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Research Article

Adaptive Educational Hypermedia System Based on Variational Bayesian Petri Net

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The traditional teaching model fails to support the modern requirements, which seek to support the diversity of each student in terms of skills, inclinations, and educational level. The adaptive educational hypermedia systems are a learning model that is both adaptive and personalized, and it is gaining popularity (AEHSs). These tools can be used by students to present, navigate, provide feedback, and assess. However, even in these systems, internal differentiation should include a wide range of practices, personalized forms of learning process organization, and high-quality education, taking into account each students' diverse educational needs and capabilities, interests, unique experiences, personal rhythms of integration of educational functions, and personal learning style. So, the learning style, the cognitive background, and the student's interest are decisive factors for the structure of a next-generation learning system. To overcome the issues of the traditional learning systems, this paper proposes an AEHS based on Variational Bayesian Petri Net (VBPNet). It is an intelligent system that can, by overcoming the significant limitations of the Petri Nets, depict any complex procedure with great precision and without considerable computing power requirements. The proposed VBPNet was used as an AEHS implementation algorithm to classify students based on their skills and real educational needs.

1. Introduction

The rapid evolution of the Internet and current types of artificial intelligence is bringing modern technology closer to traditional educational systems [1]. More and more educators are using electronic means to provide educational materials to students, and professionals in various disciplines of education are continually sharing their knowledge with the public, mainly through web pages, social media, vlogs, and so on [2, 3].

The recent COVID-19 pandemic crisis has shown that educational processes must be able to be carried out with e-learning methods as an exclusive teaching tool. Respectively, regarding the attitude of the learners, the views that agree that the modern or asynchronous teaching with or without the instruction of the instructor, as well as the teaching with the use of multimedia, are important factors of e-learning [4, 5].

AEHS is an alternative to the educational software development process by taking advantage of the advanced methods of artificial intelligence, which are the most basic systems that may put into practice the concept of creating a model that takes each student's goals, interests, and knowledge into account [6].

Using intelligent models, the student throughout his interaction with the system can fully benefit from processes tailored to his own needs, which are dynamically adjusted [7–9].

It should be emphasized that in an AEHS, the environment of the traditional classroom should be simulated in various and perhaps alternative ways so that in a changing virtual space the significant changes imposed by the new educational methodologies can take place. Thus, learners build knowledge through innovative forms of teaching, supportive tools, and tools that enhance the learner through continuous interaction with the learning environment [4, 10]. In any case, the main goal is to provide rich multimedia educational material and the adoption of personalized training methods adapted to individual learning needs.

In conclusion, by upgrading technology as a completely important new factor in shaping smart learning methods, the current practices are not sidelined or devalued. On the contrary, this practice emphasizes the need for continuous use of technology in the field of education, which is a creative process based on an ever-evolving dialectical relationship between the possibilities it provides and the basic concepts, views, and practices that technology proposes [3, 11, 12].

Based on this consideration, this paper proposes an AEHS, which utilizes an innovative artificial intelligence system to further upgrade the AEHS implemented in practice by various educators or proposed in literatures [12–14].

Section 2 of the paper gives an outline of the approaches identified in the literature as well as comparisons to similar techniques. The approach of the proposed system is detailed in Section 3. The experiments for implementing the proposed approach are described in Section 4. Finally, section 5 summarizes the findings of the study and discusses future goals that could be pursued to further it.

2. Related Literature

To enable adaptive features and functions, adaptive educational hypermedia systems require three parts: the document space, observations, and user model. Brusilovsky provided the first definition of adaptive hypermedia in 1996 [7]. After that, in 2006, the definition was expanded to Adaptive Educational Hypermedia Systems [2] and he described that processing information is necessary from the underlying hypermedia system (the document area), the runtime information required (findings), and the user model characteristics, focusing on the components of these systems (user model).

Mulwa et al. did a literature review in 2010 [15] on the educational benefits that Technology Enhanced Learning Environments (TELEs) adapt and personalize the learning experience provided to students. They concentrated on Learning Styles-Integrated Adaptive Educational Hypermedia Systems (AEHSs). Even though other experts disagreed, their study spanned the years 2000 to 2008 and highlighted the importance of incorporating several learning styles within AEHS in order to provide an individualized and successful learning experience. They also stated that the AEHS environment is rich in ideas and innovative solutions and that learning styles combined with various forms of adaptivity (e.g., user goals and prior knowledge) improved learner satisfaction and knowledge gain. Several researchers, on the other hand, seemed to point to elements of specific learners' performance since adaptation had no effect on their performance. One explanation for this might be the dynamic process of the AEHS systems. Also, the dynamic content and navigation customization depending on several contextual parameters (e.g., prior knowledge) significantly enhance the whole concept.

In 2017, Andaloussi et al. [16] conducted extensive research on the topic of AEHS by analyzing 50 AHES generated between 2000 and 2015 in a variety of online sources. The study's goal was to examine in depth the many approaches, methodologies, and solutions presented by AEHS designers in order to assist future developers of various technological approaches and their issues. They presented and contrasted the results. This study also provided guidelines for designing new AEHS that better fit the needs of students. Finally, they outlined the drawbacks and suggested potential solutions.

Finally, Brusilovsky et al. [12] concentrated their research on the design and authorship of AEHS. According to the authors, an AEHS author must organize the knowledge space and draw connections between the knowledge space and the hyperspace of educational content in addition to developing the hyperspace and composing pages with instructional information. The authors arranged this evaluation around the design and authoring steps that must be followed while creating adaptive educational hypermedia systems to make this process easier.

Based on the aforementioned literature, we can deduce that the research community is focused on figuring out how to combine technology with traditional educational methods in order to provide a personalized learning experience through the use of AEHS. A small number of studies also attempted to provide advice for maximizing the use of this technology [2, 14, 15].

3. The Proposed AEHS

In a flow of teaching modules that is tailored to the learning peculiarities and user's expectations, her learning profile determines both the content and the way of presentation. The learning style, the cognitive background, and the interest of the student are decisive factors for the structure of the next unit that AEHS will present to the student. This paper proposes an adaptive learning content management process based on an innovative VBPNet system [10, 15, 17].

A Petri Net [18, 19] is a graphic and mathematical depiction of a process, suitable for modeling resource management systems. These are spatial networks which are a special category of networks and are used as a way of modeling mainly in distributed systems.

In Petri Nets at the location of the nodes, there are places, the importance of which depends on the system in question to be modeled. Each position is represented by a circle [20, 21]. Also, in addition to the knots and edges, there is an additional symbol, the token. The tokens, which are placed on the places, are linked to the system's capacity and indicate the existence of quantities. Finally, there is the symbolism of the transition that indicates the activation of a process.

The nodes in a Petri Net indicate transitions, and the nodes constitute a directed bidirectional graph, i.e., events that can occur and spaces, i.e., conditions. The edges are obligatorily directed and are characterized neither by any value nor by equation but are in charge of moving the tokens from node to node. The nodes in turn have some capacity in tokens, while the edges have a capacity of only one token. In short, it can be said that they are networks that move tokens [22, 23].

The mathematical definition of the simple form of Petri Nets is as follows [24, 25]:

(1) A network is a 5-group N = (T, P, F, W, m0) where P and T are finite sets
(2) T is the range of positions
(3) P is the range of transitions
(4) Relation F c (PxT) U (TxP) is the "flow relation" of N, including the edges, i.e., (p,t) or (t,p) where t is a position and p is a transition
(5) An illustration W : F⟶N, which corresponds to each edge (χ,ψ) to an integer, the weight of the edge W(χ,ψ)
(6) An initial marking m0: T⟶N, which corresponds to each position t with an initial number of points (token), m0(t).

In a Petri Net grid map, the places are unadventurously denoted by rings, conversions with long narrow squares, and arches as one-way arrows showing location networks with changes or transitions to parts. If the map is an elementary grid, then these positions in a formation would be unadventurously characterized as rings, where each circle contains a single dot called a distinctive [24, 26].

In the diagram of the example of a Petri Net shown in Figure 1, the part circles can include more than one badge to indicate the number of times a part seems in a formation. The formation of the tokens that are spread over an entire Petri Net map is called marking [27, 28].

These networks are often a good modeling solution, especially in cases where many entities that have a specific function interacting with each other, and at the same time, multiple processes are performed at different rates each. However, their main disadvantage is that they cannot display all systems due to their limitations in displaying large and complex models and therefore are not widely used.

In this work, we try to solve the above problem using the Term Weighting methodology. The suggested model, in particular, assumes the presence of a term interval T in the information space, which is a collection of mutually incompatible words. Each term in T is independent and has a related regularity in the evidence space, which is defined as the probability that a term t is linked based on the probability distribution P in the interval T as follows [20, 23, 24]:

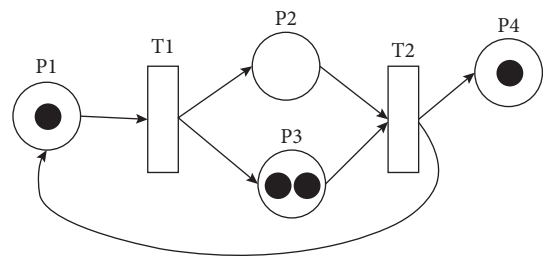

Figure 1: An example of Petri Net diagram.

$$P(t) = \frac{ntf(t)}{\sum t \in T^{ntf(t)}}, \tag{1}$$

where $ntf(t)$ is the normalized frequency of the term t in the term interval T.

This probability is updated based on fresh data acquired from the interaction using a rule implemented at the conclusion of each relativity path. Let P′ be the new probability, and this relativity path p is regarded a fresh source of information for updating it. Viewing a depiction p_i creates new proof about the terms in the depiction.

The rule is used to update the likelihood based on this new data using the following calculation [29]:

$$P'(t) = \left[P(t=1|p_l)\frac{P'(t=1)}{P(t=1)} + P(t=0|p_l)\frac{P'(t=0)}{P'(t=0)}\right] \cdot P(t). \tag{2}$$

This estimate estimates the reread likelihood of interest for a term t given $\mathbf{p_i}$ depiction, where P(t = 1) is the likelihood of observant the term t and P(t = 0) is the likelihood of not observant t. A relativity path comprises a series of depictions, and the likelihoods are updated after crossing the route.

The length of a relativeness path varies between 1 and 6 steps, and its length is represented by N. When this length is larger than one, the odds along this route are updated. The likelihood of relativity of a term to the entire length N of the path is meant by $\mathbf{P_N}$ and given by the calculation as follows [30, 31]:

$$P_N(t) = \sum_{i=1}^{N-1} c_l \cdot I_l \cdot \left[\left(P_l(t=1|p_l)\frac{P'_{l+1}(t=1)}{P'_l(t=1)} + P_l(t=0|p_l)\frac{P'_{l+1}(t=0)}{P'_l(t=0)}\right) \cdot P_l(t)\right], \tag{3}$$

where a representation in step i on path p is represented by p_i. Trust in the value of the depiction is denoted by c_i and l_i is the informative value of the representation. According to this equation, the order of a user's signature on a relativity path is essential. After each route, a maximum likelihood estimator will be used to estimate the number of maximum probable periods in which an event is likely to take place, and by calculating the extent to which a probability distribution Q is different from a second, a reference probability distribution P is such that in the following [20, 32]:

$$D(Q\|P) \triangleq \sum_Z Q(Z)\log\frac{Q(Z)}{P(Z/X)}, \tag{4}$$

which is the Kullback–Leibler divergence, so [33–35]

$$D_{KL}(Q\|P) = \sum_Z Q(Z)\left[\log\frac{Q(Z)}{P(Z,X)} + \log P(X)\right]$$
$$= \sum_Z Q(Z)[\log Q(Z) - \log P(Z,X)] \quad (5)$$
$$+ \sum_Z Q(Z)[\log P(X)].$$

As a result, optimization of a $L(\theta)$ a function is necessary. In the example, we looked that we have a k-dimensional distribution $N_\kappa(\mu, \Sigma)$ with μ and Σ unidentified. As a result, the worth θ becomes $\theta = (\mu, \Sigma)$ which means that we have a vector and an array [29, 31].

Suppose that we have an n from a multivariate distribution case, i.e., $X \sim N_p(\mu, \Sigma)$, $i = 1, 2, \ldots, n$, and are unrelated. The collection likelihood is thus provided by the relation as follows [36, 37]:

$$L = f(x_1, x_1, \ldots, x_n)$$
$$= \prod_{i=1}^{n} \frac{1}{(2\pi)^{p/2}} \cdot |\sum|^{1/2} \exp\left[-\frac{1}{2}(x_i - \mu)'\Sigma^{-1}(x_i - \mu)\right], \quad (6)$$

and so

$$L = (2\pi)^{-np/2} \cdot |\sum|^{-n/2} \exp\left\{-\frac{1}{2}\sum_{i=1}^{n}\left[(x_i - \mu)'\sum^{-1}(x_i - \mu)'\right]\right\}. \quad (7)$$

By calculating the logarithm, we have

$$l = \log L$$
$$= -\frac{np}{2}\log(2\pi) - \frac{n}{2}\log|\sum|$$
$$-\frac{n}{2}\left[\sum_{i=1}^{n}(x_i - \mu)^{-1}(x_i - \mu)\right] \quad (8)$$
$$= \text{constant} - \frac{n}{2}\log|\sum|$$
$$-\frac{n}{2}tr\left(\Sigma^{-1}S\right) - \frac{n}{2}(\overline{x} - \mu)\Sigma^{-1}(\overline{x} - \mu).$$

Due to the fact that x is vectors px1 and A array pxp, it is declaredthat

$$\sum_{i=1}^{n} x_i' A x_i = tr(AT), \quad (9)$$

where $T = \sum_{i=1}^{n} x_i \cdot x_i$ is a table of dimensions pxp and therefore estimating the maximum probability with respect to μ will generate the following [36, 38, 39]:

$$-\frac{n}{2}(\overline{x} - \mu)'\Sigma^{-1}(\overline{x} - \mu), \quad (10)$$

which is any minus quantity as the negative of a minus form, and consequently, for $\mu = \overline{x}$, the operation is maximized. So, using the Gaussian distribution, the problem is explained as follows [29, 34]:

$$q_\mu^*(\mu) \sim N\left(\mu \mid \mu_N, \lambda_N^{-1}\right),$$
$$\text{where } \mu_N = \frac{\lambda_0\mu_0 + N\overline{x}}{\lambda_0 + N},$$
$$\text{where } \lambda_N = (\lambda_0 + N)E_\tau[\tau], \quad (11)$$
$$\text{where } \overline{x} = \frac{1}{N}\sum_{n=1}^{N} x_n.$$

It should be noted that only the interval terms appearing in the relativity path are considered when calculating the probabilities. Finally, as soon as the probabilities are updated, they remain constant until the next revision (i.e., the next route of interest).

So, with the above implementation, the proposed VBPNet is now possible to depict any complex system without the general limitations of the initial models.

4. Experiments

The hypothesis of the experiment to verify the model is based on the fact that human interests change over time. For example, a young student is initially interested in the first year of study, but this interest gradually decreases over time. Therefore, the proposed AEHS needs the latest information to automatically update the user profile, which will follow a dynamic time-dependent chart. Feedback is therefore a key element of the proposed system, given that there is an optimized multimedia database related to the training object of interest to the user.

The idea for the user is to participate in the information retrieval process to improve the search result. Thus, the process is as follows:

(1) The user conducts a search
(2) The system returns an initial set of results
(3) The user then evaluates the results as relevant or irrelevant
(4) The system recalculates the results based on user feedback
(5) The next search presents the updated results
(6) The relevant feedback is repeated one or more times

Typically, it is possible to distinguish two types of feedback, namely, positive information (information that the user liked) and negative information (i.e., information that the user is not interested in). Negative information without reducing system accuracy can lead to a dramatic improvement in system performance.

The two ways the system uses to gather feedback are to use information that is explicitly given by users or information that is indirectly observed by user interaction. In addition, a hybrid approach is used combining both above information. The need to clearly mark objects as relevant or irrelevant carries the risk of users being reluctant to provide information of interest immediately. Indirect feedback, by which the system discreetly monitors search behavior,

eliminates the need for users to explicitly state which items they are interested in.

Indirect feedback results from observations of user behavior during interaction with the system, such as which media they choose or do not choose to view, the length of time spent viewing multimedia content or browsing related content.

When using VBPNet to build the process, the suggested method's limitations were constructed randomly based on the preceding description. Extensive direct and indirect feedback experiments were conducted to determine the ideal values for which the algorithm functions best, in which the user was able to perform three direct feedbacks, resulting in the corresponding three indirect feedbacks.

A graphical depiction of the results is shown in Figure 2, which indicates the best, worst, and average values of the feedback results.

Also, Figure 3 is presented visually under clusters type, the sequence between direct, and indirect feedback information.

The solutions were evaluated for their homogeneity according to the Coefficient of Variation (CV) [33, 39] to calculate the index for sample data in the following equation:

$$CV = \frac{100S}{\overline{Y}}, \tag{12}$$

where S is the measure of dispersion and $\overline{Y}$ is the collection values' summation.

Closer values near 0 imply typical uniformity, while closer numbers to 1 indicate inhomogeneity. The CV indicators, on the whole, reveal that values close to 0 indicate homogeneity in characteristic, while values close to 1 indicate inhomogeneity. In general, the values of the CV index show the following [33, 39, 40]:

(1) High level $[0.00 < \mathrm{Cv} \leq 0.25]$

(2) Moderate $[0.25 < \mathrm{Cv} \leq 0.40]$

(3) Low level $[\mathrm{Cv} > 0.40]$

The Kruskal–Wallis tests [33, 39] are used to see if the null hypothesis that the random samples are comparable is true by looking at if the values R_i/n_i, $i = 1, \ldots, k$, $k \rangle 3$ are nearly similar to one another and identical to $(n+1)/2$ or if the following comparative in (13) is minimal [39]:

$$\sum_{i=1}^{k} \left(\frac{R_i}{n_i} - \frac{(n+1)}{2} \right)^2. \tag{13}$$

The size effects were calculated using Eta Squared η^2 and Cohen's d [33, 39].

The new design improves forecast outcomes while also providing generalization, which is one of the most important aspects of Machine Learning. It implements a robust prediction model capable of reacting to very complex issues by reducing bias and variance and eliminating overfitting. Furthermore, the suggested VBPnet treats the noisy distributed points of inaccurate categorization that existing approaches cannot manage with absolute accuracy.

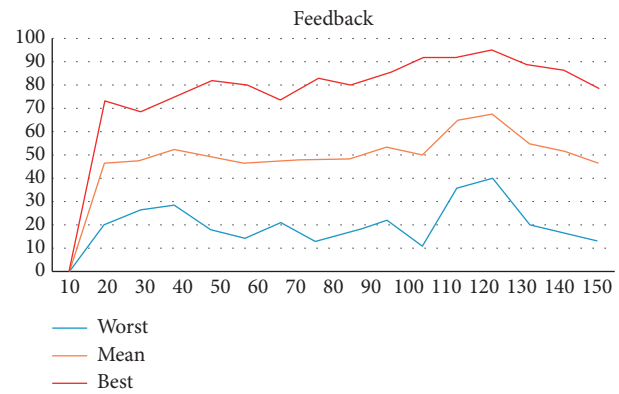

Figure 2: Feedback plot.

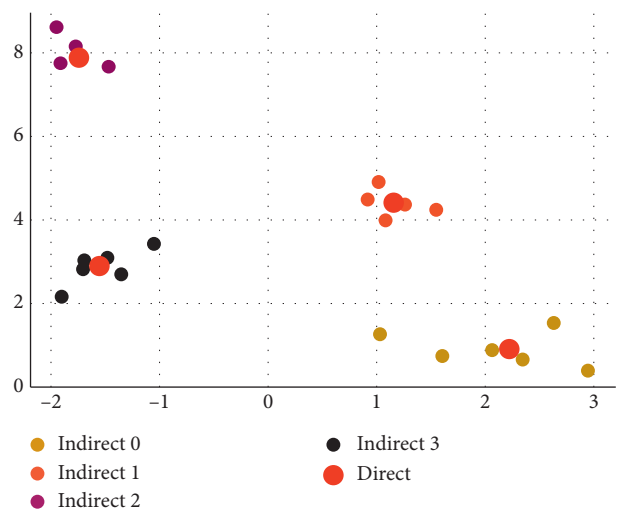

Figure 3: Feedback clusters.

The main benefit of the VBPNet is that we are capable of learning smooth latent state representations of the input data. As you can see in the results, focusing only on reconstruction loss does allow us to separate out the classes which should allow our model the ability to reproduce the original data point, but there is an uneven distribution of data within the latent space. In other words, there are areas in latent space that do not represent any of our observed data. On the other hand, if we only focus only on ensuring that the latent distribution is similar to the prior distribution (through our KL divergence loss term), we end up describing every observation using the same loss unit, which we subsequently sample from to describe the latent dimensions visualized. When the two terms are optimized simultaneously, we can describe the latent state for observation with distributions close to the prior but deviating when necessary to describe salient features of the input. This effectively treats every observation as having different characteristics; in other words, we have succeeded to describe the original data.

Based on the findings of the prior technique, it is clear that the proposed algorithm's function might provide a dependable solution to the highly difficult challenge of

designing and constructing AEHS for the execution of tailored curriculums.

5. Discussion and Conclusions

This research proposes a VBPNet-based AEHS. This intelligent system that can overcome the significant limits of Petri Nets representing any complex system with remarkable precision and without substantial processing power needs. Students' abilities and actual educational requirements might be considered while creating an AEHS. Hierarchical neuronal arrangements are more feasible when short-term network capabilities are required rather than shallow designs, which would have to use the same total number of iterative or recursive units to get the same results. As a result, the number of non-zero repeating links on many-core systems lowers when a multilevel architecture of neurons is introduced into the design of a neural system. It is clear from the process outputs that low complexity and time savings are essential for completing specialized tasks.

Intelligent learning systems can be developed by effective use of philosophical methods, even if the students are diverse in their abilities, learning obstacles, or cognitive profiles. In this approach, the educational system may not only be innovative, but it can also simply manage the student potential of each class and comprehend the distinctive traits of each unit in the classroom. Individualized approaches that take into account each user group's educational needs and skills and their interests, personal experiences, and specific learning cycles can also be used to deliver more excellent instructional tools.

A future extension of the system is the implementation of a reinforcement learning technique that will use only indirect indications of interest, gathered from the user's engagement with the system, to modify the original query. In this way, the dynamic process of adapting the educational material will be fully automated.

Data Availability

Data will be provided upon request to the author.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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