APPLICATION OF ARTIFICIAL NEURAL NETWORKS TO SUPPORT PERSONALISED LEARNING

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Abstract

The paper aims to analyse possible application of artificial neural networks (ANNs) to support learning personalisation and optimisation in terms of enhancing learning quality and effectiveness. ANNs are referred here as a computing system made up of a number of simple, highly interconnected processing elements, which process information by their dynamic state response to external inputs. Information that flows through the network affects the structure of the ANN because a neural network changes – or learns, in a sense – based on that input and output. An ANN has several advantages but one of the most recognised of these is the fact that it can actually learn from observing data sets. In the paper, first of all, systematic review was performed in Clarivate Analytics (formerly Thomson Reuters) Web of Science database. The following research question has been raised to perform systematic literature review: "What are existing ANN methods, tools, and techniques applied to support personalised learning?" During XXI century (2001-2017), 100 articles in English were found in Web of Science database on the topic “TS=(artificial neural network* AND education)”. After applying Kitchenham’s systematic review methodology, on the last stage 20 suitable articles were identified to further detailed analysis on possible application of ANN to support personalised learning both in general and Higher education. Systematic review has shown that ANNs are already quite actively used in both school and University education to solve different problems e.g. academic assessment, predicting students’ success and dropout, predicting instructional effectiveness of virtual learning environments, performance evaluation of online teaching and learning, improving students’ motivation, analysing emotional social and cognitive competencies, modelling student cognitive processes, cognitive diagnostic, course timetabling etc. At the same time, ANNs are still rarely used to personalise learning according to students’ needs, and future research is needed in the area. After that, the author’s original learning personalisation methodology based on identifying students’ learning styles and other needs is presented in more detail. The last but not the least, some insights on possible application of ANN to support personalised learning are provided. This should be helpful to enhance learning quality and effectiveness.

Keywords: artificial intelligence, neural networks, learning styles, personalised learning.

1 INTRODUCTION

The paper aims to analyse possible application of artificial neural networks (ANNs) to support learning personalisation and optimisation in terms of enhancing learning quality and effectiveness. ANNs are referred here as a computing system made up of a number of simple, highly interconnected processing elements, which process information by their dynamic state response to external inputs. An ANN has several advantages but one of the most recognised of these is the fact that it can actually learn from observing data sets.

Learning personalisation is helpful to enhance learning quality and effectiveness.

Learning personalisation by applying learning styles and intelligent technologies became very popular topic in scientific literature during last few years [1], [2], [3], [4], [5], [6], [7], [8], [9], [10].

Personalisation can be seen from two different perspectives, namely, while only one learning object [11], [12], [13], [14] or a learning unit / scenario [15], [16], [17] is selected, and while a set of them is composed, i.e. personalisation of a learning unit / scenario by finding a learning path [7]. The former perspective formulates learning objects selection problem, and the latter one solves curriculum sequencing problem [18].

In the paper, personalised learning units / scenarios are referred as learning units / scenarios composed of the learning components having the highest probabilistic suitability indexes [19] to particular students according to Felder-Silverman Learning Styles Model [20].
In the paper, first of all, systematic review was performed in Clarivate Analytics (formerly Thomson Reuters) Web of Science database. The following research question has been raised to perform systematic literature review: “What are existing ANN methods, tools, and techniques applied to support personalised learning?”

After that, the author’s original learning personalisation methodology based on identifying students’ learning styles and other needs is presented in more detail. At the end, some insights on possible application of ANN to support personalised learning are provided.

The rest of the paper is organised as follows: systematic review on ANN application in education is provided in Section 2, the author’s original learning personalisation methodology applying ANN and based on identifying students’ learning styles and other needs is presented in Section 3, and Section 4 concludes the paper.

2 SYSTEMATIC REVIEW

During XXI century (2001-2017), 100 articles in English were found on March 26, 2017, in Web of Science database on the topic “TS=(artificial neural network* AND education)” (Fig. 1):

After applying B. Kitchenham’s systematic review methodology [21], on the last stage 20 suitable articles were identified, and 11 articles were chosen to further detailed analysis on possible application of ANN to support personalised learning both in general and Higher education.

According to [22], the neural network technique proves to be a worthy scientometric data mining and visualisation tool which automatically carries out multiparametric scientometric characterisations of the production profiles of analysed Higher Education Institutions. With this procedure the authors automatically identify and visually depict clusters of institutions that share similar bibliometric profiles in bidimensional maps. Four perspectives were represented in scientometric maps: productivity, impact, expected visibility and excellence. Since each cluster of institutions represents a bibliometric pattern of institutional performance, the neural network helps locate various bibliometric profiles of academic production, and the identification of groups of institutions which have similar patterns of performance.

E. Bahadir [23] considers that the ability to predict the success of students when they enter a graduate program is critical for educational institutions because it allows them to develop strategic programs that will help improve students’ performances during their stay at an institution. In this study, the author presents the results of an experimental comparison study of Logistic Regression Analysis (LRA) and ANN for predicting prospective mathematics teachers’ academic success when they enter graduate education. A sample of 372 student profiles was used to train and test the model. The strength of the model can be measured through LRA. The average correct success rate of students for ANN was higher than LRA. The successful prediction rate of the back-propagation neural network, or a common type of ANN was 93.02%, while the success of prediction of LRA was 90.75%.

The authors of [24] claim that their paper is totally different than the research design and research method in the related literature for investigating how information technology-based reading and learning process of network distance teaching affects the assessment result in the past, that is,
innovative research architecture and process is adopted. In the paper, quantile regression analysis is applied to the investigation of how the time and frequency of log-in curriculum, browsing teaching material, and curriculum discussion in learning process record affects the final-term assessment result of multimedia design digital teaching material subject. In depth research is done under such research architecture, and it is hoped that how each independent variable affects the final-term assessment result under different quantile can be investigated. In addition, this paper has applied new ANN technology to set up expert system for teacher's assessment result in distance teaching so as to reduce teacher's teaching pressure. The research result shows that the use of quantile regression to analyse the influence of different variable on the teacher's final-term assessment result of distance teaching is a feasible way. According to [24], FOAGRNN model, as compared to other five models, has better forecasting capability.

The objective of the following [25] study is to introduce an intelligent E-Learning software system, which aims to improve students' motivations and academic achievements in computer programming courses. The system is based on an intelligent analysis approach, which is formed via an ANN model trained by Cognitive Development Optimization Algorithm. This intelligent approach tries to provide appropriate materials to students by evaluating learning levels. At this point, types of learning levels are defined by teachers and associated with specific abilities regarding to computer programming. After determining learning levels according to results of the performed activities, it is then possible for software system to provide appropriate materials / applications corresponding types of low learning levels. Thanks to the system, it is possible to learn abstract, difficult computer programming based subjects easily. In order to have idea about effectiveness of the system, it was evaluated in some computer programming courses with contribution of 110 students and eventually, positive results were obtained after several evaluation works.

M. Demir's study [26] predicts the number of correct answers given by pre-service classroom teachers in Civil Servant Recruitment Examination's (CSRE) educational sciences test based on their high school grade point averages, University entrance scores, and grades (mid-term and final exams) from their undergraduate educational courses. This study was therefore designed by using a general survey model. The participants were 219 graduates of the Departments of classroom teacher education from the education faculties of two different state universities. ANNs were used to predict the numbers of correct answers from the CSRE educational sciences test. As a result of different trials, the correlation between the predicted and actual numbers of correct answers was examined, and 10 ANN models were included in the study. Statistically, significant positive correlations were found between the numbers of correct answers predicted by the ANN and the students' actual correct answers in the CSRE. The highest loading was $r = .63 (p < .01)$, and the lowest was $r = .43 (p < .05)$.

According to [27], E-learning is the use of technology that enables people to learn at anytime from anywhere. Various single knowledge-based methods (KBM) such as rule-based reasoning (RBR) and case-based reasoning (CBR), and intelligent computing methods (ICM) such as genetic algorithm (GA), particle swarm optimisation (PSO), artificial neural network (ANN), multi-agent systems (MAS), ant colony optimisation (ACO), fuzzy logic (FL) etc. Integrated KBM-ICM methods such as GA-CBR, ANN-RBR, GA-Ontology and ANN-Mining have been used in various e-learning contexts such as: the learning path generation, adaptive course sequencing and personalisation of recommended learning object etc. The authors have made a study of different individual KBM and ICM methods; and integrated KBS-ICM methods applicable to e-learning domain right from the mid 1990s to 2014. The study is presented in a tabular form, showing the KBM-ICM methods, e-learning problems to be addressed, specific features and the implementation in the e-learning domain. From the results, it is observed that a single KBM is not deployed to solve any e-learning problem. A single ICM and integrated KBM-ICM methods are used to solve various e-learning problems.

The authors of [28] consider that the dropout high rate is a serious problem in E-learning programs. Predicting the dropout potential of students is a workable solution for preventing dropouts. Based on the analysis of related literature, this study selected students' personal characteristics and academic performance as input attributions. Prediction models were developed using ANN, Decision Tree (DT) and Bayesian Networks. A large sample of 62,375 students was utilised in the procedures of model training and testing. The results of each model were presented in a confusion matrix and were analysed by calculating the rates of accuracy, precision, recall, and F-measure. The results suggested all of the three machine learning methods were effective for student dropout prediction, but DT presented a better performance.

The purpose of [29] is to explain and document the creation of a computational model in the form of an ANN capable of simulating student cognition. Specifically, the model simulates students' cognition as...
they complete activities within a science classroom. This study also seeks to examine the effects, as evidenced in the ANN, of an intervention designed to develop increased levels of critical thinking related to science skills. This model is based on the identification of cognitive attributes and integration of two advanced measurement frameworks: cognitive diagnostics and Item Response Theory. Both frameworks examine student response patterns, providing initial inputs for the ANN portion of the model. Once initial task response patterns are identified, they are parameterised and presented to the ANN. The ANN within this study is the foundational component of a computational model based upon the interaction of multiple, connected, adaptive processing elements known as cognitive attributes. These cognitive attributes process student responses to cognitive tasks within science tasks. Using the Student Task and Cognition Model, the study authors simulated a cognitive training intervention using a randomised control trial design of 100,000 students. Results of the simulation suggest that it is possible to increase levels of student success using a targeted cognitive attribute approach and that computational modelling provides a means to test educational theory for future education research. The paper [29] also discusses limitations of the use of this computational model within education and the possible future directions for educators and researchers.

According to [30], there has been an increase in student achievement testing focusing on content and not underlying student cognition. This is of concern as student cognition provided for a more generalizable analysis of learning. Through a cognitive diagnostic approach, the authors model the propagation of cognitive attributes related to science learning using Serious Educational Games (SEGs). One-way to increase the focus on the cognitive aspects of learning that are additional to content learning is through the use of cognitive attribute task-based assessments (Cognitive Diagnostics) using an ANN. Results of this study provide a means to examine underlying cognition which influences successful task completion within science themed SEGs. Results of this study also suggest it is possible to define, measure, and produce a hierarchical model of latent cognitive attributes using a Q-matrix relating virtual SEGs tasks, which are similar to real-life SEG tasks aiding in the modelling of transference.

In [31] study using a large and feature rich dataset from Secondary Education Transition System in Turkey we developed models to predict secondary education placement test results, and using sensitivity analysis on those prediction models we identified the most important predictors. The results showed that CS decision tree algorithm is the best predictor with 95% accuracy on hold-out sample, followed by support vector machines (with an accuracy of 91%) and ANNs (with an accuracy of 89%). Logistic regression models came out to be the least accurate of the four with an overall accuracy of 82%.

According to [32], building computerised mechanisms that will accurately, immediately and continually recognise a learner’s affective state and activate an appropriate response based on integrated pedagogical models is becoming one of the main aims of artificial intelligence in education. The goal of [32] is to demonstrate how the various kinds of evidence could be combined so as to optimise inferences about affective states during an online self-assessment test. A formula-based method has been developed for the prediction of students’ mood, and it was tested using data emanated from experiments made with 153 high school students from three different regions of a European country. The same set of data is analysed developing a neural network method. Furthermore, the formula-based method is used as an input parameter selection module for the neural network method. The results vindicate to a great degree the formula-based method’s assumptions about student’s mood and indicate that neural networks and conventional algorithmic methods should not be in competition but complement each other for the development of affect recognition systems. Moreover, it becomes apparent that neural networks can provide an alternative for and improvements over tutoring systems’ affect recognition methods.

Systematic review has shown that ANNs are already quite actively used in both school and University education to solve different problems e.g. academic assessment, predicting students’ success and dropout, predicting instructional effectiveness of virtual learning environments, performance evaluation of online teaching and learning, improving students’ motivation, analysing emotional social and cognitive competencies, modelling student cognitive processes, cognitive diagnostic, course timetabling etc. At the same time, ANNs are still rarely used to personalise learning according to students’ needs, and future research is needed in the area.
3 LEARNING PERSONALISATION METHODOLOGY APPLYING ARTIFICIAL NEURAL NETWORKS

According to [33], learning software and all learning process should be personalised according to the main characteristics / needs of the learners. Learners have different needs and characteristics, that is, prior knowledge, intellectual level, interests, goals, cognitive traits (working memory capacity, inductive reasoning ability, and associative learning skills), learning behavioural type (according to his / her self-regulation level), and, finally, learning styles.

Future education means personalisation plus intelligence [33]. Learning personalisation means creating and implementing personalised learning units / scenarios based on the recommender system suitable for particular learners according to their personal needs. Educational intelligence means application of intelligent technologies and methods (such as ANN) enabling personalised learning to improve learning quality and efficiency.

In personalised learning, first of all, integrated learner profile (model) should be implemented. The author's approach to creating students’ profiles is as follows:

- Selecting pedagogically and psychologically sound taxonomies (models) of learning styles
- Creating an integrated learning style model (e.g. [20]) which integrates characteristics from several models. Dedicated psychological questionnaires are applied here (e.g. [34])
- Creating an open learning style model
- Using an implicit (dynamic) learning style modelling method
- Integrating the rest features in the student profile (cognitive traits, knowledge, interests, goals).

After that, interlinking of learning components (learning objects, activities, and environments) with learners’ profiles should be performed, and an ontologies-based personalised recommender system should be created to suggest learning components suitable to particular learners according to their profiles [33].

After the interlinking and ontologies creation stage, a recommender system should be created to link students’ personal data in their profiles, relevant learning objects according to corresponding metadata fields, and learning activities and tools suitable to particular students according to their learning styles and other profiles’ data.

Interlinking and ontologies creation should be based on the expert evaluation results (e.g. [35]). Experienced experts should evaluate learning components in terms of its suitability to particular learners according to their learning styles and other preferences / needs. A recommender system should form the preference lists of the learning components according to the expert evaluation results.

Probabilistic suitability indexes [19] should be identified for all learning components in terms of its suitability level to particular learners. These suitability indexes could be easily calculated for all learning components and all students if one should multiply learning components’ suitability ratings obtained while the expert is evaluating the suitability of the learning components to particular learning styles (like in [35]) by probabilities of particular students’ learning styles (like in [19]). These suitability indexes should be included in the recommender system, and all learning components should be linked to particular students according to those suitability indexes. The higher the suitability indexes, the better the learning components fit the needs of particular learners.

Thus, personalised learning units / scenarios (i.e. personalised methodological sequences of learning components) could be created for particular learners. An optimal learning unit / scenario (i.e. learning unit of the highest quality) for particular student means a methodological sequence of learning components having the highest suitability indexes.

A number of intelligent technologies should be applied to implement this methodology, for example, ontologies, recommender systems, intelligent software agents, decision support systems to evaluate quality of learning units / scenarios etc.

The main advantages of this methodology are analysis of interlinks between students' learning needs, for example, learning styles and suitable learning components based on using pedagogically sound vocabularies of learning components, experts’ collective intelligence to evaluate suitability of learning components to particular learners’ needs, and application of intelligent technologies.
This pedagogically sound learning units / scenarios personalisation methodology is aimed at improving learning quality and effectiveness. Learning unit / scenario of the highest quality for particular student means a methodological sequence of learning components with the highest suitability indexes. The level of students’ competences, that is, knowledge / understanding, skills and attitudes / values directly depends on the level of application of high-quality learning units / scenarios in real pedagogical practice.

One of possible ways of applying ANNs to implement the presented learning personalisation methodology is as follows: after recommender system should recommend optimal learning units / scenarios to particular students based on suitability indexes, corresponding intelligent software agent should be implemented to run these learning units / scenarios, and application of ANN should be helpful to collect and analyse the real data on running these recommended learning units / scenarios by students. Collecting and analysis of these real data should be helpful in order to further optimise recommended learning units / scenarios in the case of any discrepancies between recommended learning units / scenarios and units / scenarios running by particular students in real pedagogical practice.

4 CONCLUSION

ANNs are already quite actively used in education to solve different problems e.g. academic assessment, predicting students’ success and dropout, predicting instructional effectiveness of virtual learning environments, performance evaluation of online teaching and learning, improving students’ motivation, analysing emotional social and cognitive competencies, modelling student cognitive processes, cognitive diagnostic, course timetabling etc. At the same time, ANNs are still rarely used to personalise learning according to students’ needs, and future research is needed in the area.

In the paper, pedagogically sound learning units / scenarios personalisation methodology is presented aimed at improving learning quality and effectiveness. According to this methodology, learning unit / scenario of the highest quality for particular student means a methodological sequence of learning components with the highest probabilistic suitability indexes. After recommender system should recommend optimal learning units / scenarios to particular students based on corresponding probabilistic suitability indexes, corresponding intelligent software agent should be implemented to run these learning units / scenarios, and application of ANN should be helpful to collect and analyse the real data on running these recommended learning units / scenarios by particular students. Collecting and analysis of these real data should be helpful in order to further optimise recommended learning units / scenarios in the case of any discrepancies between recommended learning units / scenarios and units / scenarios running by particular students in real pedagogical practice.

REFERENCES


