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An evaluation of the quality of university education based on multidimensional time series analysis

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ABSTRACT: A model is proposed in this article, for the evaluation of the quality of university education based on multidimensional time series analysis. This analysis takes into account the integrated effect of multiple influential factors along with the periodicity and random effect of environmental variables. Multiple quantified indexes of teaching evaluation were input into the model, while teaching effects were output. A more accurate evaluation of the quality of university education can be obtained using multidimensional time series. Comparing the proposed model with other traditional time series models, it was found that the multidimensional hidden periodic auto-regression model was useful and accurate in analysing the multiple influential factors time series on the quality of university education. The optimum model can be used to evaluate the quality of university education, and to determine the period and random change rules of multiple influential factors.

INTRODUCTION

Over the past 20 years, there has been an increased focus on the importance of an undergraduate education, a reconsideration of the intrinsic value of teaching, and an interest in establishing criteria to identify excellent teaching for both formative and summative evaluation purposes. A requirement is to improve the assessment system for higher education as an important tool to strengthen the guidance to management of higher education given the new circumstances of expanding school autonomy. However, it is difficult to evaluate objectively the quality of teaching in higher education. There are many factors that impact on higher education teaching at different levels. These have different weightings, and there are also the integrated effects of multiple influential factors, along with the periodicity and random effects of environmental variables. These features imply a preference for a model based on a periodical multidimensional comprehensive evaluation to assess the quality of higher education teaching.

In recent years, many scholars have focused on the evaluation of education quality. However, most researchers have focused on the use of intelligent methods, which are limited [1-8]; they only emphasise the fit of the model [1-4] and give little consideration to the reasoning ability and predictive capabilities of the model [5-8].

Multidimensional time series analysis is a method of establishing a multidimensional stochastic model for multidimensional time series based on their autocorrelation and cross-correlation and utilises the stochastic model to predict trends. Traditional time series analysis usually ignores the period change rule or the integrated effect of multidimensional time series.

In this article, a new multidimensional composite time series model for the evaluation of education quality is proposed, taking into account the integrated effects of multiple influential factors along with the periodicity and random effect of environmental variables.

MULTIDIMENSIONAL TIME SERIES MODELLING

In the monitoring of education quality, multiple influence data are usually collected at defined intervals, producing a homogeneous variance. Let $\mathbf{Y}_t$ denote the multiple influential factors measurement at time t. Based on the Cramer Decomposition Theorem, any multidimensional time series $\{\mathbf{Y}_t\}$ can be decomposed into two components: a deterministic component and a stationary random component.

Due to the periodic effect of environmental variables, the deterministic components of influential factors are usually periodic rather than aperiodic. Hence, the deterministic component $\mathbf{Y}_t$ can be expressed as:

$$\mathbf{Y}_t = \mathbf{S}_t + \mathbf{R}_t,$$
$$\mathbf{Y}_t = \begin{pmatrix} y_{1t} \\ y_{2t} \\ \vdots \\ y_{nt} \end{pmatrix}, \mathbf{S}_t = \begin{pmatrix} s_{1t} \\ s_{2t} \\ \vdots \\ s_{nt} \end{pmatrix}, \mathbf{R}_t = \begin{pmatrix} r_{1t} \\ r_{2t} \\ \vdots \\ r_{nt} \end{pmatrix}, \ t = 1, 2, \cdots, N \tag{1}$$

Here $\mathbf{S}_t$ is the multidimensional seasonal component; $\mathbf{R}_t$ is the multidimensional stationary random component; y_{it} is a monitoring data of the i^{th} influential factor; s_{it} is the seasonal component of the i^{th} influential factor; r_{it} is the stationary random component of i^{th} influential factor; $i = 1,2,\ldots, n$, where n is the total number of influential factors and N is total sampling time.

Multidimensional Seasonal Component Modelling

$\mathbf{S}_t$ is modelled using a multi-dependent Hidden Periodic model:

$$\mathbf{S}_t = \mathbf{S}(t) = \begin{pmatrix} S_{1t} \\ S_{2t} \\ \vdots \\ S_{nt} \end{pmatrix} = \begin{pmatrix} \sum_{j=1}^{k} a_{1j} \cos(\omega_j t + \varphi_{1j}) \\ \sum_{j=1}^{k} a_{2j} \cos(\omega_j t + \varphi_{2j}) \\ \vdots \\ \sum_{j=1}^{k} a_{nj} \cos(\omega_j t + \varphi_{nj}) \end{pmatrix} \tag{2}$$

Here $\mathbf{S}(t)$ is a n-dependent variable hidden periodic function, which effectively fits the period of the monitoring data; a_i is the amplitude of i^{th} influential factor; k is the total number of angular frequencies; ω_j is the j^{th} angular frequency; φ_j is the j^{th} phase, $i = 1,2,\ldots,n$.

Multidimensional Random Component Modelling

The multidimensional seasonal component $\mathbf{S}_t$ is extracted from multiple influential factors. Then, the multidimensional random component $\mathbf{R}_t$, is modelled using a multidimensional auto-regressive model:

$$\mathbf{R}_t = \sum_{j=1}^{p} \mathbf{H}_j \mathbf{R}_{t-j} + \mathbf{E}_t,$$
$$\mathbf{H}_j = \begin{pmatrix} \eta_{11j} & \eta_{12j} & \cdots & \eta_{1nj} \\ \eta_{21j} & \eta_{22j} & \cdots & \eta_{2nj} \\ \vdots & \vdots & \ddots & \vdots \\ \eta_{n1j} & \eta_{n2j} & \cdots & \eta_{nnj} \end{pmatrix}, \mathbf{E}_t = \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \vdots \\ \varepsilon_{nt} \end{pmatrix} \tag{3}$$

Here p is the order of the multidimensional auto-regressive model; $\mathbf{H}_j$ is an $n \times n$ multidimensional auto-regressive coefficient matrix. $ç_{ikj}$ is the i^{th} influential factor multidimensional auto-regressive coefficient for the k^{th} influential factor; $\mathbf{E}_t$ is a n-dimensional white noise vector, which obeys $N[0, \mathbf{Q}]$; $å_{it}$ is the white noise of i^{th} influential factor, $i = 1,2,\ldots,n$, $k = 1,2,\ldots,n$.

Multiple Influential Factor Time Series Modelling

The multi-dependent Hidden Periodic model for the multidimensional cyclical component $\mathbf{S}_t$ and the multidimensional AR model of the multidimensional stationary random component $\mathbf{R}_t$ are combined yielding $\mathbf{Y}_t$. Hence, the influential factor measurement $\mathbf{Y}_t$ is obtained as:

$$\mathbf{Y}_t = \mathbf{S}_t + \mathbf{R}_t = \mathbf{S}(t) + \sum_{j=1}^{p} \mathbf{H}_j \mathbf{R}_{t-j} + \mathbf{E}_t \tag{4}$$

It can also be expressed as:

$$\begin{pmatrix} y_{1t} \\ y_{2t} \\ \vdots \\ y_{nt} \end{pmatrix} = \begin{pmatrix} \sum_{j=1}^{k} a_{1j}\cos(\omega_j t+\varphi_{1j}) \\ \sum_{j=1}^{k} a_{2j}\cos(\omega_j t+\varphi_{2j}) \\ \vdots \\ \sum_{j=1}^{k} a_{nj}\cos(\omega_j t+\varphi_{nj}) \end{pmatrix} + \sum_{j=1}^{p} \begin{pmatrix} \eta_{11j} & \eta_{12j} & \cdots & \eta_{1nj} \\ \eta_{21j} & \eta_{22j} & \cdots & \eta_{2nj} \\ \vdots & \vdots & \ddots & \vdots \\ \eta_{n1j} & \eta_{n2j} & \cdots & \eta_{nnj} \end{pmatrix} \begin{pmatrix} r_{1(t-j)} \\ r_{2(t-j)} \\ \vdots \\ r_{n(t-j)} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \vdots \\ \varepsilon_{nt} \end{pmatrix} \tag{5}$$

Equation (5) is a new multidimensional composite time series model, and it is also called the Multidimensional Hidden Periodic Auto-regression (MHPAR) model in this article.

MHPAR Model Prediction

The l^{th} step prediction of $\mathbf{Y}_t$ is obtained from the best linear unbiased prediction of Equation (4). The predictive formula is:

$$\mathbf{Y}_{N+l} = \mathbf{S}_{N+l} + \mathbf{R}_{N+l} = \mathbf{S}\left(N+l\right) + \sum_{j=1}^{p} \mathbf{H}_j \mathbf{R}_{N+l-j}, l = 1, 2, \cdots \tag{6}$$

VALIDATION OF EDUCATION QUALITY EVALUATION MODEL

Teaching conditions, the teaching process and teaching quality are the main factors that affect the quality of education. Reported in this article is the assessment of an automation major in a university. A survey was undertaken of an undergraduate teaching assessment. Seven indices were used in a questionnaire, i.e. 1) clear, natural language and standard Mandarin; 2) skilled content in the teaching and accurate concepts; 3) systematic and good logic; 4) fair and orderly classroom organisation; 5) mobilise the enthusiasm and initiative of the students; 6) regulate teaching according to the feedback of students; and 7) students' benefits from the course.

Hence, teaching language; teaching content; being logical and systematic; students' progress and outcomes are seven influential factors in this article. Teaching quality is the reference index to judge the quality of education. Twenty months of monitored data of the seven influential factors of teaching quality from an automation major in a university from September in 2011 to July in 2013 were selected to validate the MHPAR education quality evaluation model for universities. The results are shown in Table 1 and Figure 1.

Table 1: Influential factors and teaching quality (TQ) data.

Year/ Month	Influential factors							TQ
	1	2	3	4	5	6	7	
2011/09	6.5	4	5.5	6	9	8.5	4.5	7.2
2011/10	6	6	6	7.5	5	6.5	7	6.7
2011/11	7	7.5	8	7	8.5	7	7.5	8.5
2011/12	4	4	3	4.5	5	6.5	5.5	6.2
2012/01	5	5.5	6.5	5	4	5.5	6	6.2
2012/03	7	3	6	5	4	5.5	6.5	6.7
2012/04	8	5	6	5	5.5	6	7	7.5
2012/05	6	5	8	5.5	4	4	4.5	6.2
2012/06	4	8	6	5	6	5	7	6.7
2012/07	5.5	4	4	3	2.5	4	6	6.2
2012/09	8	7.5	7	7	8.5	7.7	8	8
2012/10	6	9	5.5	6.5	5	6.5	6	6.5
2012/11	8.5	8.5	5.5	7	8	8.5	7.5	7.5
2012/12	3	9	6	6	7	6	6	6.7
2013/01	5	4	4	3	3	4	6	7
2013/03	8	7	7	6	6	5.5	6.5	7.5
2013/04	3.5	4.5	5	5.5	4	4.5	5.5	6
2013/05	8.5	4.5	9	5	6	8.6	7.5	6.7
2013/06	6	9	7	7.5	4	6.5	7	7.5
2013/07	7.5	6.5	5	4.5	5.5	6.5	7	6.7

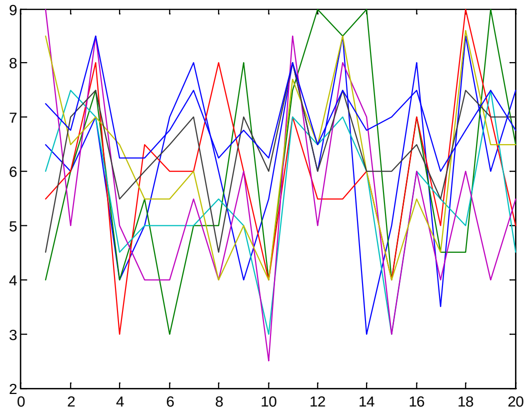

Figure 1: 20 months' monitoring data.

Nineteen months of monitoring data of seven influential factors of teaching quality from September 2011 to June 2013 are shown in Figure 2. These data were used for MHPAR modelling and to predict the reference indices for the 20th month, i.e. July 2013.

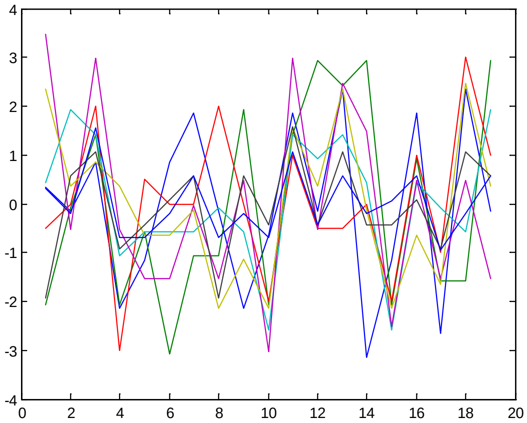

Figure 2: 19 months' pre-processed monitoring data.

The seasonal component of 19 months of monitoring data is shown in Figure 3. Here, blue curves are monitoring data, and the red curves are the seasonal component of the monitoring data.

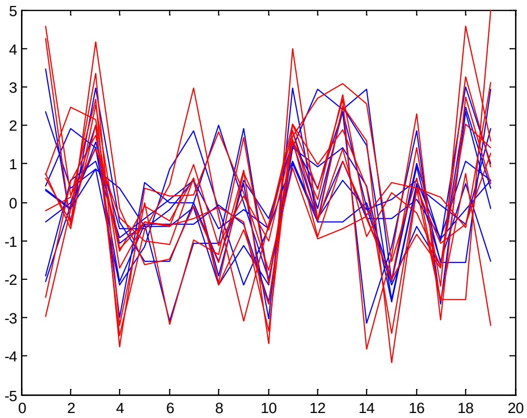

Figure 3: Seasonal component of the monitoring data.

The teaching quality of the 20th month evaluated by the MHPAR model, is shown in Figure 4 and Table 2. Here, the blue curves are the monitoring data; the green curves are the evaluation data of the seven influential factors; the red dotted curve is the evaluation of teaching quality; and the black dotted curve is the teaching quality. Note that the monitoring data of teaching quality are very close to the evaluation data of teaching quality, i.e. the red dotted curve and black dotted curve coincide with each other, making the black dotted curve invisible.

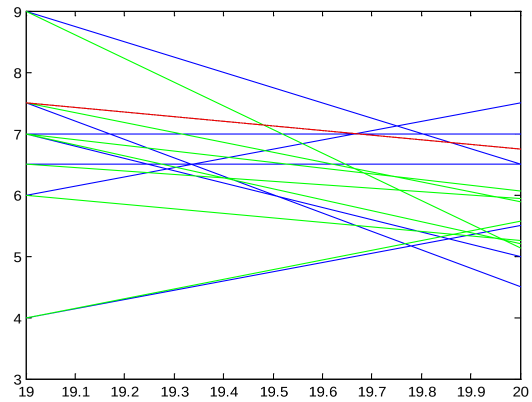

Figure 4: 20th month evaluation by MHPAR model.

The same monitoring data were also used for one-dimensional Hidden Periodic Auto-regression (HPAR) modelling and estimation for comparison. The evaluation result for the HPAR model is shown in Figure 5 and Table 2.

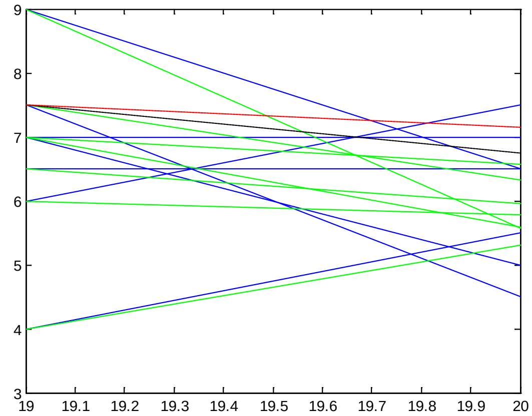

Figure 5: 20th month evaluation by HPAR model.

Teaching quality at the 20th month evaluated by the MHPAR model and by the HPAR model is shown in Figure 6. The blue dotted curve is the real monitoring data of teaching quality at the 20th month; the magenta dotted curve is the teaching quality at the 20th month evaluated by the HPAR model; the red dotted curve is the teaching quality at the 20th month evaluated by the MHPAR model. Note that the monitoring data of teaching quality is very close to the evaluation data of teaching quality; therefore the red dotted curve and blue dotted curve coincide and, hence, the blue dotted curve is invisible.

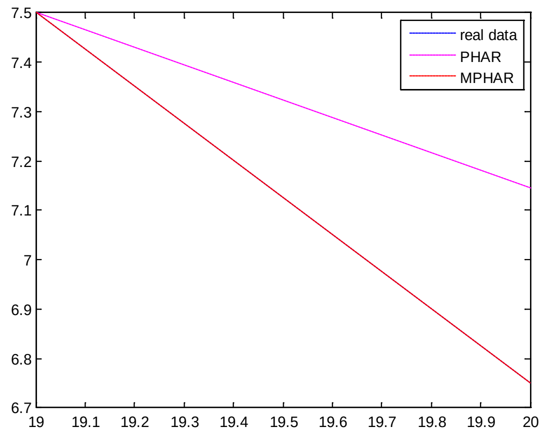

Figure 6: 20th month evaluation of teaching quality by two models.

The teaching quality at the 20th month evaluated by the MHPAR model and by the HPAR model, and their evaluation errors, are shown in Table 2.

Table 2: Comparison of education quality evaluation by different models.

Model	HPAR	MHPAR	Real data
Teaching quality	7.1445	6.7504	6.75
Evaluation error	2.1043	0.002	-

From Table 2 and Figures 4 to 6, the accuracy of MHPAR is higher than HPAR in education quality. The MHPAR was improved based on HPAR by taking into account the integrated effects of multiple influential factors.

CONCLUSION

A new MHPAR model is proposed to analyse multiple influence factors time series for the evaluation of education quality. A more accurate model of education quality was obtained by combining time series methods. The evaluation results demonstrate the effectiveness of the proposed model.

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