Research Article

A Study on the Application of Deep Learning Methods Based on Nonlinear Random Matrices in the Design of Intelligent Research Management System

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The database of the intelligent science management system includes the exchange of data between the basic data of the school and the various business systems, with centralised storage and centralised management, constituting a unified data centre. The completed intelligent science management system will become a reliable source of data to integrate the system to be developed with existing systems, making the data of the whole system unified, thus providing reliable data for information enquiry and decision analysis within the university, and laying a good foundation for the construction of the digital campus. The NRM_DeepNet model is an application model of the deep learning method of the nonlinear random matrix in the intelligent research management system, mainly in data processing and analysis, using deep learning technology for data classification processing, and then for research data modal feature extraction, the process of modal extraction applies the nonlinear random matrix for feature weighting. In the process of modal extraction, a nonlinear random matrix is applied to weight the features, and finally, different research data features of different research projects can be classified as intelligent and regularised. In this paper, we combine the practice of scientific research management, introduce the nonlinear random matrix and deep learning technology into the intelligent scientific research management system, and update its data and system management so as to realize intelligent and humanised scientific research management, thus reducing the labour intensity and improving the efficiency of scientific research work.

1. Introduction

The informatization of China’s universities started late, and at the beginning of the 21st century, the informatization of some universities [1], such as campus networks, had just started. In the last decade, the informatization of research management in China has been going on. From a computer system oriented to scientific research results, a web page oriented system oriented to scientific research projects [2], a process oriented scientific research management system, a scientific management information system oriented to statistical reports, and a scientific research management information system based on big data with scientific research data processing as the core [3]. At the same time, the technology adopted has gradually changed from client/server mode to browser/server mode gradually, which is characterised by simple installation, low cost, easy maintenance, and convenient upgrade.

Compared with ordinary universities, most higher vocational and technical colleges lack a scientific research system that is compatible with their development needs, and the scientific research management in many universities is not really scientific [4]. On the websites of some higher vocational colleges, there are usually only declaration announcements and bulletins, while the management of scientific research information remains on static and dynamic pages. Even if there is a research management system [5], there is a lack of WEB database and maintenance, and it is not really informative and scientific. In contrast, our university has not yet established a research management system for scientific research, and currently still uses internal university notices for scientific research.
Compared to universities in Europe, the US, and other developed countries, our undergraduate and higher education institutions have major gaps and deficiencies in research management, research management models, and research evaluation [6–8].

After research, it was found that a powerful scientific management system, which must have multiple functions and be open-ended, is a very complex system. It starts out as a simple module, but it will improve over time as it develops later. In addition, continuous training and operation of the users of the research management system during the implementation process to improve their information technology is key to ensure the proper functioning of the research management system [9]. It is certainly not possible to copy other people’s scientific research materials, but there must be a follow-up expansion and training of human resources, and for this to happen, there must be sufficient funding, so it is necessary to establish a scientific management system that is compatible with one’s own requirements.

The results of the above-mentioned study show that although there are many scientific management systems in China, at present, there are only a few that can be adapted to the scientific management work of our universities. Currently, there is independence and inconsistency in the research management systems of the universities. Moreover, the system of scientific management work is a gradual process of development and expansion, and there is still much room for its development, which needs to be further studied and explored [10].

In order to standardise the management of scientific research, to better understand the progress of research projects and to facilitate statistics and organisation, many universities are experimenting with the use of web-based and computer-based technologies to manage their research work [11]. However, most of the research studies rely on paper, and computers are merely a collection and storage tool that cannot be updated in a timely manner, using only the most rudimentary techniques, nor can they engage in scientific research.

According to statistics, there are two major problems with the traditional business model that are as follows:

1. In the management of scientific research, the study of scientific research projects is a dynamic process, and if primitive management methods are adopted, it can easily lead to a poor quality of project closure, or delayed closure, resulting in the project not being completed [12].

2. Manual statistics are carried out on various scientific research data, such as publications of papers, publication of teaching materials, research on topics, patent applications, and scientific research results. Using conventional statistical methods, problems such as duplication or omission can easily occur, resulting in inconsistent data. Moreover, the data are submitted by researchers in each case, which causes them a lot of headaches.

In this paper, we combine the practice of research management and introduce the nonlinear random matrix and deep learning technology into the intelligent research management system to improve the efficiency of research work.

2. Introduction to Related Theories

2.1. Deep Learning Theory. In recent years, deep learning, as an emerging machine learning technology, has made great progress in the fields of image classification, speech recognition, and natural language processing, providing a powerful impetus for the development of artificial intelligence [13–16]. With the rapid development of big data and the rapid development of computer hardware resources, the emergence of deep learning is inevitable. On this basis, the concept of deep learning was introduced to the shallow-level models of machine learning. Before that, deep learning was mainly done by shallow-level models, such as SVM, Hidden Markov, AdaBoost, and so on. However, when the amount of data is too large and the problem functions are complex, the classification performance and generalisation ability of shallow-level models are greatly limited. Deep learning algorithms do not suffer from these problems and can use multilevel networks to achieve a distributed feature representation of the data that can effectively extract the essential properties of the data.

The model contains a number of simple neurons, each with an input that is an algebraic sum of the previous layer of neurons, which represents a single abstraction of the features. Deep learning is characterised by a bottom-up, multilevel feature abstraction learning that takes place without human interference. On this basis, the algorithm is used to train the deep learning model, determine the corresponding network parameters, and then input them into the network to obtain a feature representation of the data at each level of the network, which is used as input to the training classifier to obtain the final classification result. “Depth” is one of the key benefits of deep learning, which is the creation of a multilevel learning model. This idea is derived from the mammalian brain. Research has shown that the mammalian brain thinks and learns on multiple levels and that it needs to abstract and represent information at different levels. In the case of the human visual system, for example, people use specific visual neurons to detect and observe the outline features of a target when looking at an object; next, other neurons are organised from the bottom-up to form more complex visual shapes [17]. This hierarchical and layered approach to feature learning allows one to accomplish recognition more effectively.

Another advantage of deep learning is that it can automatically extract and learn a process is also derived from the human perceptual system. When a person is watching, they receive a large amount of information, but as they go through their vision, some of the information that is not relevant to the target is filtered out, leaving only the most basic information. Deep learning is a way of gradually restoring the essential properties of the data and categorising them as a basis for better classification, modelled on the human cognitive model.

2.2. Random Matrix Theory. The emergence of random matrix theory (RMT) has attracted the attention of many scholars at home and abroad, and in October 2009, an
international conference was held in Europe on the topic of RMT—Wireless Communication.

The so-called "random matrix" is a matrix composed of arbitrary variables. When the number of dimensions of an arbitrary matrix approaches infinity, we call it a large-dimensional random matrix. Large-dimensional random matrices are a good way to handle large-dimensional data and are widely used in digital communications, nuclear physics, financial mathematics, and many other applications. In wireless communications, random matrices also offer irreplaceable advantages. The empirical singular value distribution of the channel random matrix has the following excellent properties that are well suited for wireless communications [18].

1. Nonsensitivity: In random matrices, the asymptotic properties of the distribution of singularities are not sensitive.
2. Ergodicity: The spectrum of any arbitrary matrix has approximate convergence in its asymptotic limit distribution.
3. Fast convergence: The empirical odd distribution converges rapidly to its asymptotic limit distribution. This is an irresistible advantage, that is, if an appropriate probability distribution function is chosen, the accuracy of the algorithm can be guaranteed for a certain number of cases and better estimates can be obtained with a lower signal-to-noise ratio and a smaller sample size.

2.3. Theory of Nonlinear Systems. A nonlinear system is one in which the state and output parameters of the system cannot be represented by a linear relationship under the action of the external environment. The effects on the system are related to its kinematic characteristics. Because the parts that make up the system have certain nonlinear properties, there is no perfect linear system in real life. In order to improve the stability of the system, a controller must be designed in order to stabilise it, leading to the phase plane method [19], the descriptive function method, and the harmonic equalisation method. In the last decade, many new control theories have emerged as a result of research into nonlinear systems, including Lyapunov’s stability theory, such as Kokotovic’s inverse control and differential geometric control proposed by Professor Isidori in Italy, and Swaroop and Hedrick are represented by inverse control theory. So far, Lyapunov’s method has become the most widely used and mature one in nonlinear systems, establishing Lyapunov’s general functions and constructing system controllers for the stability of nonlinear systems.

3. Application Methodology Design

3.1. Application Architecture Design. The database of the intelligent science management system includes the basic data of the school and the data exchange between the various business systems, with centralised storage and centralised management, constituting a unified data centre. The completed intelligent science management system will become a reliable data source, integrating the system to be developed with the existing system, making the data of the whole system unified, thus providing reliable data for information query and decision analysis in the school, and laying a good foundation for the construction of the digital campus [20].

This paper introduces a deep learning algorithm based on a nonlinear random matrix. It is a deep learning based method that classifies data and extracts patterns from scientific data and uses them for modal feature extraction of research data, where a nonlinear random matrix is introduced in the modal extraction. Its data processing model structure, NRM_DeepNet, is shown in Figure 1.

The overall architecture of the modal neural network of scientific research data described in this thesis is tree-like and consists of two main parts: the root network and the upper network. The underlying network is like the root system of a tree divided into many branches that form the modal network of the entire scientific research system and translate it into modal data for the research. Throughout the canopy region, the upper network is divided into three levels, giving a fused representation of the scientific data modality sharing through the upper network. A branch of the root network, or subnetwork, is assigned to each input modality of information [21]. The subnets then transform the data in the various modes and use deep neural networks to perform multidimensional nonlinear transformations to extract new high-level abstract features from the original low-level data. The structure of the subneural network used is different in different modalities. Within each hidden layer, there are differences in the number of neuron nodes contained in each subnetwork.

Multiple subnets in the root network are used to extract different patterns of information to obtain higher level abstract feature representations, and because there are also potential relationships between different data patterns, a common hidden layer is shared at the top layer of each subnet of the root network to enable the association of different data patterns. When training the parameters of the root network, the BP algorithm is used, and each subnetwork shares the functional loss defined by the auxiliary bridging layer, thus enabling simultaneous regulation of each subnetwork.

An optimised set of high-level abstract features is extracted at the topmost layer of each subnetwork. Different types of data patterns are refined through different subneural networks and mapped from the original heterogeneous space to the same homogeneous space, thus obtaining homogeneous feature representations [22]. These homogeneous abstract features are then used as input and projected onto a low-dimensional feature space through a mapping transformation, and finally, the modal features of the scientific data are extracted.

3.2. Design of Nonlinear Random Matrix Applications. In a nonlinear random matrix, the boundary between network nodes without authority represents the presence or absence
of interaction between nodes, which represents the relationship between one or more elements. Much of the current research studies on complex networks, particularly in the physics community, are based on Boolean networks and has led to a large number of conclusions. As Newman (2004) states, most of the current research revolves around Boolean networks due to their ease of analysis, that is, Boolean networks are easier to analyse and study than weighted networks.

The research projects in the intelligent science management system are different, and each research project is independent but the data are multilevelled, so there is no need for orientation, only the project is defined as a node; when there is a communication act between two people, the connection of two nodes occurs; if there is no communication act, the two nodes are not connected, thus forming the corresponding undirected authorised network. The adjacency matrix of an undirected unauthorised network is a Boolean matrix, which is a 0–1 real symmetric matrix with the number of cells equal to the number of nodes in the network. Therefore, the Boolean matrix is used to portray the fungible behaviour between the different research subject materials [23].

### 3.3. Modal Feature Extraction of Scientific Research Data

Modal feature extraction in scientific research uses a non-linear random matrix. The modal characteristics of the research data are one of the biggest problems of the research object; that is, the data modalities in different modes have different characteristics, and the data in these modes have different characteristics, so the core problem of the research data modalities in the research is how to map the different modalities to the same subspace. The deep learning model is able to solve the problem of heterogeneity among data modalities well because of its good expressiveness and its ability to transform the original information.

Figure 2 shows the underlying architecture of the root network, with corresponding subnetworks for each schema. As the internal structure of each pattern varies considerably, some patterns have a relatively simple internal structure, and the low-dimensional structure hidden in the raw material can be identified from the raw material using only a shallow structure; however, for some low-dimensional flow models with high nonlinear properties, sufficient high-level abstraction features cannot be obtained using a shallow structure, which requires more hidden layers for nonlinear transformation. Inputting $m$ patterns into the overall structure constitutes $m$ different types of subnets. Depending on the input patterns, the number of hidden layers in the subnets varies. The number of neuron nodes required for each layer in the different subnets also varies due to differences in the dimensionality of the initial input data for each modality. Here, the number of hidden layers contained in the subnetworks $m$ corresponding to the $m$-th mode is defined as $n_m$, the $i$-th hidden layer is denoted as $h_i^m$, and the connection weights between the $i$-th hidden layer and its lower layers are denoted as $w_{i,m}^m$.

The process of training the root network was divided into two phases: unsupervised pretraining and supervised joint tuning of the scientific data patterns. As can be seen from
Figure 2, in the pretraining phase, the subnetworks of each independent mode are trained independent of each other. A greedy-based hierarchical training method is proposed to address the problem of parameter training failure of traditional BP algorithms in multilevel neural networks. Here, either the RBM can be chosen as the underlying architecture or an autoencoder can be used. The model uses an autoencoder based on hierarchical prelearning.

![Layer-by-layer training of hidden layers in subnetworks.](image)

Figure 3: Layer-by-layer training of hidden layers in subnetworks.

As can be seen in Figure 3, as each hidden layer is trained, a nonlinear matrix transformation is performed for the current input \( x \) by means of a weight matrix \( W_1 \) and a mapping function \( \varphi(\cdot) \), which encodes a mapping to an implicit feature representation \( h = \varphi(W_1^T x) \). In the decoding phase, the initial input is reconstructed by means of a weight matrix \( W_2 \) and a mapping function \( \varphi'(\cdot) \), resulting in a reconstructed input \( \hat{x}' = \varphi'(w_2^T h) \).

4. Experimental Analysis of the Application

4.1. Experimental System Environment

4.1.1. System Application Environment. System development platform: Eclipse.
Running server: Tomcat.
Database: MySQL.
Web language: HTML and Dreamweaver.
Development language: Java and eclipse.

4.1.2. Client Requirements. Access to the research management system client should meet the following:
- Operating system: WIN Xp, WIN7, WIN8, WIN10, Android, IOS.
- Browser version: IE9 and above, 360 browser, Sohu browser, and other mainstream browsers.
- Processor: 2G and above.

4.2. Experimental Data Preparation. Three scientific image datasets were used in this chapter which are the NUS-WIDE-Object dataset, the Animal With dataset, and the MSRA-MM dataset, in order to test whether the proposed feature selection model can effectively select the model that is most closely related to the current scientific research work to treat each of the provided features as a model, to add unrelated noise patterns to the three sets of experimental data, and to test the characteristics of the proposed model and the correctness of the model selection.

4.3. Analysis of Experimental Results. The proposed NRM_DeepNet framework was validated in the experiments for the data feature extraction capability of the heterogeneous features, and the classification results on the dataset using the SVM classifier on the original data and after feature extraction using the neural network are given in Tables 1 and 2, respectively.

|         | LSS | RGSIFT | SIFT | SURF | DeCAF | CQ | PHOG |
|---------|-----|--------|------|------|-------|----|------|
| SVM     | 0.4941 | 0.5022  | 0.4088 | 0.5271 | 0.8034  | 0.3920 | 0.3765 |
| NRM_DeepNet | 0.5507 | 0.5231  | 0.4381 | 0.5644  | 0.8401  | 0.4773 | 0.3684 |
| SVM     | Gaussian | Uniform  | Chi2  | F-dist | Beta | LSS + N | RGSIFT + N |
| NRM_DeepNet | 0.1064  | 0.1120  | 0.1058 | 0.1064  | 0.1120  | 0.3161 | 0.4070 |
| SVM     | 0.1070 | 0.1101  | 0.1164 | 0.1089  | 0.1070  | 0.4026 | 0.4138 |
| NRM_DeepNet | 0.1050 | 0.1050  | 0.1050 | 0.1050  | 0.1050  | 0.4050 | 0.4138 |

|         | CH | CORR | EDH | WT | CM | LDA31 | LDA81 |
|---------|----|------|-----|----|----|-------|-------|
| SVM     | 0.2426 | 0.3066  | 0.2894 | 0.3063 | 0.2857 | 0.5062 | 0.4564 |
| NRM_DeepNet | 0.3032 | 0.3738  | 0.3074 | 0.3733 | 0.3394 | 0.4933 | 0.5553 |
| SVM     | Gaussian | Uniform  | Chi2  | F-dist | Beta | CH + N | CORR + N |
| NRM_DeepNet | 0.1041 | 0.1044  | 0.1021 | 0.1067 | 0.1052 | 0.2221 | 0.2803 |
| NRM_DeepNet | 0.1050 | 0.1050  | 0.1050 | 0.1050  | 0.1050  | 0.2238 | 0.2940 |

Table 1: Classification accuracy of the animal with attributes dataset using unimodal features.

Table 2: Classification accuracy obtained for the NUS-WIDE-Object dataset using unimodal features.
From the experimental results, it can be seen that refinement of all data patterns except random noise by the NRM.DeepNet deep neural network results in refined features that are superior to the original features. The random noise feature population, on the other hand, has no identification information and is clearly irrelevant to the task at hand. For the original data patterns containing Gaussian noise, feature transformation was performed in NRM.DeepNet, and better results were obtained.

5. Conclusion

In recent years, the use of deep learning models for scientific data processing in data analysis has been the focus of attention of scholars at home and abroad at present. However, the currently employed deep learning models exhibit poor ability to extract local features from scientific data and are unable to make full use of the nonlinear fusion characteristics of various scientific items to improve the processing efficiency of the models. To solve this problem, this paper proposes a deep learning method using nonlinear random matrices, and based on this, we carry out the design of an intelligent scientific research management system, use deep learning techniques for data classification processing, and then carry out modal feature extraction of scientific data, apply nonlinear random matrices for feature weighting during the modal extraction process, perform feature weighting, and finally classify, intellectualise, and regularise different scientific research data features of different scientific research projects. The nonlinear random matrix and deep learning technology are introduced into the intelligent scientific research management system, and its data and system management are updated so as to realize the intelligence and humanisation of scientific research management, thus reducing the labour intensity of scientific research work and improving the efficiency of scientific research. In this paper, we have analysed and processed data from three groups of scientific image data and proved that the model is noise-resistant and can be used for data management of scientific research projects.

Data Availability

The dataset used in this paper are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

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