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Investigating the Importance of Psychological and Environmental Factors for Improving Learner's Performance Using Hidden Markov Model

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ABSTRACT In the proposed work, hidden Markov model (HMM) has been deployed to improve the learner's performance or grades on the basis of their psychological and environmental factors like connect/gather isolation, pleasure/comfort, depression, trust, anxiety, proper guidance, improper guidance, entertainment, and stress. The categorization of psychological and environmental factors has been done on the basis of two factors as positive and negative. The responsibility of the positive factor is to boost up learner's performance or grades, whereas negative factors reduce learning performance respectively. Finally, this paper addresses the application of HMM to determine the optimal sequence of states for different states as grades A, B, and C for different emission observations. The states identification leads to training the HMM model where optimal value of individual states computed using different observation sequences which determines the probability of state sequences. The probability of achieved optimal states is shown in different logical combinations where best state is searched among available different states using different search techniques. The computational results obtained after training are encouraging and useful.

INDEX TERMS Hidden Markov model, psychological, environmental, negative, positive, validation.

I. INTRODUCTION

E-learning, a term introduced in 1999 during CBT system seminar is a way to learn and access emerging technologies through online interface and provides interactive or personalized training with the help of electronic media and widgets [19], [42]. Lara *et al.* [33] demonstrated that E-learning is one of the means to use internet by learners to learn specific information and content in personalized manner. In the recent years, many researchers are working on certain e-learning based problems [2], [3], [31]. The prime intent of e-learning is to deliver rigorous dynamic content to learners based on their preferences, learning abilities, skills and interests etc. also known as adaptive learning [37], [49]. Variety of multifarious researchers focused their work on personalized content delivery and different attributes or learner's characteristics such as: trust, motivation, comfort, background knowledge etc., but researchers concluded that these demographic factors not only responsible for improving the learning capability and performance of learners. There are different important factors like: psychological (P) such as: isolation, depression, anxiety and environmental (E) factors

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such as: stress and improper guidance also played crucial role in enhancing capability of learner [1], [4], [5], [10], [21] but till now none of any researcher utilized such factors in improving the learner capability of learner.

The Psychological and Environmental factors have been categorized into positive and negative factors. Positive factors are responsible for improving or boost up the learner's performance and negative factors reduces the ability of learner. If the consequences obtained through usage of negative factors will not be diagnosed at initial stages then learner's performance get affected. If in initial stages of learning complimentary positive factors have been provided to mitigate the effects of negative factors then overall performance of learner could be improved to great extent.

Thus, in current proposed work we have considered Hidden Markov Model (HMM) for improvement in learner's performance with consideration of these psychological and environmental factors and their complimentary factors vice versa. The HMM differentiated other models as it focuses mainly on prior probabilities (generative approach) whereas Artificial Neural Network (ANN) and supervised classifier Support Vector Machine (SVM) utilizes posterior probability distribution (discriminative approach) [29], [32], [35], [38].

To evaluate the effectiveness of the proposed approach the following research hypothesis has been proposed as: "If the students learning performance is degraded by psychological negative factor and environmental negative factor then their learning capability can be improved by imparting psychological and environmental positive factors to them".

For validating the proposed hypothesis, our work focuses on following aims or objectives to meet the desired criteria:

1. Identification of psychological and environmental factors and their impact observed on proposed Hidden Markov Model for enhancement in learner's performance.
2. Deployment of Hidden Markov Model for improvement of learner's performance.
3. Mapping of individual negative Psychological and Environmental factors with their complimentary factors to determine optimal state sequence.

The remainder work of paper comprised of various sections which are outlined as follows related to e-learning systems. Section 2 emphasized on detailing related works. Section 3 discussed about complimentary positive and negative psychological and environmental factors. Section 4 focused on involvement of HMM system, training, data collection and methodology for e-learning system. Section 5 detailed on results, accuracy of proposed model and experimental validation work. Finally, concluded the work in Section 6.

II. RELATED WORKS

Variety of emerging applications like virtual e-learning content system, augmented reality education, recognition of personalized sound involved variety of personalized and adaptive statistical and machine learning techniques for prediction of future aspects of these applications [18], [20], [24], [32]. Due to mathematical foundation of statistical and probabilistic techniques they are gaining attention among e-learners community [12], [13], [15], [16]. Earlier works reported on the cognitive driven strategies adopted by human agents or tutors for teaching students in various interdisciplinary domains. Hidden Markov model focuses on prior probabilistic approach where hidden states being represented over observed sequence values. Birney [6] utilized Markov chain process for capturing the activity of students while interacted with mathematical expert and tutoring system and record their learning path sequences. Jiyong *et al.* [28] observed behavior of students in teacher centric learning environment where different hidden variables have been considered for activity recognition related to state sequences. Tseng *et al.* [48] preferred clustering and hidden variable approach on solving queries reported by students in design-oriented problem-solving sessions and discover the effectiveness of sharing knowledge and interactions performed with other peer learners. Boyer *et al.* [8] applied HMM to identify tutorial strategies described in the sequence analysis of dialogs proposed for different learning acts. They demonstrated how HMM can be learned tutoring system of computer science. Similarly, Boyer *et al.* [9] focus on meta cognitive analysis and feedback received from correct tutorial strategy to be followed by tutor which improves student self-efficacy and corrective actions. Boyer *et al.* [7] tried to establish full duplex mode communication between tutor and learning and identified correlations between mode and outcome achieved. Sun *et al.* [47] utilized type-2 fuzzy HMM model for identification of text sequence using granular driven learning. Li *et al.* [34] constructed HMM detectors for multivariate time series anomaly detection. They have compared obtained results with fuzzy C-means and integral clustering techniques. Dang *et al.* [14] proposed HMM framework for learning efficient brain regions connectivity based on fMRI signal. (Yang and Jiang [53] proposed HMM based effective solution for initialization problems based on temporal data clustering techniques. The proposed algorithm automatically determines agglomerative clusters and outperforms other benchmark techniques. Nikdelfaz and Jalili [36] proposed HMM driven semantic similarity identification technique between various genes using gene ontology and K-means. Samanta *et al.* [43] proposed HMM based handwritten word segmentation script based on gaussian mixture model. The proposed HMM based classifier also used for recognition of Bangla and English handwritten words. The effective candidate gene was predicted by HMM model. Saini *et al.* [41] utilized global and segmentation driven HMM method to classify the trajectory using genetic algorithm. Yang *et al.* [52] proposed high order dynamic prediction of financial trading strategies using Hidden Markov Models. Fuzzy expert system is used to design hierarchical software usability model [54], [55] to foresee live auction portal [56], [57] and software development life cycle models [58]. Live auction and SDLC datasets has been

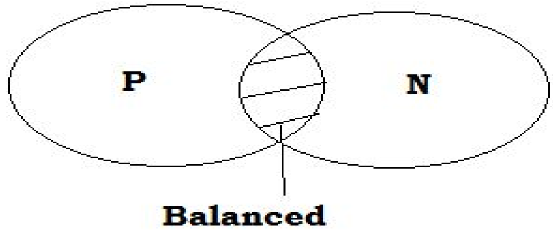

FIGURE 1. Psychological and Environmental Set (Positve & Negative factors).

discoursed in [59]. The prediction of disease can be synchronized [60] and uniquely identified [61]. The literature review conducted is summarized into Tabular format which is categorized using different techniques, their specific features and applications.

III. PSYCHOLOGICAL AND ENVIRONMENTAL SETS

Psychological factors comprised of Positive (P) and Negative (N) factors as shown in Fig. 1.

1. N is set of negative factors i.e. $N = \{X_i: X_i$ is a negative factor$\}$
2. P is set of positive factors i.e. $P = \{Y_i: Y_i$ is a positive factor$\}$
3. $P \cap N$: X: $\langle X_i, Y_i \rangle$ where $X_i \epsilon$ P, $Y_i \epsilon$ N and X_i is complimentary factor of Y_i

The learning capability of student having all personality psychological factor lying in N (LC_N) is less than the learning capability of student lying in $P \cap N$ ($LC_{P\cap N}$). The learning capability of ($LC_{P\cap N}$) is less than learning capability of the student in P (LC_P) as shown in equation 1.

$$LC_N < LC_{P\cap N} < LC_P \tag{1}$$

Therefore, from equation 1 it is clear that, If the student personality-psychological factor lying in N then by counseling (or by imparting any positive factor belongs to P) the performance of the student can reach to balanced level i.e. $P \cap N$. In this region ($P \cap N$) we only provide the positive factor which is complimentary to the negative factors with which students are suffering. Further when student reached at balanced level, we provide some more positive factors belongs to P to enhance the student performance.

Similarly, Environmental factors also comprised of Positive (PE) and Negative (NE) factors as shown in Fig. 1.

NE is set of negative factors i.e. $NE = \{X_k: X_k$ is a negative factor$\}$.

PE is set of positive factors i.e. $PE = \{Y_k: Y_k$ is a positive factor$\}$.

$PE \cap NE$: X: $\langle X_k, Y_k \rangle$ where $X_k \epsilon$ PE, $Y_k \epsilon$ NE and X_k is complimentary factor of $Y_{k,}$

X_k is complimentary factor of Y_k if the negative effect of X_k attribute is neutralized or reduced by the positive effect of $Y_{k.}$

The learning capability of student having all environmental factor lying in NE (LC_{NE}) is less than the learning capability of student lying in $PE \cap NE$ ($LC_{PE\cap NE}$). The learning capability of ($LC_{PE\cap NE}$) is less than learning capability of the student in PE (LC_{PE}) as shown in equation 2.

$$LC_{NE} < LC_{PE\cap NE} < LC_{PE} \tag{2}$$

Therefore, from equation 2 it is clear that, if the student environmental factor lying in NE then by counseling (or by imparting any positive factor belongs to PE) the performance of the student can reach to balanced level i.e. $PE \cap NE$. In this region ($PE \cap NE$) we only provide the positive factor which is complimentary to the negative factors with which students are suffering. Further when student reached at balanced level, we provide some more positive factors belong to PE to enhance the student performance.

We have considered pairs of complimentary negative and positive attributes for improving learner's performance. The Positive Psychological factors are Connect/Gather(C/G), Pleasure/Comfort(P/C) and Trust (T) and the corresponding complementary negative Psychological factors are Isolation (I), Depression (D) and Anxiety (A) respectively. The pairs formation will be <C/G, I>, <E, S> etc. Similarly, the Positive Environmental factors are Proper Guidance (PG) and Entertainment (E) NEF are their complementary factors such as Improper Guidance (IG) and Stress(S) respectively.

IV. HIDDEN MARKOV MODEL

A. DATA COLLECTION

The subject of this study included 40 students of under graduate school pursuing three-year courses in Northern India. The data collected will be represented in terms of Positive and Negative factors as demonstrated in previous section. The data was collected using survey containing 30 MCQ based questions, out of which five questions for each factor. The answer of MCQ comprised of negative and positive factor and the participant will select either of positive or negative. In this study the HMM consists of four grades A, B, C and D. Each state represents the year of the degree i.e. 12^{th} or previous degree, 1^{st}, 2^{nd} and 3^{rd} year respectively. In each year the set of factors varies for each participant i.e. factor set of each participant is temporal. We used same questionnaire to collect the data at each state. The partial dataset collected from 10 students is shown in Table 2. For ease of computation, we have considered only observation sequence length of 6 factors in HMM model which may increase depending upon the requirement.

Hidden Markov Model (HMM) is also known as dynamic Bayesian network which demonstrated Markov chain process with involvement of hidden states or variable through statistical analysis. Markov model output depends only on state itself but in HMM it focuses on probability of state represented as distinguished output. The transitions from one state to another stated is determined by transition probabilities and from one state to observations is called emission probabilities. The states captured through hidden variables are hidden; hence it is called Hidden Markov Model [48], [50], [51].

TABLE 1. Comparative view of HMM and other techniques.

Authors	Methods or Technique	Specific features	Application areas
Chen et al. [15]	HMM	Adaptive content delivery of learning materials according to requirement	English Language learning system
Huang et al. [25]	Bi-Weighted HMM	Computation of learning oath consistency and predict future learning action of learners	Java Programming system
Hsia, Shie, and Chan [27]	Mining techniques	Prediction of future learning predicted paths of learners for continuing education and preferences.	Foreign language learning system
Norwawi et al. [37]	Decision tree and K-means clustering	Improvement in learners programming skills using VARK style and recommend suitable learning object	Web based system
Hassan and Nath [22]	Adaptive HMM	Identification and forecasting of stock prices	Business Analytics
Cooper et al. [11]	Multimedia and Logistic methods	Modeling of learners learning trajectory through usage of multimedia usages and prediction of their future action and performance.	Multimedia based systems
Birney [6]	Hidden Markov Model	Semi structured sequence identification of plants for prediction of DNA and RNA protein coding.	Genetic systems
Homsi et al. [23]	HMM	Adaptive English language web based system used for navigation and prediction of successive concepts visited by students.	English language learning system
Hsieh et al. [27]	Genetic Algorithms and HMM	Suitable learning object has been referred and improved learning path is generated based on their skills and preference.	Web based system
Yang et al. [52]	Multi criteria decision making approach	Multi-Dimensional Personalization Criteria System (AMDPC) focuses on demographic students attributes using Silverman and cognitive traits	Adaptive web based system
Seters et al. [44]	ANN, HMM and Decision tree	Measure motivation and prior knowledge of learners and predict next path for learner on basis of their characteristics or features	Programming language system
Wang and Liao [49]	Data mining	Predict the student performance based on gender, anxiety and personality level	English language system

TABLE 1. Comparative view of HMM and other techniques.

Gilbert and Han [17]	Case based reasoning	New learner assigned to group depending on prior learning experience and preferences provided with personalized material	Web based system
Pandey et al. [30]	Case based Reasoning	Delivery of personalized and adaptive dynamic content of learner based on their characteristics and preferences.	C Programming system
Sun et al. [47]	Fuzzy and HMM	To fuse labeled data and unlabeled observation HMM utilized to fulfill granular information in sequence recognition.	Text sequence recognition
Li et al. [34]	HMM	Multivariate time series prediction performed using HMM detectors.	Anomaly detection
Dang et al. [17]	HMM and CNN	Brain MRI signals utilized to identify activity recognition and connectivity taken inside brain.	Signal processing and Human Computer Interaction.
Yang and Jiang [53]	HMM	Utilized initialization problems for data clustering.	Clustering
Nikdelfaz and Jalili [36]	HMM and Ontology	HMM driven semantic similarity identification technique used for genes identification.	Similarity keyword identification
Samanta et al. [43]	HMM	Handwritten word segmentation script based on gaussian mixture model. The proposed HMM based classifier also used for recognition of Bangla and English handwritten words	Handwritten word recognition
Saini et al. [41]	HMM and Genetic algorithm	Global and segmentation driven HMM method to classify the trajectory using genetic algorithm.	Trajectory classification
Wang et al. [52]	HMM	High order dynamic prediction of financial trading strategies using Hidden Markov Models	Stock market prediction

HMM consists of three parameters as: HMM $\lambda = (A\ B\ \pi)$ where A = Transition matrix, $a_{ij} = P$ (state S_j at t + 1 | state q_i at t); B = N * M Emission matrix where N = number of states in model and M = number of observation symbols.

$b_j(k) = P$(observation k at t| state q_j at t) where A and B are row stochastic in the sense that sum of elements in a row is one and π = initial states.

HMM addresses three fundamental problems as:

- Given the model and observation sequences, $b_t = b_{01}\ b_{02}b_{03}\ldots\ldots\ b_{ON}$, the objective is to determine $P(O|\lambda)$ efficiently i.e. the probability of the observation sequences for the given model λ.
- To determine the optimal sequences of states for given model, λ and observation sequences, O_i. This is solved efficiently by Viterbi algorithm.
- Estimation: It is to get the maximum $P(O|\lambda)$ by estimating the parameters of model λ. This is solved by Baum-Welch Algorithm.

B. HMM TRAINING

OPTIMAL VALUE OF STATE

For a generic state sequence of length n, the state equation is given by (3):

$$X = (x_0 x_1 x_2 x_3 \ldots\ldots\ldots x_{n-1} x_n) \tag{3}$$

TABLE 2. Partial Data set description.

Students	<C/G, I>	<P/C, D>	<T, A>	<PG, IG>	<E, S>
S1	C/G	D	T	PG	S
S2	I	P/C	A	IG	F
S3	I	D	T	PG	S
S4	C/G	P/C	T	PG	F
S5	C/G	P/C	A	IG	F
S6	C/G	P/C	A	IG	S
S7	I	D	A	PG	S
S8	C/G	D	T	IG	F
S9	I	D	T	PG	S
S10	C/G	P/C	A	IG	F

And corresponding observation of length m is given by (4):

$$O = (o_0 o_1 o_2 o_3 \ldots\ldots . o_{m-1} o_m) \quad (4)$$

The probability of state sequence X is given by

$$P(X) = \pi x_0 b x_0(o_0) a x_{0,} x_1 b x_1(o_1) a x_1 x_2 \; b x_2(o_2) a x_2 x_3 b x_3(o_3) \ldots . a x_{n-1} x_{n-2} b x_n(o_n) \quad (5)$$

For three states and six observations, we have A as 3*3 and B_1(positive) as 3*5 matrix and B_2 (negative) as 3*5 matrix respectively. The initial state is a vector 1*3. The matrix A, B1, B2 and initial state vector is represented as:

A=

	A	B	C
A	0.6	0.3	0.1
B	0.5	0.3	0.2
C	0.5	0.4	0.1

B_1 =

	C	P	T	PG	E
A	0.1	0.2	0.3	0.1	0.3
B	0.2	0.1	0.3	0.2	0.2
C	0.3	0.1	0.1	0.3	0.3

B_2=

	I	D	A	IG	S
A	0.2	0.2	0.2	0.3	0.1
B	0.2	0.3	0.2	0.1	0.2
C	0.2	0.2	0.3	0.2	0.1

Π_0 = [0.4 0.3 0.2]

We take three states in form of grades as A, B and C. Similarly, five observations [2 6 8 4 3] for different emission probabilities as 2 = pleasure, 3 = Trust, 4 = Proper guidance, 8 = Anxiety, and 6 = Isolation respectively that logically produces 243 combinations as shown in Table 3. We calculate the probabilities of optimal states as shown in line of the different logical combinations.

C. PROPOSED ALGORITHM

As shown in Table 3 A, B and C represent different states in form of grades which are obtained by student respectively [62]–[65]. The numerical value in the even columns i.e. product of states corresponding to their respective logical combinations in odd column is calculated by (3). For example in Table 1, the various values in numerical form in the first row of columns 2, 4, 6, 8, 10 as 0.000012441, 0.000003456, 0.00000162, 0.000000864 and 0.00000144 respectively correspond to the logical combinations, given in the same row in the columns 1, 3, 5, 7, 9 as AAAAA, ABCBA, BABCA, BCBAA and CBABA.

Table 4 shows the sum of A (grades) states, where A is in the first, second, third, fourth and fifth places in Table 3. Similarly, the second row shows the sum of B in the increasing order of places in Table 3. From each of the column we select the highest value which is 0.0001461 in the first place in first column corresponding to observation (2) i.e. pleasure out of given observations. Similarly, for second observation (6) i.e. Isolation the highest value is 0.00013105 as shown in second column. The detailed description of Table 4 is given below.

V. RESULTS COMPUTATION

The order of probability of occurrence of a particular state depends on the observation of a particular set of emissions in a time sequence. In our case, the observation [2 6 8 4 3] is for the time sequence, starting from t_0 as present and t_1, t_2, t_3, t_4, t_5 for the consecutive past times, corresponding to observation 2 6 8 4 3 respectively. Table 2 is obtained by the calculation of the sum of probabilities, when the states A, B and C are in the first, second, third, fourth and fifth positions in the 243 logical combinations of states as shown in Table 1. The interpretation of Table 4 is as follows:

For the 2 as P (Pleasure) observation at time t_1 the value of state P(A) is 0.0001461, for state B it is 0.000054854 and for the state C it is 0.000036717 in the first column of Table 4. It means that state A is more active than the state B and C. Similarly, it is observed that for the observations at other consecutive past time sequences i.e. Working at time t_2 for 6 as I (Isolation), P(A):0.00013105 > P(B):0.000077539 > P(C):0.000029082; for 8 as A (Anxiety) P(A):0.00011799 > P(B):0.000075354 > P(C):0.000044323; P(B):0.00009179 > P(A):0.000085686 > P(C):0.000060194 for observation instance 4 as PG (Proper guidance); for instance 3 as T (Trust) P(A):0.00014029 > P(B):0.000085113 > P (C): 0.000012271.

We obtain the optimal sequence of states AAABA for the observation sequence [2 6 8 4 3] i.e. P I A PG T taking into account the greater value from each column of Table 4.

The computation of product of states for the observation sequence (2 6 8 4 3) and the states logical combination AAABA is done in following steps:

Step 1: The initial value for state A is taken as πx_0 is 0.4 and bx_0 (o_0) and its value from the emission table B_1 in the first row for A is P (0.2) and their product is 0.08.

Algorithm 1

```
1.  Start
2.  Read number of states, numstate from user.
3.  Read number of observations, numobs from user
4.  Read state symbols, vec[1, numstate] from user.
5.  Read initial probability of states, p[1, numstate] from user
6.  for l = 1 to numstate
7.     Read positive emission matrix, emis_pos [l,:] from the user for lth state
8.     Read negative emission matrix, emis_neg[l,:] from the user for lth state
9.  end for
10. for l = 1 to numstate
11.        Read transition matrix, trans[l,:] from user
12. end for
13. Totalposs = numstate^numobs
14. D = totalposs/numstate
15. Create state combination table using following algo
16.   for k = 1 to numobs
17.   q = 1, z = 1
18.       for l = 1 to totalposs
19.               if(z <= d)
20.                   a(l,k) = vec(1,q);
21.                   z = z + 1
22.                   if(z == d + 1)
23.                        q = q + 1
24.                        z = 1
25.                   end if
26.                   if(q == (numstate + 1))
27.                        q = 1
28.                   end if
29.               end if
30.       end for
31.   d = d/numstate
32. end for
33. Read observation sequence, veco[1,numobs] from user
34. repeat 35 to 60 for all state combinations
35.           initial_bit_test = 0
36.           previous_state = 1
37.           product_of_state = 1
38.              for k = 1 to numobs
39.                   t = a(l,k)
40.              Repeat 41 to 60 for all State Symbols
41.              Read position of state symbol in vec matrix,pos
42.                if( initial_bit_test == 0)
43.                       if(veco(1,k) < ((numobs)) + 1)
44.                          product_of_state = product_of_state* (p(1,pos)*EMIS(pos,veco(1,k)));
45.                       else
46.                          hg = veco(1,k)-(numobs)
47.                          product_of_state = product_of_state * (p(1,pos)*((EMIS1(pos,hg))))
48.                       end if
49.                    initial_test = 1
50.                    previous_state = pos
51.               else
52.                 if(veco(1,k) < ((numobs)) + 1)
53.                     product_of_state = product_of_state*(TRANS(prevstate,pos)*EMIS(pos,veco(1,k)))
54.                else
55.                     hg = veco(1,k)-(numobs)
```

Algorithm 1 *(Continued.)*

```
56.                    product_of_state = product_of_state*(TRANS(prevstate,pos)*((EMIS1(pos,hg))))
57.                end if
58.                    previous_state = pos
59.              end if
60. end for
61. repeat 62 to 69 for all states
62.   for l = 1 to totalposs
63.    for s = 1 to numobs
64.      if(statecombination(l,s) == vec[1,1]
65.          sumofbitswise_of_state(i)[1,s] == product_of_state
66.        end if
67.     end for
68.   end for
69. i = 1 + 1
70. repeat 71 and 72 for all bits of observations
71. find maximum of ith bit from sumofbitswise_of_state of all states
72.   beststate[1,i] = state with maximum bit sum
73. search beststate among state combinations using any search technique
74.   find corresponding product of state
75. End
```

Step 2: Write the transition from state A to A from the state transition matrix A which is 0.6 and the value of observation variable from the matrix B_2 as I (0.2) and their product is 0.12.

Step 3: Repeat the step 2 to obtain the transitions A-A, A-B and B-A as 0.6, 0.3 and 0.5 respectively to obtain the product of logical combination of states A A A B A as 0.000010368 as shown in Table 3.

A. EMPIRICAL EXPERIMENT VALIDATION

The demographic study has been performed on learners of sample size 40 to check the feasibility and effectiveness of opted HMM system. The categorization of distinguished learners performed into experimental group (G1) and control group (G2) where each comprised of 20 learners. In addition to test and verify the homogeneity between the control group and the experimental group, both groups took a pre-test in which both learners group solved the same type of questionnaire for assessment at individual level. Based on the grades scored by learners, their Mean (M) and Standard deviation (SD) have been computed. The pre-test results showed that M and SD of the experimental group (G1) was 35.40, 7.06 respectively. For the control group (G2), M was 36.71 and SD was 8.75. The obtained t- test result deprived that there was no significant difference ($t = -0.521$, $df = 38$, $p\text{-value} = 0.605$) among two different learner's groups as depicted in Fig. 5.

To evaluate student performance after learning programming course, student from both groups were compared in the post-test. In post-test, the experimental group adopted the HMM based system whereas control group preferred Non-HMM based system [39], [40], [45], [46]. In HMM based system, an observation had been captured from student and replace negative factors from observations by providing its complimentary factors to move for next better state. Whereas in Non-HMM system, an observation had been captured but it will not change the negative factors from observations and move to next state.

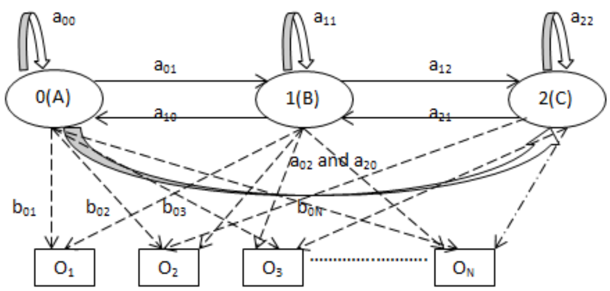

FIGURE 2. Proposed HMM Model.

If Student in state 1 (q1) is having grade variable C and capture observation [P_1, P_2, P_3, E_1, E_2, E_3] from student which comprised of three psychological and three environmental factors. Factor P_1 and P_2 are +ve except P_3 which is −ve, Similarly factor E_1 and E_2 are +ve except E_3 as shown in Fig. 3.

In HMM model we provide observation sequence $O_1 = [P_1(+), P_2(+), P_3(+), E_1(+), E_2(+), E_3(-)]$ which is obtained by replacing P_3 by its complimentary positive (P_3+) which cause to move to a next better state q2 i.e. CB. Similarly, at state (q2) student captures new observation in which all psychological factors are +ve and only E_3 is −ve. So In HMM again observation sequence $O_2 = [P_1(+), P_2(+), P_3(+), E_1(+), E_2(+), E_3(+)]$ is provided which is obtained by replacing E_3 by its complimentary negative

TABLE 3. States computation.

Logical Combination	Product of states	Logical Combination	Product of states	Logical Combination	Product of states	Logical Combination	Product of states	Logical Combination	Product of states
AAAAA	0.000012441	ABCBA	0.000003456	BABCA	0.00000162	BCBAA	0.000000864	CBABA	0.00000144
AAAAB	0.00000622	ABCBB	0.000002073	BABCB	0.000001296	BCBAB	0.000000432	CBABB	0.000000864
AAAAC	0.000000691	ABCBC	0.00000046	BABCC	0.000000108	BCBAC	0.000000048	CBABC	0.000000192
AAABA	**0.000010368**	ABCCA	0.000001296	BACAA	0.00000081	BCBBA	0.000000864	CBACA	0.00000072
AAABB	0.00000622	ABCCB	0.000001036	BACAB	0.000000405	BCBBB	0.000000518	CBACB	0.000000576
AAABC	0.000001382	ABCCC	0.000000086	BACAC	0.000000045	BCBBC	0.000000115	CBACC	0.000000048
AAACA	0.000005184	ACAAA	0.000001728	BACBA	0.00000108	BCBCA	0.000000864	CBBAA	0.000000864
AAACB	0.000004147	ACAAB	0.000000864	BACBB	0.000000648	BCBCB	0.000000691	CBBAB	0.000000432
AAACC	0.000000345	ACAAC	9.6E-08	BACBC	0.000000144	BCBCC	0.000000057	CBBAC	0.000000048
AABAA	0.000005184	ACABA	0.00000144	BACCA	0.000000405	BCCAA	0.000000324	CBBBA	0.000000864
AABAB	0.000002592	ACABB	0.000000864	BACCB	0.000000324	BCCAB	0.000000162	CBBBB	0.000000518
AABAC	0.000000288	ACABC	0.000000192	BACCC	0.000000027	BCCAC	0.000000018	CBBBC	0.000000115
AABBA	0.000005184	ACACA	0.00000072	BBAAA	0.000001944	BCCBA	0.000000432	CBBCA	0.000000864
AABBB	0.00000311	ACACB	0.000000576	BBAAB	0.000000972	BCCBB	0.000000259	CBBCB	0.000000691
AABBC	0.000000691	ACACC	0.000000048	BBAAC	0.000000108	BCCBC	0.000000057	CBBCC	0.000000057
AABCA	0.000005184	ACBAA	0.000001152	BBABA	0.00000162	BCCCA	0.000000162	CBCAA	0.000000864
AABCB	0.000004147	ACBAB	0.000000576	BBABB	0.000000972	BCCCB	0.000000129	CBCAB	0.000000432
AABCC	0.000000345	ACBAC	6.4E-08	BBABC	0.000000216	BCCCC	0.00000001	CBCAC	0.000000048
AACAA	0.000002592	ACBBA	0.000001152	BBACA	0.00000081	CAAAA	0.000002592	CBCBA	0.000001152
AACAB	0.000001296	ACBBB	0.000000691	BBACB	0.000000648	CAAAB	0.000001296	CBCBB	0.000000691
AACAC	0.000000144	ACBBC	0.000000153	BBACC	0.000000054	CAAAC	0.000000144	CBCBC	0.000000153
AACBA	0.000003456	ACBCA	0.000001152	BBBAA	0.000000972	CAABA	0.00000216	CBCCA	0.000000432
AACBB	0.000002073	ACBCB	9.216E-07	BBBAB	0.000000486	CAABB	0.000001296	CBCCB	0.000000345
AACBC	0.00000046	ACBCC	7.68E-08	BBBAC	0.000000054	CAABC	0.000000288	CBCCC	0.000000028
AACCA	0.000001296	ACCAA	0.000000432	BBBBA	0.000000972	CAACA	0.00000108	CCAAA	0.000000432
AACCB	0.000001036	ACCAB	0.000000216	BBBBB	0.000000583	CAACB	0.000000864	CCAAB	0.000000216
AACCC	0.000000086	ACCAC	0.000000024	BBBBC	0.000000129	CAACC	0.000000072	CCAAC	0.000000024
ABAAA	0.000005184	ACCBA	0.000000576	BBBCA	0.000000972	CABAA	0.00000108	CCABA	0.00000036
ABAAB	0.000002592	ACCBB	0.000000345	BBBCB	0.000000777	CABAB	0.00000054	CCABB	0.000000216
ABAAC	0.000000288	ACCBC	7.68E-08	BBBCC	0.000000064	CABAC	0.00000006	CCABC	0.000000048
ABABA	0.00000432	ACCCA	0.000000216	BBCAA	0.000000972	CABBA	0.00000108	CCACA	0.00000018
ABABB	0.000002592	ACCCB	0.000000172	BBCAB	0.000000486	CABBB	0.000000648	CCACB	0.000000144
ABABC	0.000000576	ACCCC	0.000000014	BBCAC	0.000000054	CABBC	0.000000144	CCACC	0.000000012
ABACA	0.00000216	BAAAA	0.000003888	BBCBA	0.000001296	CABCA	0.00000108	CCBAA	0.000000288
ABACB	0.000001728	BAAAB	0.000001944	BBCBB	0.000000777	CABCB	0.000000864	CCBAB	0.000000144
ABACC	0.000000144	BAAAC	0.000000216	BBCBC	0.000000172	CABCC	0.000000072	CCBAC	0.000000016
ABBAA	0.000002592	BAABA	0.00000324	BBCCA	0.000000486	CACAA	0.00000054	CCBBA	0.000000288
ABBAB	0.000001296	BAABB	0.000001944	BBCCB	0.000000388	CACAB	0.00000027	CCBBB	0.000000172
ABBAC	0.000000144	BAABC	0.000000432	BBCCC	0.000000032	CACAC	0.00000003	CCBBC	0.000000038
ABBBA	0.000002592	BAACA	0.00000162	BCAAA	0.000001296	CACBA	0.00000072	CCBCA	0.000000288
ABBBB	0.000001555	BAACB	0.000001296	BCAAB	0.000000648	CACBB	0.000000432	CCBCB	0.00000023
ABBBC	0.000000345	BAACC	0.000000108	BCAAC	0.000000072	CACBC	9.6E-08	CCBCC	0.000000019
ABBCA	0.000002592	BABAA	0.00000162	BCABA	0.00000108	CACCA	0.00000027	CCCAA	0.000000108
ABBCB	0.000002073	BABAB	0.00000081	BCABB	0.000000648	CACCB	0.000000216	CCCAB	0.000000054
ABBCC	0.000000172	BABAC	0.00000009	BCABC	0.000000144	CACCC	0.000000018	CCCAC	0.000000006
ABCAA	0.000002592	BABBA	0.00000162	BCACA	0.00000054	CBAAA	0.000001728	CCCBA	0.000000144
ABCAB	0.000001296	BABBB	0.000000972	BCACB	0.000000432	CBAAB	0.000000864	CCCBB	8.64E-08
ABCAC	0.000000144	BABBC	0.000000216	BCACC	0.000000036	CBAAC	9.6E-08	CCCBC	0.000000019
CCCCA	0.000000054	CCCCB	0.000000043	CCCCC	0.000000003				

TABLE 4. Sum of states.

	1	2	3	4	5
A	**0.0001461**	**0.00013105**	**0.00011799**	0.000085686	**0.00014029**
B	0.000054854	0.000077539	0.000075354	**0.00009179**	0.000085113
C	0.000036717	0.000029082	0.000044323	0.000060194	0.000012271

(E_3+) which cause it to move to a next better state q3 i.e. CBA. Similarly, the process has been carried out for next state.

If Student in state 1 (q1) is having grade variable C and capture observation [P_1, P_2, P_3, E_1, E_2, E_3] from student which comprised of three psychological and three

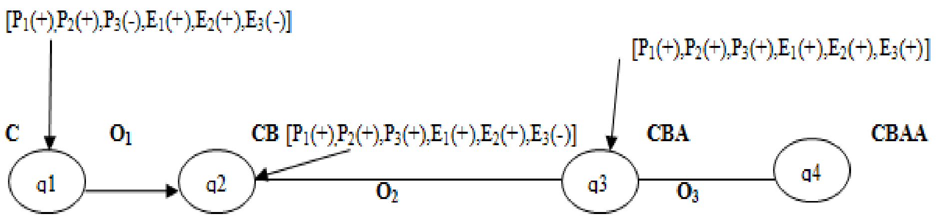

FIGURE 3. Working of HMM based system.

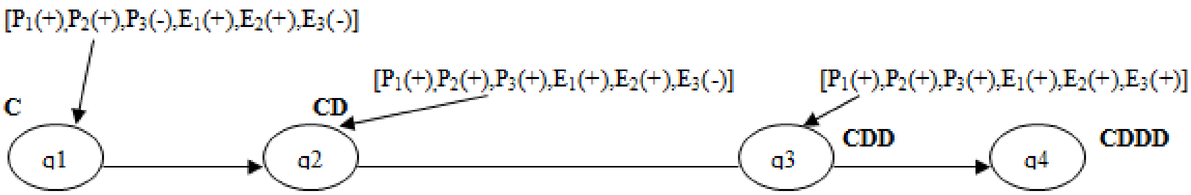

FIGURE 4. Working of Non-HMM based system.

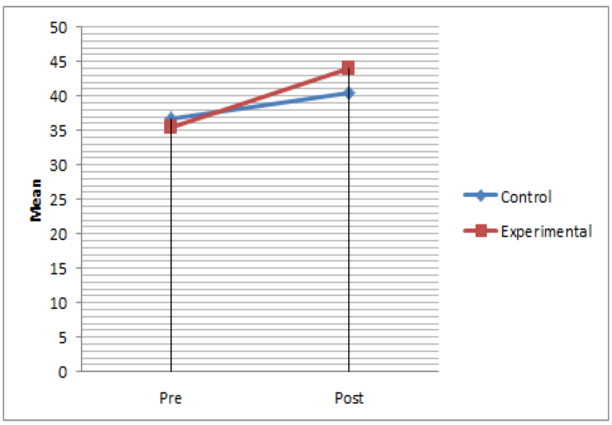

FIGURE 5. Pre-test and Post-test analysis.

environmental factors. Factor P_1 and P_2 are +ve except P_3 which is −ve, Similarly factor E_1 and E_2 are +ve except E_3 as shown in Fig. 3.

In Non-HMM model the observation captured from student directly passed to next state q2 i.e. CD without providing any complimentary factor to observations. Similarly, at state (q2) student captures new observation which forwarded to next state q3 i.e. CDD. Similarly, the process has been carried out for next state as shown in Fig. 4.

The post-test results indicated that for experimental groups (G1) who have adopted HMM based system their M and SD was 43.96 and 3.24 respectively. For control group (G2) who used Non-HMM based system their M and SD was 40.39 and 6.22 respectively. The achieved t-test result showed a significant difference ($t = 2.27$, $df = 38$, p-value $= 0.028$) among two groups as depicted in Fig. 5. The achieved consequences demonstrated that Group G1 learners, who adapted HMM based approach, they scored better and higher than Group G1 learners who adapted Non-HMM based method.

VI. CONCLUSION

In this study, a statistical HMM has been utilized in improvement of learner's grades and related performance with the involvement of psychological and environmental related factors. To compute the observable sequence of states, HMM requires training where transition (A), emission or observation (B_1 and B_2) and initial state (π) has to be initialized for model training. For verification and feasibility improvements in implementation of HMM model, different logical combinations of states being considered in which best state would validate the suitability of particular observation sequence. The schematic performance of HMM proved that it could be effectively utilized in emerging areas related to e-learning or computer-based system which enhance learner's performance. With the help of HMM model the total number of computations is reduced at great extent and with help of it we predict the grade at intermediatary stage also which is not possible by any other prediction models.

CONFLICT OF INTEREST

The authors do not have financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work.

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