation sequence (2, 1, 0, 0), Probability is 0.01517000

Observation sequence (2, 1, 0, 1), Probability is 0.01046

Observation sequence (2, 1, 0, 2), Probability is 0.01017

Observation sequence (2, 1, 1, 0), Probability is 0.01185999

Observation sequence (2, 1, 1, 1), Probability is 0.01213

Observation sequence (2, 1, 1, 2), Probability is 0.01312

Observation sequence (2, 1, 2, 0), Probability is 0.01202

Observation sequence (2, 1, 2, 1), Probability is 0.01345

Observation sequence (2, 1, 2, 2), Probability is 0.01482

Observation sequence (2, 2, 0, 0), Probability is 0.01546

Observation sequence (2, 2, 0, 1), Probability is 0.01083

Observation sequence (2, 2, 0, 2), Probability is 0.0106

Observation sequence (2, 2, 1, 0), Probability is 0.01312

Observation sequence (2, 2, 1, 1), Probability is 0.01366

Observation sequence (2, 2, 1, 2), Probability is 0.01483

Observation sequence (2, 2, 2, 0), Probability is 0.013579

Observation sequence (2, 2, 2, 1), Probability is 0.0153599

Observation sequence (2, 2, 2, 2), Probability is 0.01695

Final sum is $0.9999907800000002 \approx 1.0$

Problem – 2.10

a). Choose $N = 2$ hidden states. What do the hidden states represent?

a. How did Mr. Beato determine that the "new artist" referred to in the title of the video was AI-generated?

Beato used Logic Pro, which is an Apple version of AI track splitter. With old songs recorded in studio, it should be able to split out the vocals, guitars, drums and keyboards. If it's an AI generated tune, it should have a problem doing this and we will hear a ton of artifacts in different parts. We can hear some artifacts in the reverbs that show song that was recorded on analog tapes 55 years ago. If you have an AI song, they are full of artifacts. It's trained on low quality MP3s where they feed in entire mix. So, it can't separate out the parts.

b. What could be done to make it more difficult to detect AI generated music?

They need multitrack recordings so they can hear the voices and instruments. Even if you have multitrack, you don't have the effects that were used in the mix unless they were printed in the session, which is possible. But for old songs, this is not the case, you can hear how the system really struggles to separate out the guitar parts, and the keyboard parts. Some vocal parts have a little weird artifact in them, but guitars and keyboards are separated poorly.