Expert Systems with Applications 42 (2015) 2691–2702

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Reconciling internal and external performance in a holistic approach: A Bayesian network model in higher education

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ARTICLE INFO

Article history:
Available online 15 November 2014

Keywords:
Bayesian networks
Internal and external performance
Holistic approach
Quality in higher education

ABSTRACT

University education is crucial for cultural and economic growth. Thus, the academic mission recognizes the achievement of both institutional and social objectives, and research provides the basis for the systematic creation of knowledge and the development of human capital. Universities attempt to manage a global system with a holistic vision based on data and facts and oriented to the continuous improvement of its effectiveness and efficiency. The goal is achieved by implementing a monitoring system based both on internal and external performances. As a consequence, it is necessary to consider both students perspective regarding needs, expectations, level of satisfaction and loyalty and internal key performance indicators.

This paper proposes the use of Bayesian networks for jointly monitoring internal and external performance of a Master's programme of an Italian University in a holistic approach. A Bayesian network is estimated using a learning algorithm able to analyze the association structure among mixed ordinal and nominal variables. Various scenarios are evaluated thanks to efficient computational algorithms of Bayesian networks.

1. Introduction

Quality in the higher education system is essential for cultural and economic growth, considering that the mission of universities recognizes the achievement of both institutional and social objectives, and research provides the basis for the systematic creation of knowledge and the development of human capital (Di Pietro, Guglielmetti Mugion, & Renzi, 2012).

Since 1980, total quality management (TQM) has become an essential of the higher education system and was considered an interesting philosophy for governance (Srikanthan & Dalrymple, 2002). To increase the quality of input, processes, and output, university systems must monitor their internal and external performance and emphasize the need for continuous improvements to achieve efficiency and effectiveness. The principles of TQM have been adopted in university systems to address external factors. Hwarng and Teo (2001) note that higher education has so far been sustainable because education has traditionally been funded by the government and the competition for quality students and grants has been less intense. The authors emphasize that this scenario is currently changing because of the increased competition that has been created by rapidly changing technology and growing international competition for students, faculty, and a demand for the delivery of excellent programmes from research institutions.

Furthermore, due to declining public funds and rising tuition fees, higher education establishments worldwide have adopted a customer perspective (Eagle & Brennan, 2007). Certain universities, as suggested by Paswan and Ganesh (2009), are realizing that higher educational institutions are business entities, and as such, they too must compete for resources and customers, or students, in local and international markets. With respect to higher education, students are the main consumers of the didactic offer (Gremler & McCollough, 2002; Hill, 1995; Moosmayer & Siems, 2012; Sander, Stevenson, King, & Coates, 2000); therefore, university management must respond to stakeholders' desires and needs (students, parents, etc.). Thus, the opinion of students with respect to teaching, organization and related auxiliary services, is relevant for the identification of inefficiencies and ineffectiveness within a

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http://dx.doi.org/10.1016/j.eswa.2014.11.019
0957-4174/

system and for the initiation of appropriate corrective actions. However, student opinion needs to be analyzed in conjunction with the significant key performance indicators (KPIs) that reflect student performance (Ramsden, 1991).

In fact, the internal KPI monitoring system of a Master's programme is important for the Board in the development of future strategies and in the demonstration of the effective and efficient use of public resources and funds, but it needs to be integrated with the students perspective regarding needs, expectations, level of satisfaction and loyalty. For instance, if a student does not study or partake in lectures, such behavior can adversely affect resulting satisfaction levels.

In this complex context, it becomes crucial to develop a model embracing administrative activities, teaching, community service areas and student key performance indicators (such as number of exams passed). We address such all-embracing models, as *holistic* models.

Up to now statistical models have not been proposed to analyze higher education systems from this global point of view. In this paper we propose the use of a multivariate statistical model such as a Bayesian network (henceforth BN) to study and derive the association structure among the various higher education features. BNs appear to be particularly useful in this context since they allow to distinguish the variables directly affecting from those indirectly affecting student satisfaction and student KPI. Moreover BNs are themselves decision support systems so that they provide not only an easy-to-read picture of the satisfaction generating process and successful student performance but also an efficient tool to evaluate various scenarios and/or the impact of possible decisions of the programme boards.

On the other side, estimating, i.e. learning, the BN from real data is a challenging problem. In fact, most variables of interest are ordinal since they refer to satisfaction levels about various different aspects of the education programme and levels of performance indicators. Additionally, other features are surveyed on a nominal scale. This means that the analyzed data resulting from education surveys generally comprise both nominal and ordinal variables.

Often, categorical data (ordinal and nominal) are treated as if they were all nominal when structural learning is performed. In such a way, relevant information in the data could be overlooked and consequently the estimated association structure could miss crucial relations. Therefore, we need to use structural learning algorithms suitable to catch the most of information contained in the survey data. To this aim, in this paper we will resort to a variation of the PC algorithm (Musella, 2011, 2013) allowing to analyze ordinal-to-ordinal and nominal-to-ordinal associations with test statistics specifically chosen for the variables pair.

The paper is organized as follows. A brief introduction about the state of the art in measuring the student satisfaction is discussed in Section 2. A background on Bayesian networks is provided in Section 3. Section 4 is devoted to describe the Italian higher education sector. The application is provided in Section 5 that discusses the estimation and the usage of the model. Section 6, addresses conclusions, the main research contributions and possible implications for the next future.

2. Measuring student satisfaction – state of the art

Many universities began implementing total quality strategies under an administrative leadership and shied away from classroom and curriculum issues (Brigham, 1993). Bonvillian et al. (cited in Sims & Sims, 1995 p. 39) confirmed that TQM is not focused on '*core functions of teaching and learning*'. Freed, Klugman, and Fife (1997) discuss the implementation of an adaptation of total quality management to higher education.

Clewes (2003) highlighted several studies that demonstrated the complexity in defining the multifaceted concept of quality in higher education; therefore, there is no unique way to identify and measure this type of service quality.

The literature review presents interesting contributions on students evaluation regarding perception of courses and their impact on students learning. Marsh (1987) identified the following drivers: workload, teachers' explanations, empathy (interest in students), openness, and the quality of assessment procedures (including quality of feedback) and he reports that "there is agreement between lecturers and students on the characteristics of good teaching in higher education, despite the fact that lecturers are usually more generous in their ratings of themselves."

Browne, Kaldenberg, Browne, & Brown, 2008 proposes a survey based on the SERVQUAL method (Parasuraman, Zeithaml, & Berry, 1994) on the relations between students satisfaction and the judgment of the service performance provided by a university college considering the overall satisfaction, the willingness to recommend and value received from the educational experience (curriculum, courses content, breadth of curriculum, exposure to practical topics, diversity and career provision etc.). An interesting study realized by Sangeeta (2011) advises the integration of multiple methodologies (the Servqual, the Kano model and the Quality Function Deployment) to gain students insights into a customer satisfaction systematic programme. Clemes, Gan, & Kao, 2008 noted that educational outcomes are the consequences or results associated with instructional experience – the *end* results of institutional, programme, or curricular goals. Assessing student outcomes often requires discovering what students are capable of after they have completed their studies or requires measuring the knowledge, skills and abilities students have attained (Gardiner, Anderson, & Cambridge, 1997) after instructional experiences. Student satisfaction represents a useful indicator with respect to the ability of a university to comprehend and satisfy student needs. However, students' satisfaction results have to be considered within an overall perspective in order to implement improvement strategies (Nair, Adams, Ferraiuolo, & Curtis, 2006; Nair & Bennett, 2010).

As far as a quantitative analysis is concerned, from the above literature review it came out that higher education student satisfaction has been generally studied with traditional methods, such as SERVQUAL and Kano model. The relevant literature contributions are generally focused on conceptual models for performance in higher education (Alves & Raposo, 2007; Clewes, 2003; Douglas, McClelland, & Davies, 2008; Schertzer & Schertzer, 2004); only few case-studies have been quantitatively studied by using a statistical model and much less have been analyzed according to a holistic approach (Bliuc, Goodyear, & Ellis, 2007; Srikanthan & Dalrymple, 2002). In this sense, this paper aims at providing an innovative contribution to the applied field and a first attempt to build a BN based holistic model to analyze the student satisfaction generating process together with student performance indicators.

3. Background on Bayesian networks

Graphical models (Lauritzen, 1996) are a family of multivariate statistical models satisfying set of (conditional) independence statements contained in a graph. The easy-to-read graphical representation associated with the statistical model has increased the use of graphical models in many fields such as physics (Gibbs, 1902), genetics (see for instance Wright (1921) and Friedman (2004)), process problems detection (Perkusich, Hyggo Almeida, & Perkusich, 2015), economics (Mortera, Vicard, & Vergari, 2013; Wold, 1954), forensic genetics (Dawid, Mortera, & Vicard, 2007) and social science (Blalock, 1971). In particular, BNs (Cowell, Dawid, Lauritzen, & Spiegelhalter, 1999) portray the statistical