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Context-Aware Recommender System based on Machine Learning in Tourist Mobile Application

Nor Liza Saad
Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Perak branch Tapah Campus
norli070@uitm.edu.my

Nurkhairizan Khairudin
Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Perak branch Tapah Campus
nurkh098@uitm.edu.my

Azilawati Azizan
Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Perak branch Tapah Campus
azila899@uitm.edu.my

Abdullah Sani Abd Rahman
Faculty of Sciences and Information Technology, Universiti Teknologi Petronas, Perak, Malaysia
sani.arahman@utp.edu.my

Roslina Ibrahim
Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia
iroslina.kl@utm.my

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ABSTRACT

The amount of information available in the World Wide Web has drastically increased nowadays. All this information may be particularly useful for users who plan to visit any places of their interest but a list possibilities search results by the Web search engines will be overwhelming. To decide which options suit to their interest from the long list of options can be tricky and time consuming mainly for Muslim travelers who have a few of religion constraints. The objective of this research is to develop a tourist mobile application that can be incorporated with machine learning based recommender system. For the initial framework, the tourist mobile application prototype was developed based on Penang tourist areas by using Waterfall Model system development approach. The application prototype was evaluated based on usability study as to get insight the users' acceptance. Furthermore, data were collected simulated based on the mobile application prototype to be used for finding the suitable machine learning algorithms in the recommendation system module. Based on usability study, most users agreed that the tourist mobile application is easier and useful for them. From the machine learning evaluation, Random Forest algorithm has generated the most accurate prediction compared to Decision Tree, Logistic Regression and Generalized Linear Model. This paper provides the fundamental knowledges on machine learning design and evaluation useful in the tourist mobile application with context-aware recommender system.

Corresponding Author:
Nor Liza Saad
Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Perak branch Tapah Campus
Email: norli070@uitm.edu.my

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1. Introduction

Muslim tourists must meticulous in their planning and selection of interesting tourist places, food and accommodation[1]. They need to give serious attentions during their searching of tourist interest places to be within the Muslim basic requirements mainly the halal status of foods, nearest place for prayers at the particular time and water-usage friendly washrooms. They also have to avoid places that have non-halal activities such as going to pub and bar, participating in other religious activities in church or temple and gambling.

Despites the massive information that can be search on the Internet World Wide Web, the relevant search results are always overwhelming even after filtering the search criteria. The decision on selecting the most suitable tourist place tend to be complicated and time consuming. Thus, to resolve this issue, recommender system has been useful to be provided in any kinds of application domain such as in the tourist application. Recommender system is a key technology in addressing the concerns of information overwhelming and has been widely used in tourist domain application to assist travellers in making their optimal decisions.

However, this research attempts to fill the gap by addressing the Muslim concerns in a context-aware recommender system. This paper provides the fundamental design and evaluation techniques of the context-aware recommender system based on machine learning prediction based on simulated data from a prior developed tourist mobile application. Besides Muslim context-aware, other users information including the pattern of clicking, strolling and the history of search were included in the machine learning prediction of the recommender system in the tourist application. The contributions of this paper are two-folds. First, it presents the design and development of the tourist mobile application. Second, it demonstrates the design and evaluation of machine learning prediction based on the simulated data collected from the tourist mobile application with Muslim attributes and the history of search pattern.

2. Literature Review

2.1 Tourist Recommender System

To enhance the journey experiences, peoples usually look for assistance in planning and selecting their tour decision. Travelling is not just about the places of interest but it is important to consider the other aspects such as transportation, accommodation, weather, events and tour packages. Therefore, most of travellers look for assistance in planning the tour decision by using any Information Technology (IT) application from the Web or in mobile platform. Recommender system has been widely used and useful in the travel or tourist IT application to assist the users by providing valuable and personalized suggestion in relevant to the users' preferences and contexts. One interesting work is in [2], that provides recommender system itinerary suggestion based on the semantic trajectory pattern of the geo-tagged photos by the users. On the contrary, the researchers in [3] have considered latent factors such as food, cleanliness, operating hours, location's popularity, ratings as well as inputs from the sentiment analysis on the interest places. Providing a more personalized suggestion is the mechanism used in the tourist recommender system introduced in [4]. In this study, the recommender system considered text input and pattern of writing to predict the user's interest. Concern to support health-centric tourism recommender system that hybrid user's personal choice with nutritive food values have been introduced in [5]. To enhance the recommendation with a more personalized suggestion, researchers in [6] developed a Context-Aware Hybrid Travel Recommender System by incorporating user's contextual information that hybrid the user's and items features. In this research, the information on users', Point of Interest (POI), environmental, temporal, mobility history is defined based on the User Profile, POI profile and Context Profile respectively. Then, based on Pearson Correlation Coefficient (PCC) similarity computation, prediction of ratings is generated. The context profiling used in the recommender system has taken this research attention to address the issue of Muslim requirements during travelling. Different with the context-aware recommender system in [6], this research employed machine learning predictive approach to detect the user's travelling interests.

2.2 Machine Learning

Machine learning is a robust technique that has been widely used in the prediction problem of many application domains. Machine learning can infer knowledge for the prediction based on the pattern of data given to the algorithm during the structured training phase. The pattern of input data of a particular human or users can be given by many aspects such as the click-through activities [7], search activities and styles[8], mouse movement and keystroke dynamic [9], and also based on the user's preferences, personal attributes and many other aspects. To identify the user's interest based on user's devices behavior[10] is another important finding. For an example, researchers can reveal that users tend to click more often when having stronger interest on the application contents[11]. To date, hybridizing users' searching and clickable behaviour with the personal attributes as well as the Muslim constraints is a new significant finding in the machine learning recommender system. In recommender system, there exists many ways can be used for predicting the user's interest for item recommendation and one promising way is machine learning [12], [13]. Deep learning recommender system is an example of predicting user's interest in online advertising [8]**.** In other works, Random Forest and Decision Tree were the two machine learning used to suggest tourist attractions of each traveller[13]. Artificial Neural Network has been used in predicting tourist arrival of popular places to be forecasted with ARIMA[14]. In [15], prediction and behavioral analysis of travel mode can be derived from Random Forest algorithm and results shown higher predictive accuracy generated by the Random Forest compared to conventional mixed logit model.

3. Research Method

3.1 Research Tools

The main tool for the tourist mobile application development is Android Studio. The application has been developed to be connected with Geographical Positioning System (GPS) to enable location tracking function. Figure 1 is the general application architecture.

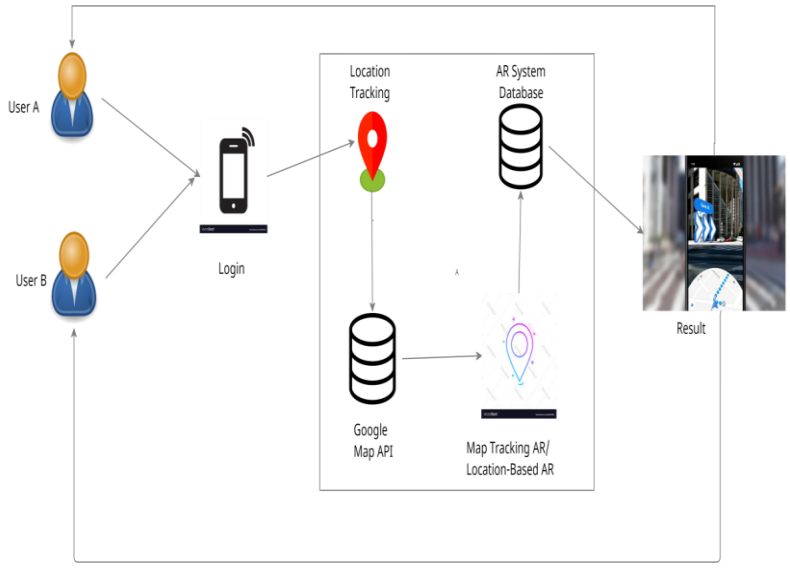

Figure 1. Application architecture

Users can login to the mobile application and must activate the devices GPS detector. Users must register prior to login and give entry on their personal information including name, gender and religion. To incorporate the tourist application with GPS tracking system, JavaScript codes with Geolocation API in HTML has been used. Once the mobile application has been developed and ready to be used after several testing processes, data were collected by simulating the application with variety of possibilities of users' input and output (preferences). Based on the collected data, machine learning models based on three algorithms have been developed. The algorithms are Decision Tree, Random Forest, Logistic Regression and Generalized Linear Model.

The predictive model is to predict the rating class that will be given by users, which can be either relevant (1) or not relevant (0). The determiners of the model are *login_time, current_location, halal_status_of_the_places, prayer_facility, lastpointoftheprev_search, time_spendofselectedplace, user_religion, temporal_click_of_current_places.* The dataset was divided into the training and testing ratio at 70:30 percentages with split training approach. Experiments to run the training and validation has been conducted with RapidMiner Auto-Model. Based on the auto hyper-parameters tuning by the Auto-Model, the optimal *maximal depth* of the Decision Tree is 7 with 20.0% of *error_rate* while the optimal *maximal depth* for Random Forest is 7 with 20 *Number_of_trees,* which producing 16.7% of *error_rate.* The best machine learning suggested from the Auto-Model RapidMiner can be used for future expansion on the proposed tourist mobile application.

3.2 The Tourist Mobile Application

The flowchart of the application is depicted in Figure 2.

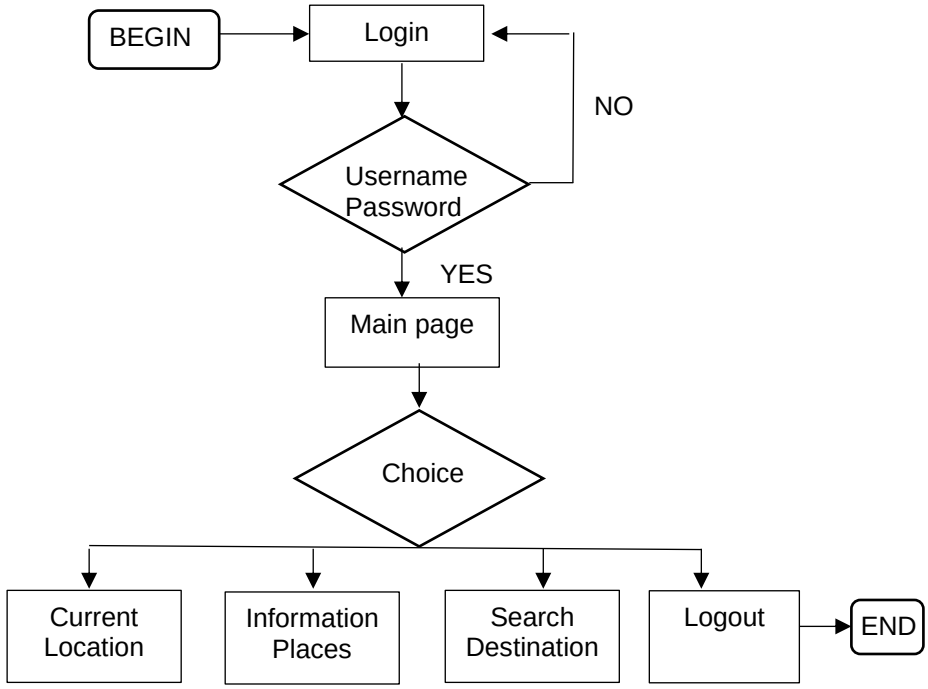

Figure 2. Application flow

From the login page, a user needs to key in the admin username and password for authentication process that only allow three time of attempts. In the main(dashboard) page, users are provided with four choices namely Current Location, Information Places, Search Destination and Logout (Refer to Figure 3).

Figure 3. Dashboard page

Figure 4 presents the page when users click the first button to track their location and the application will furthermore display some recommendations of interest within the nearest locations as shown in Figure 5.

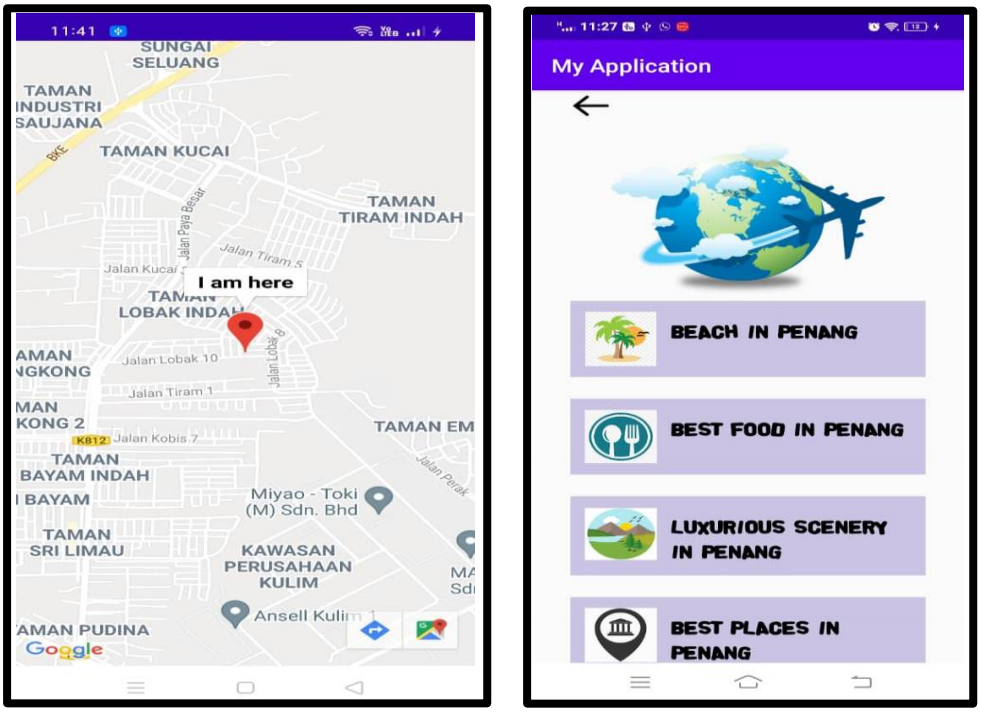

Figure 4. Track location and recommender places of interest

For each option, users can extend the search by clicking the button and more suggestions will be displayed in different pages as shown in Figure 5.

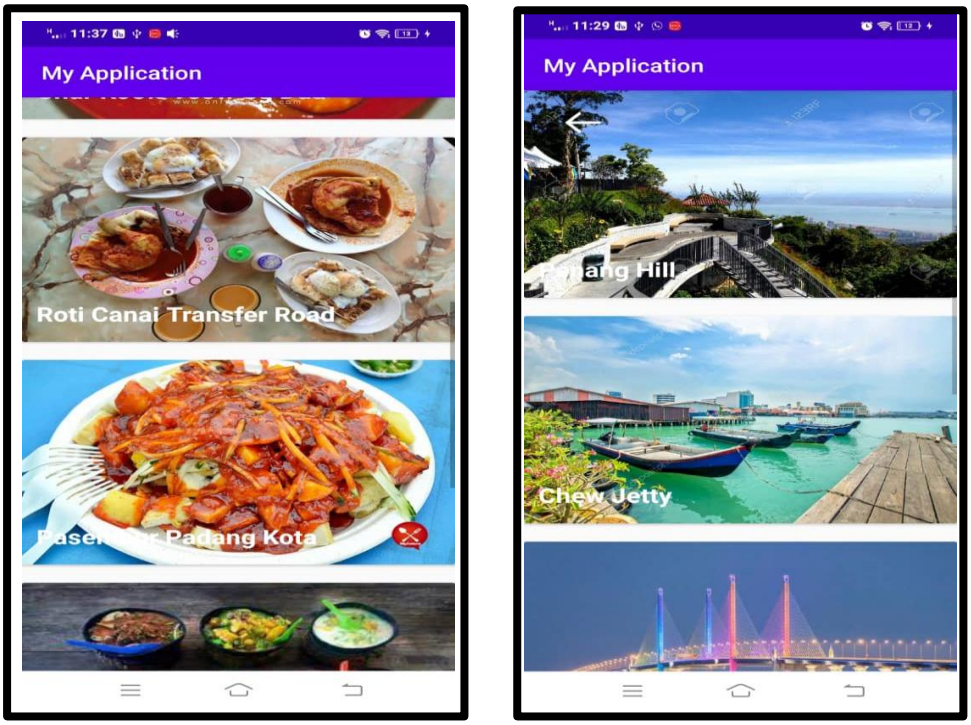

Figure 5. Additional tourist places recommendation

More information that users can read on the selected places will be displayed as seen in Figure 6. The times users spent for the final page of the selected page can be used as the determinant of the machine learning predictive model.

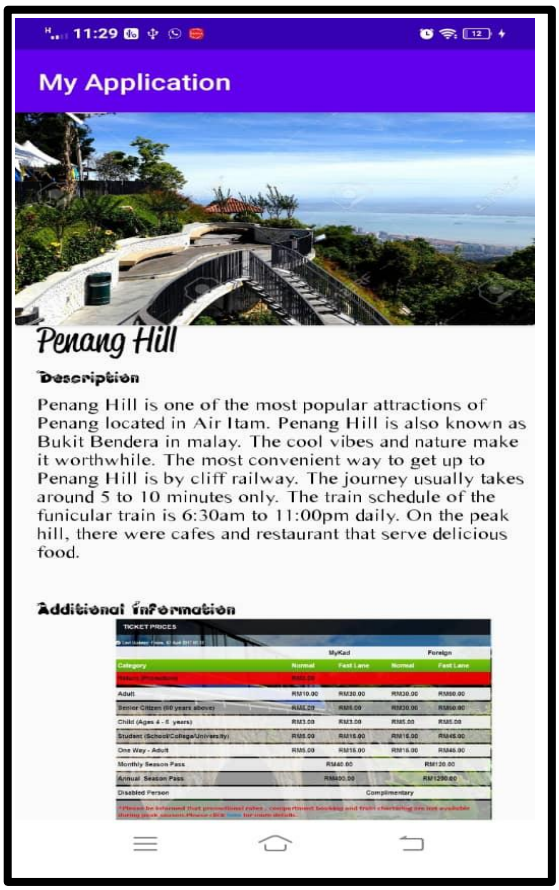

Figure 6. Additional information on the selected place

3.3 Evaluation

To conduct a usability testing, more than 100 users have been requested to use the systems and to provide feedback on the system ease of use. These users are the students from the Degree of Computer Sciences in the Universiti Teknologi MARA, Perak Branch. Besides usability evaluation, this research measured the performances of the machine learning predictive models based on the classification confusion matrix so that the accuracy, classification error, specificity and sensitivity of the classification model can be calculated. Explanation on these metrics are available in [16].

4. Results and Discussion

Users who embarked on the usability survey have mostly agreed (more than 80%) that the system is easy to use and functional at all provided pages. A few of them who were disagree suggested that the tourist mobile application should be expanded with virtual reality to provide users an immersive feeling on the tourist places and some of them proposed a chatting tool with intelligent bots or to connect users with the tourist representative.

Furthermore, the results of the machine learning evaluations are divided in accordance to two different types of machine learning; linear and tree-based algorithm. The four metrics used for measuring the performances were calculated based on the generated confusion matrix of each machine learning as listed in Table 1.

Table 1. Performances results of the linear based machine learning

Metrics	Description
Accuracy	The total correct prediction from the total prediction for both classes (relevant (1) vs irrelevant place (0))
Classification error	The total incorrect prediction from the total prediction for both classes (relevant (1) vs irrelevant place (0))
Sensitivity	How good is the model in predicting the relevant ratings the actual relevant and irrelevant classes
Specificity	How possibility is the model in detecting the irrelevant rating from the total actual irrelevant places.

Accuracy is the ratio of the correctly labelled classes to the whole pool of classes. For an example, the number of correct predictions for the relevant and irrelevant places from the total of 30 datasets used for machine learning testing is used to denote the accuracy of the model. On the contrary, classification error is the incorrect labelled classed to the whole pool of classes. Sensitivity in this case is the ratio of the correctly relevant ratings to all the rated places. Therefore, it is representing how good is the model in recommending the relevant places. On the other hand, specificity is the correctly irrelevant places that can be detected by the machine learning from the total actual irrelevant places, which will not be recommended by the tourist application. Table 2 lists the results of the machine learning from the linear based algorithms.

Table 2. Performances results of the linear based machine learning

	Logistic Regression		Generalized Linear Model	
Metrics	**%**	**±Std.Dev**	**%**	**±Std.Dev**
Accuracy	66.7	2.6	77.7	2.6
Classification error	30.0	3.2	23.3	3.3
Sensitivity	88.9	3.4	94.7	3.8
Specificity	36.3	3.4	45.5	3.4

Although the accuracy from both algorithms in Table 2 is not highly promising (lower than 80%), the ability to provide suggestions that closed to users' context and preferences seems encouraging. The Generalized Linear Model presents promising ability in terms of sensitivity to detect the relevant places, 94.7%. Table 3 shows the results from Random Forest and Decision Tree models, which categorized as tree-based machine learning.

Table 3. Performances results of the tree-based machine learning

	Decision Tree		Random Forest	
Metrics	**%**	**±Std.Dev**	**%**	**±Std.Dev**
Accuracy	80.0	2.6	83.3	2.7
Classification error	20.0	2.8	16.7	2.8
Sensitivity	94.7	3.4	94.7	3.8
Specificity	54.5	3.4	63.6	3.6

Both algorithms from the tree-based machine learning generate higher accuracy than the linear based machine learning algorithms. The most outperformed can be seen from the Random Forest algorithm with accuracy 83.3%, sensitivity at 94.7% and specificity 63.6%. The possibility of not recommending the irrelevant places by Random Forest will be higher than other algorithms.

5. Conclusion

The fundamental design of the system architecture and user interfaces for the tourist mobile application have been presented in this paper. Additionally, this paper demonstrates the possibility of utilizing recommender system with machine learning in providing the tourist place suggestions based on interest place rating classification model. The concern is to incorporate multiple aspects of attributes that address the important matters of Muslim traveller and to utilize the searching and clicking behavior. The significant ideas can be adapted in or furtherly extended with more types of application domains that requires item recommendations in a context-based recommender system.

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Conflict of Interest
The authors declare no conflict of interest in the subject matter or materials discussed in this manuscript.

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Biography of all authors

Picture	Biography	Authorship contribution
	**Nor Liza Saad** works as Senior Lecturer at Universiti Teknologi MARA, Department of Computer Science. She received Bachelor Degrees in Computer Science and Msc in Computer Science from Universiti Putra Malaysia. Her area of research interest includes information system, educational games and multimedia. She can be contacted at email: norli070@uitm.edu.my	Drafting and final checking the article
	**Nurkhairizan Khairudin** works as Senior Lecturer at Universiti Teknologi MARA, Department of Computer Science. She is currently pursuing her study in PHD in Intelligent System at Universiti Putra Malaysia (UPM). She received Bachelor Degrees in Computer Science and Msc in Information Science from Universiti Kebangsaan Malaysia Her main research interest is in recommendation system and neural network.	Recommender system
	Azilawati Azizan is currently a senior lecturer in the faculty of Computer & Mathematical Sciences, UiTM Perak Campus, Tapah Branch. She completed her degree in Information Technology (major in Information System) in 2000 at Universiti Kebangsaan Malaysia. Then she continued her master's degree in Information Retrieval at the same university. Her areas of interest are in text processing, query processing, and search engine. She can be contacted at azila899@uitm.edu.my.	Methodology of the application design and development
	**Ts. Abdullah Sani Abd Rahman** obtained his first degree in Informatique majoring in Industrial Systems from the University of La Rochelle, France in 1995. He received a master's degree from Universiti Putra Malaysia in Computer Science, with specialization in Distributed Computing. Currently, he is a lecturer at the Universiti Teknologi PETRONAS, Malaysia and a member of the Institute of Autonomous System at the same university. His research interests are cybersecurity, data analytics and machine learning. He is also a registered Professional Technologist. He can be contacted at email: sani.arahman@utp.edu.my.	Machine learning

	Assoc. Prof Dr Roslina Ibrahim is a lecturer and researcher at Universiti Teknologi Malaysia, Kuala Lumpur. She graduated with PhD from Universiti Kebangsaan Malaysia in information science. Currently she is working on several research grants on the use of information technology in education including games and augmented reality. Her research interest are acceptance of information system, educational games and User Experience. She can be contacted at iroslina.kl@utm.my.	Literature review