Towards Intelligent System Framework for Smart University Using Big Data Analysis

Khin Sandar Kyaw[1*], Tharnpas Sattayaraksa[1], Praman Tepsongkroh[2], Chanwut Thongkamkaew[3], Farida Sasha[4], Natsamol Jirangvoraphot[5] and Jekita Charoen[5]

[1] Dr., Lecturer, Department of International Business Management, Didyasarin International College, Hatyai University, Thailand.

[2] Assoc. Prof. Dr., Dean, Department of Airline Business, Didyasarin International College, Hatyai University, Thailand.

[3] Head of Department, Department of International Business Management, Didyasarin International College, Hatyai University, Thailand.

[4] Dr., Lecturer, Department of Management, Hatyai Business School, Hatyai University, Thailand.

[5] Lecturer, Department of International Business Management, Didyasarin International College, Hatyai University, Thailand.

[*]**Corresponding author, E-mail:** khinsandarkyaw@hu.ac.th

Abstract

In the era of information technology, there is a tremendous flow of data on the digital platform, both private and public. Development of intelligent models through data analysis has gained relevance in various sectors including education, business, agricultural, and medicine. The astronomical surge in data volume, variation, and velocity has been described as big data. Simultaneously, analysis scheme for data has changed progressively from offline to real time big data analysis on the internet platform. Meanwhile, the evolution and adoption of digital platform and smart system by various sectors poses a complex challenge to data analysis. In this paper, intelligent system for smart university using big data analysis conceptual framework is proposed to enhance the performance of learning, teaching, and administration to accommodate the unexpected changes imposed by the current Covid-19 pandemic. The proposed conceptual framework is intended to ease stress, improve life standard, and ensure safety and developments for the education sector and university strategy sector.

In addition, smart users can save time, and maximize learning, teaching, and administrating by effectively working from home without communication lacuna.

Keywords: Real Time Series Analysis, Internet Of Things, Smart Education Platform, Intelligence Model, Recommendation System, Argument Reality

Introduction

In recent years, the development of smart system has become a fascinating trend in several sectors due to the remarkable progress in internetworking service and IoT devices. In general, smart system incorporates functions of sensing, actuation, and control to perform analysis for current situation and create decision-making system based on the knowledge derived from data resources. The effective transformation into smart system requires sophisticated analysis process for huge volume of data to model the intelligent system. Data analysis is a process that involves data collection, transformation, cleaning, and visualization. In data analysis process, data collected from smart system is processed through the cleaning and visualization step to determine useful character of data required for intelligence system modelling for prediction, recommendation, decision-making system.

The concept of smart university entails the incorporation of digital, innovative, and internet-based technologies to enhances the education, research, and work experience of stakeholders and promote the betterment of the society at-large. Smart university consists of several sectors including smart campus, smart education, and smart administrations. This work proposes an intelligent system framework for transforming from a manual based university into a smart university. The proposed intelligent system framework includes the collection of data from possible data sources, preprocessing, visualization and analysis of the preprocessed data, and modelling recommendation system for learner, decision-making system for instructor, and prediction system for administrators based on the historical data analysis results from all possible university data sources.

Objectives

This research framework is intended for higher education development with the following concise purposes:

- To develop smart university platform with intelligent system framework
- To establish robust educational platforms suited for current pandemic situation
- To create a universal broadband education platform through knowledge-based automation system

Literature Review

In this section, the fundamental and critical domains needed to build the intelligent system framework for smart university are described based on recent related work. The development of smart infrastructure is the most fundamental requirements for transforming from a conventional university into a sophisticated smart university. This is because all university digital data can be accumulated through smart campus framework. Moreover, smart users including students, instructors, and administrators are required to build a smart education and smart administration frameworks since they constitute the primary resource of data needed for analysis and knowledge discovery process for smart university.

Smart Campus Framework and Technology

Smart campus framework can be a supportive platform for obtaining data resources that can assist the data analysis process in learning, teaching, and administration. Regarding the technology for smart campus framework, several mechanisms are proposed such as radio-frequency identification (RFID) (Malatji 2017), Internet of Things (IoT) (Alghamdi and Shetty 2016), cloud computing (Du, Meng, and Gao 2017), 3D visualization technology and argument reality (Torres-Sospedra et al. 2015), sensor technology (Ariyanti 2016), mobile technology (Atif, Mathew, and Lakas 2015), and web service (Manqele et al. 2015). In (Alghamdi and Shetty 2016), the authors investigated the challenges and research opportunity regarding IoT technology for smart campus. In addition, radio frequency identification (RFID) and wireless sensor network (WSN) technology was proposed for solving problems concerned with smart student attendance,

smart automation of electrical items and roll call in authenticated manner (Al Shimmary, Al Nayar, and Kubba 2015).

Smart Education Framework and Technology

Smart education framework is an automatic digital platform system that connects people with several roles in the university, mainly those involved in teaching and learning. Parties utilize smart devices to access digital teaching and learning resources via wireless network and to immerse in both personalized and seamless teaching and learning. The concept of smart education entails the emergence of technologies such as smart boards, smart screens, and wireless Internet access from everywhere. Smart education framework is composed of two sets of smart users including smart learners and smart instructors. In addition, it includes the development of several functional smart units including smart tutoring units, smart teaching monitoring unit, smart learning monitoring unit, smart classroom management unit, smart library access unit, smart learner performance analysis unit, and so on. Authors in (Zhu, Yu, and Riezebos 2016), proposed a four-tier framework of smart pedagogies and ten key features of smart learning environments. They described the smart pedagogy framework including individual-based personalized learning, mass-based generative learning, group-based collaborative learning, and class-based differentiated instruction. An intelligent tutoring system for learning computer network was described by (Al-Hanjori, Shaath, and Abu Naser 2017). They utilized the Intelligent Tutoring System Builder (ITSB) tool in the implementation of the intelligent tutoring system for learning computer network. The ITSB development tool consists of two functions including set up teaching material, questions and answers for instructor and learning access and responding tests for learners.

Smart Administration Framework and Technology

Smart administration framework has a spread of several functions across all sectors of the smart university such as registration, authentication, employee assessment, social network contribution, payment transaction, work-flow management, events, and context control, and so on. According to (Bueno-Delgado et al. 2012), several technologies have been developed for transforming into a smart based administration system. Near Field Communication (NFC) is one popular technology for combining a wireless proximity communication technology with mobile phones. It enables the

unaware user interaction with the smart computing elements of the environment by simply “touching” them, thereby adding new value to mobile phone users. Basically, NFC intends to develop applications for attendance registering-system and theory lessons, and payment-system at university.

Research Methodology

Background Knowledge

Smart University Units and Technologies

The transformation from digital to smart university platform entails implementation of several new technologies for the development of the information system. Figure 1 illustrates the block diagram for smart university units and technologies. The implementation of emerging intelligent system-based smart university involves smart campus infrastructure development as a major concern unit. The infrastructure of smart campus demands fundamental integration of Internet of things, internetworking, and cloud-based storage on the physical layer.

Since university data from several resources passes through the cloud platform to supply real time information among several university sectors vis-a-vis teaching, learning, and administration, the role of real time-series data processing, big data analysis and distributed computing technologies critically participates in the analysis and computing layer of smart university. Moreover, the topmost layer of smart university is concerned with the generation of intelligence for smart users within the smart university environment by providing knowledge-based systems such as prediction, decision making, and recommendation. The intelligent framework for smart university is modelled using feature patterns derived from knowledge discovery process on the visualized and analyzed data from several data sources.

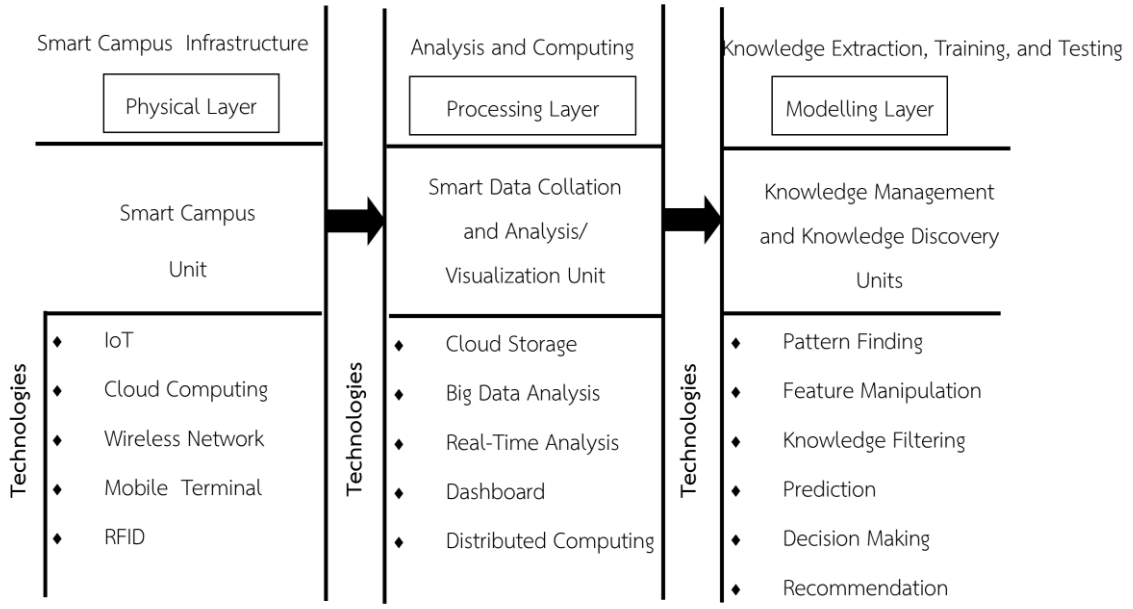

Figure 1 Block Diagram for Smart University Units and Technologies

Big Data Analysis Unit in Smart University

With the passage of real-time data through information system in the smart university, huge amount of unstructured dynamic data is accumulated on the cloud platform. Thus, smart university data on the cloud platform increases in volume, velocity and variety and transforms into big data, which can be utilized for knowledge extraction for intelligent system including decision-making system, recommendation system, prediction system. In the process of knowledge discovery, big data analytic play a critical role for data mining to provide pattern and business knowledge at unprecedented scale and specificity. Figure 2 presents functional diagram for big data analysis unit in smart university. It includes four main phases including collation, processing, cleansing, and analyzing, to accomplish the big data analysis process on three smart university data resources. Moreover, big data analysis utilizes the analytical methodologies and tools including correlations, cluster analysis, filtering, decision trees, Bayesian analysis, neural network analysis, regression analysis, and textural analysis.

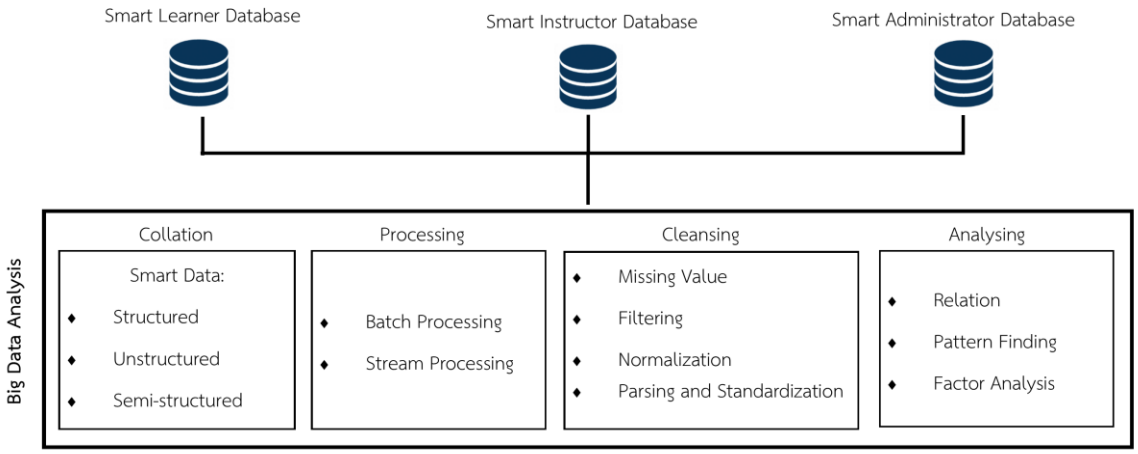

Figure 2 Functional Diagram for Big Data Analysis Unit in Smart University

Cloud Computing Unit in Smart University

Recently, the cloud-based platform has been recognized as a hot trend technology in smart university domain. Cloud computing utilizes distributed computation which enables to access a shared pool of configurable computing resources including networks, storage, and applications. Smart university applies cloud computing with software platform to develop an information system for several sectors of the university to access server virtualization, teaching management, and communications and administration services.

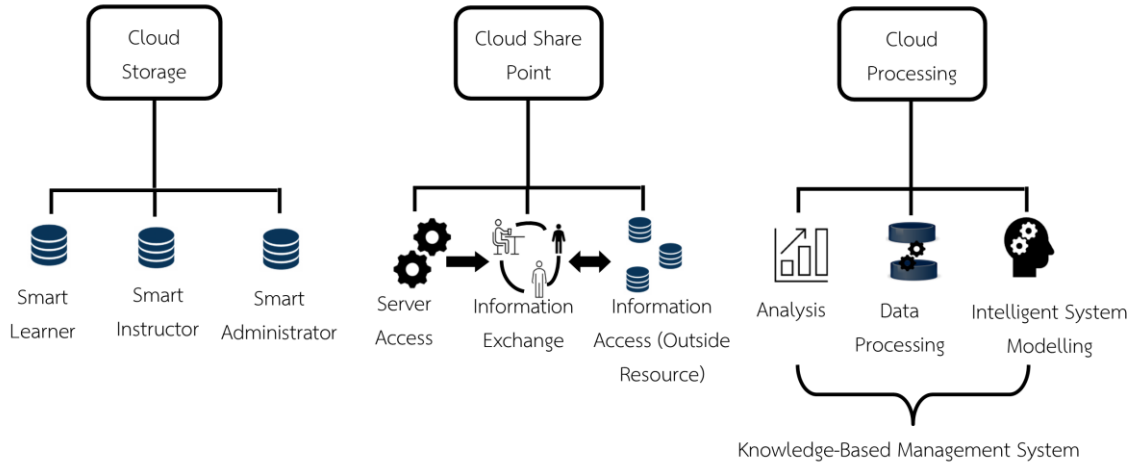

Figure 3 Process Block Diagram of Cloud Computing Unit in Smart University

Figure 3 shows the process block diagram of cloud computing unit in smart university. Cloud computing allows the learners to achieve access to online learning resources conveniently in an unstructured environment with high speed, infinite scalability, and low computation cost. It enables the seamlessly creation and sharing of virtual learning materials. In addition, cloud processing can help to compute knowledge for modelling intelligent system for smart users.

Distributed Data Processing in Smart University

Several distributed data processing technologies involving Hadoop and Spark are developed to support the smart grid data analytics. The framework contains several comprehensive analysis algorithms that can be applied in real-time, and close-loop data solutions for grid data storage (D. Wang and Xiao 2012), data processing, and data analysis. Since smart university data is distributed on several sources, the processing of data is a big challenge for performing computing on every single node. In addition, smart university utilizes the cloud platform for huge data accumulation. Therefore, distributed data processing is proposed for parallel processing on data partitions and computing for big data analysis on the cloud platform. Data partitioning involves the fragmentation of a logical database into separate independent blocks for the scaling of data to speed up parallelism computing. The shared nothing scale-out parallelism (distributed computation) provides the best data partitioning strategy to achieve performance, load balancing, and least cross-partition coordination. In the perspective of computing, the role of distributed data processing is to provide the scheme for balancing the computation load on multiple nodes of the analytics cluster.

Intelligent System Modelling Unit in Smart University

Since smart university integrates IoT and other data sensing technologies in the physical layer, a huge amount of information pass through the cloud data platform in every time. This motivates the implementation of several intelligence systems based on feature impact for different role of the university. Based on education and administration role in smart university, student recommendation system (SRS), instructor decision-making system (IDS), and administrator prediction system (APS) can be developed in the intelligent system framework (ISF) layer.

In addition, internal ISF outcomes can be used for business intelligence in university strategy development sector. In the ISF development phase, multi-layer calculations including data gathering, data visualization, data analysis, feature analysis, pattern finding, knowledge management process, are employed to retrieve relevant knowledge from corresponding intelligent systems. Figure 4 demonstrates three intelligent models for the proposed smart university intelligent system framework (SmartU-ISF). The knowledge outcome can be applied as a business intelligent for the development of university strategy in different sectors including staff, student, administrator, industrial collaboration.

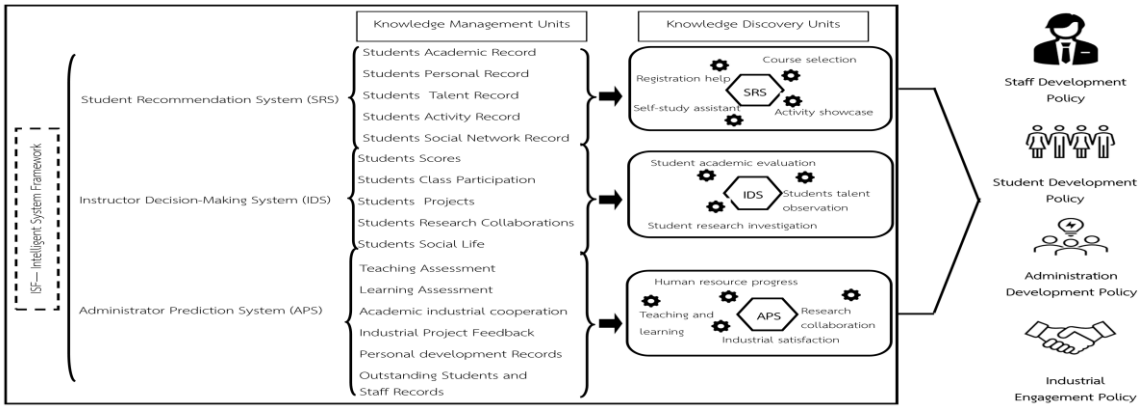

Figure 4 Intelligent System Modelling Unit in SmartU-ISF and University

The definition of student recommendation system (SRS) integrates several functions such as course selection, registration help, university facility acquisition (student loan, student health care and insurance), self-study assistant with learning management system (LMS), activity showcase, supervisor finding, career connectivity, research space and so on. In the role of instructor decision-making system (IDS), student academic evaluation, student talent observation, student research investigation, student personal relationship monitoring (depends on the group activity criteria), student industrial collaboration bridge.

The administrator prediction system (APS) plays the role to forecast university policy statements that are used for future university development based on the analysis results from all possible university sources including learning and teaching, industrial satisfaction, rate of collaboration for research, human resource progress, and so on. In addition, APS involves the implementation of prediction on future customer and student invitation with offering of promotion program and scholarship program based on behavior analysis results from student relationship management, and customer relationship management system.

Background Methodology

Intelligent system framework for smart university (SmartU-ISF) is designed with regards to the layer of operations involving data accumulation, data preprocessing, data analysis, feature manipulation, knowledge discovery and management process.

Proposed Intelligent System Framework in Smart University (SmartU-ISF)

The proposed SmartU-ISF includes several operations such as big data storage and sharing, big data analysis, unified identity management and authentication, one-stop personalized integrated management service system, mobile smart campus, and security design. Smart university data derived from IoT devices, and teaching, learning and management systems are connected to the university private storage module on the cloud platform. In the cloud computing module, distributed processing scheme is used to perform various data manipulation parallelly. The outcome of data visualization is used to collect suitable features to develop the intelligent systems for various smart users. In addition, the proposed framework intends to develop a recommendation system for smart learners, and a decision-making system for smart instructors with regards to assisting the education community, and a prediction system for administration act to perform a bridge between academic and industry sector. The functions and description of three intelligent systems in SmartU-ISF are summarized in Table 1.

Smart University Data Resources Management

While smart learners, smart instructors, and smart administrators act as the internal data suppliers, the smart customers, and smart partners play the role as the external data suppliers. To manage both internal and external data, data resource management framework integrates three layers including data resource layer, data partition layer, and data center layer. Data resource layer is the most fundamental layer which stores the overall information from multiple data sources to attain the comprehensive and accurate data, support data exchange between systems, provide a unified authentication service and so on. The core function of data resource management is performed on the data center. Data center is created on the cloud platform by connecting several data resources from the smart university. Before allocating the raw smart user data from data resource layer into their corresponding data block in smart data center, data resource management system works with a distributed

Table 1 Functions and description of three intelligent systems

Intelligent System	Smart/Intelligent Assistant	Function
Recommendation System [Smart Learners]	Course selection	Recommend course for students
	Registration help	Provide suggestion for student registration
	Facility acquisition	Support guidelines for acquiring student loan, student health care and insurance
	Self-study assistant with learning management system (LMS)	Recommend category of electronics books and research database
	Activity showcase	Alarm interesting activity based on student hobby
	Supervisor finding	Recommend mentor for supervision based on project and research interest
	Career connectivity	Provide information of career opportunity based on talent and skill
	Research space	Recommend joining research group based on student research interest, talent, and skill

Table 1 (Cont.)

Intelligent System	Smart/Intelligent Assistant	Function
Decision-making System [Smart Instructors]	Student academic evaluation	Provide grade level based on student performance
	Student talent observation	Guide student to have right career path
	Student research investigation	Assist student to have network for industrial research
	Student personal relationship monitoring	Help students to achieve healthy relationship for collaboration work (depends on the group activity criteria)
	Student industrial collaboration bridge	Provide industrial appointment based on student skill and passion
Prediction System [Smart Administrators]	Teaching and learning	Predict the possibility of education outcome
	Industrial satisfaction	Forecast the possible collaboration between academic and industry
	Rate of collaboration for research	Predict impact research area and future demand rate of research
	Human resource progress	Estimate personal development for providing coach in future
	Future customer and student invitation	Offering of promotion program and scholarship program, student relationship management, and customer relationship management system

Smart University Data Preprocessing

Data preprocessing is to clean and correct raw input data for speeding-up a machine learning process with a higher accuracy. Former methods are unable to provide a preprocessed smart dataset and therefore, are being redesigned with Big Data technologies to develop a collection of tools to enhance the acquisition of smart data from raw, unstructured data. Machine learning library (Salloum et al. 2016) is the most well-known library for Big Data and it is composes of a wide range of data preprocessing techniques for Spark community. The data preprocessing process includes several phases including discretization and normalization, feature extraction, feature selection, feature indexers and encoders, and text mining. Based on the characteristic of Big Data, several techniques can be applied to the raw data. For example, text mining techniques can be utilized to structure the input text with the yielding of structured patterns of information. In addition, Hadoop (L. Wang et al. 2018) can be used for preprocessing the raw Big Data with high computing speed. Another emerging platform likes Flink (Alcalde-Barrosa et al. 2018) can be employed to fill the gap of stream and batch processing. Moreover, scaling data preprocessing techniques such as instance reduction, missing values imputation, and noise treatment are also very fundamental and effective techniques for handling big data preprocessing.

Smart University Big Data Analytic

Data analytic is the process of applying algorithms to analyze sets of data and extract useful and unknow patterns, relationships, and information. The most common advanced data analytics methods include association rules, clustering, classification and decision trees, and regression have become common tools with big data. Smart university data analytic process involves finding the patterns among big data to build up the intelligent models such as recommendation system, decision-making system, and prediction system for corresponding sectors. In addition, big data analytics and decisions framework (Elgendy and Elragal 2016) can be applied to build decision making system using the big data analytic tools.

In addition, sentiment analysis can be applied for the analyzing and understanding of emotions from subjective text patterns. Sentiment analysis utilizes natural language processing and text analytics to identify and extract information by finding words that are indicative of a sentiment, as well as relationships between words. The updated potential growths among big data analytics options is Advanced Data Visualization (ADV) and visual discovery (Misra and Bera 2018). ADV composes of data analysis methods and interactive visualization to enable comprehensive data exploration. Since it is a data driven exploratory approach, it suitable for the situations where analysts have little knowledge about the data. Along with the size and complexity of big data, intuitive visual representation and interaction is needed to guide the analyst's perception and reasoning.

Smart University Feature Manipulation

Since smart university data has the complex characteristics of big data, it brings about a difficulty in obtaining a common feature selection method. Normally, several types of data are involved in big data including static big data, dynamic data, missing data, heterogeneous data, unreliable data, and imbalanced data. Thus, several available feature selection methods can be used for peculiar data type. These data can generally be classified into two, namely, large-scale data with a high dimension and small sample data with a high dimension.

For large-scale data with a high dimension, mRMR (max-relevancy and min-redundancy) (Gnana 2016) is a common and efficient tool that can search a set of features where the relevance between the feature and the class is maximized (max-relevancy) while the pairwise information between the features in the set is minimized (min-redundancy). Since pairwise comparisons for calculating the correlations between features are conducted, mutual information-based measures are used to cope with computational complexity. In a small sample with high dimensional data, the dimension is a major barrier to creating a predictive model to improve the efficiency of a feature selection method. Many schemes have been developed to extract features using both training data set and the unlabeled test data, such as MINT (He et al. 2016). Apart from the mutual information-based measure, the distance-based measure can be used to handle the process of feature selection with small-scale and high dimensional data.

In addition, TF-IDF (Manochandar and Punniyamoorthy 2018), Word2Vec (Ballı and Karasoy 2019), Tokenizer (Ghosh and Sanyal 2018), StopWordsRemover (Mohasseb et al. 2019), n-gram(Pang, Xue, and Namin 2016) calculations can be applied for selection of relevant feature from smart university text data. For dynamic data, several mechanisms have been developed such as SFS (El-Kenawy et al. 2020), Online streaming feature selection (OSFS) (H. Wang et al. 2018), and so on. Moreover, heterogeneous smart university data are often collected from different sources, with features consist of both numerical and non-numerical features and different characteristics and therefore it is not easy to evaluate heterogeneous features concurrently. Though several feature selection algorithms for heterogeneous data exist, rough set and mutual information are two efficient tools for heterogeneous feature selection problem.

Conclusion and Future Work

The proposed conceptual framework provides for the development of an intellligent systems for smart university using big data analysis. The paper describes the functionalities of three intelligent systems and provides some technologies for big data analytics, data preprocessing, and feature manipulations to help building the intelligent system framework in future smart university. This proposed SmartU-ISF can derive the business intelligent for the university strategy develpoment in three roles of smart users. The proposed framework will be implemented on cloud platform in which big data analysis will be performed on our private university data from three different roles including student, instructor, and administrator in future. In the development of proposed SmartU-ISF, Data mining and Machine Learning-based schemes will be applied on the stages of process including visulization, analysis, data preprocessing, knowledge extration, and intelligent system modelling. In addition, the detailed implementation tools and experimental set up for the proposed three models will be presented as a future work.

Acknowledgement

The authors wish to acknowledge the Department of International Business Management, Didyasarin International College, Hat Yai University and Dr Ozioma F. Nwabor for his assistance throughout the manuscript preparation phase.

References

Al-Hanjori, Mones M, Mohammed Z Shaath, and Samy S Abu Naser. 2017. "Learning Computer Networks Using Intelligent Tutoring System." *International Journal of Advanced Research and Development* 2(1): 2455–4030.

Alcalde-Barrosa, Alejandro, Diego García-Gila, Salvador García, and Francisco Herrera. 2018. "DPASF: A Flink Library for Streaming Data Preprocessing." *arXiv* 8: 1–17.

Alghamdi, Abdullah, and Sachin Shetty. 2016. "Survey toward a Smart Campus Using the Internet of Things." *Proceedings - 2016 IEEE 4th International Conference on Future Internet of Things and Cloud, FiCloud 2016*: 235–39.

Ariyanti. 2016. "Environtal Monitoring as an IoT Application in Building Smart Campus of Universitas Udayana" 42(1): 1–10.

Atif, Yacine, Sujith Samuel Mathew, and Abderahmane Lakas. 2015. "Building a Smart Campus to Support Ubiquitous Learning." *Journal of Ambient Intelligence and Humanized Computing* 6(2): 223–38.

Ballı, Serkan, and Onur Karasoy. 2019. "Development of Content-Based SMS Classification Application by Using Word2Vec-Based Feature Extraction." *IET Software* 13(4): 295–304.

Bueno-Delgado, M. V., P. Pavón-Marino, A. De-Gea-García, and A. Dolón-García. 2012. "The Smart University Experience: An NFC-Based Ubiquitous Environment." *Proceedings - 6th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, IMIS 2012*: 799–804.

Du, Shouyan, Fansheng Meng, and Baozhong Gao. 2017. "Research on the Application System of Smart Campus in the Context of Smart City." *Proceedings - 2016 8th International Conference on Information Technology in Medicine and Education, ITME 2016*: 714–18.

El-Kenawy, El-Sayed M., Marwa Metwally Eid, Mohamed Saber, and Abdelhameed Ibrahim. 2020. "MbGWO-SFS: Modified Binary Grey Wolf Optimizer Based on Stochastic Fractal Search for Feature Selection." *IEEE Access* 8: 107635–49.

Elgendy, Nada, and Ahmed Elragal. 2016. "Big Data Analytics in Support of the Decision Making Process." *Procedia Computer Science* 100: 1071–84. http://dx.doi.org/10.1016/j.procs.2016.09.251.

Ghosh, Monalisa, and Goutam Sanyal. 2018. "Performance Assessment of Multiple Classifiers Based on Ensemble Feature Selection Scheme for Sentiment Analysis." *Applied Computational Intelligence and Soft Computing* 2018.

Gnana, D Asir Antony. 2016. "Literature Review on Feature Selection Methods for High-Dimensional Data." 136(1): 9–17.

He, Dan, Irina Rish, David Haws, and Laxmi Parida. 2016. "MINT: Mutual Information Based Transductive Feature Selection for Genetic Trait Prediction." *IEEE/ACM Transactions on Computational Biology and Bioinformatics* 13(3): 578–83.

Malatji, Esrom Mahlatsi. 2017. "The Development of a Smart Campus - African Universities Point of View BT - 8th International Renewable Energy Congress, IREC 2017, March 21, 2017 - March 23, 2017." http://dx.doi.org/10.1109/IREC.2017.7926010.

Manochandar, S., and M. Punniyamoorthy. 2018. "Scaling Feature Selection Method for Enhancing the Classification Performance of Support Vector Machines in Text Mining." *Computers and Industrial Engineering* 124(July): 139–56. https://doi.org/10.1016/j.cie.2018.07.008.

Manqele, Lindelweyizizwe et al. 2015. "Preference-Based Internet of Things Dynamic Service Selection for Smart Campus." *IEEE AFRICON Conference* 2015-Novem.

Misra, Sudip, and Samaresh Bera. 2018. "Introduction to Big Data Analytics." *Smart Grid Technology*: 38–48.

Mohasseb, Alaa, Benjamin Aziz, Jeyong Jung, and Julak Lee. 2019. "Predicting Cybersecurity Incidents Using Machine Learning Algorithms: A Case Study of Korean Smes." *ICISSP 2019 - Proceedings of the 5th International Conference on Information Systems Security and Privacy*: 230–37.

Pang, Yulei, Xiaozhen Xue, and Akbar Siami Namin. 2016. "Predicting Vulnerable Software Components through N-Gram Analysis and Statistical Feature Selection." *Proceedings - 2015 IEEE 14th International Conference on Machine Learning and Applications, ICMLA 2015*: 543–48.

Salloum, Salman et al. 2016. "Big Data Analytics on Apache Spark." *International Journal of Data Science and Analytics* 1(3–4): 145–64.

Al Shimmary, Mahmood K, Muna M Al Nayar, and Abbas R Kubba. 2015. "Designing Smart University Using RFID and WSN." *International Journal of Computer Applications* 112(15): 975–8887.

Torres-Sospedra, Joaquín et al. 2015. "Enhancing Integrated Indoor/Outdoor Mobility in a Smart Campus." *International Journal of Geographical Information Science* 29(11): 1955–68.

Wang, Dewen, and Lei Xiao. 2012. "Storage and Query of Condition Monitoring Data in Smart Grid Based on Hadoop." *Proceedings - 4th International Conference on Computational and Information Sciences, ICCIS 2012*: 377–80.

Wang, Huaming et al. 2018. 11103 LNAI Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) *Multi-Label Online Streaming Feature Selection Based on Spectral Granulation and Mutual Information*. Springer International Publishing. http://dx.doi.org/10.1007/978-3-319-99368-3_17.

Wang, Lei et al. 2018. "Research and Implementation of Big Data Clustering Based on Spark." *Shuju Caiji Yu Chuli/Journal of Data Acquisition and Processing* 33(6): 1077–85.

Zhu, Zhi Ting, Ming Hua Yu, and Peter Riezebos. 2016. "A Research Framework of Smart Education." *Smart Learning Environments* 3(1). http://dx.doi.org/10.1186/s40561-016-0026-2.