Volume 1, Issue IX, September 2022, **No. 18, pp. 234-248**

Submitted 24/8/2022

Final peer reviewed 5/9/2022

Online Publication 5/10/2022

Available Online at http://www.ijortacs.com

DEVELOPMENT OF AN INTELLIGENT SUBJECTIVE-BASED EXAMINATION MARKING AND SCORING SYSTEM USING MACHINE LEARNING TECHNIQUE

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Abstract

This paper presents the development of an improved subjective-based examination marking and scoring system using machine learning technique. The major aim is to develop a subjective examination system which allows lecturers to set theory-based questions on the online platform and then give students access to take the examination. It marks the questions answered after the examination and generate the scores instantly within the time boundary of the examination. The methodologies used in this paper are experimental research methodology. The software development life cycle (SDLC) employed was the water fall model, while the software design methodology adopted was also the water fall model methodology. The methods are user registration, login, subjective exam setting, feature extraction, time control, answer matching and scoring system. The system was modeled with self-driving equations and Universal Modeling Language (UML). The model of the answer matching system was developed with K-NN algorithm while scoring system was modeled with rule-based approach. The matching algorithm was trained with classification application and then implemented with JavaScript and PHP for web-based Computer-Based Test (CBT) system alongside the rule-based scoring algorithm. The result of this system presented area under curve performance of 0.87 and accuracy of 87% when tested. The performance when compared with other CBT algorithms achieved better performance compared with the rest in terms of reliability, cost effectiveness and user friendliness.

Keywords: Automatic Marking; Object-Oriented; Rapid application; CBT; UML; K-NN

1. INTRODUCTION

Every day begins a story and today this narrative begins with the unfortunate increased rate of academic fraud in the global secondary and tertiary institutions during examinations. According to Emaikwu (2012), examination is the process of candidate evaluation in an academic environment or any legally recognized institution to test the knowledge of an individual on a particular subject matter. However, the need to maintain the integrity

of this knowledge evaluation process has remained a major topic for discussion over the years, as the process keeps getting bias on daily basis due to corruption and fraud.

There are many forms of examination such as paper based, oral and computer-based test. The paper based is the traditional mode of examination where question papers and answer scripts are produced by lecturers under the guidance of the academic institutions or the exam regulatory body and then employed for the exam process. This is the most common approach today due to low cost and simplicity, but lacks integrity due to the high rate of academic corruption such as "sorting of lecturers", delayed exam result, malpractices, etc. The oral based are employed more in interview sections and not commonly used as a general examination process.

The CBT on the other hand requires the use of computer-based system to program in the questions and answers for student to log in and take part in the exam processes. This approach was able to reduce the issues of academic fraud, delay in marking of script, sorting of lecturers' issues to gain marks among other problems, which has affected the integrity of examination, when compared to other exam modes. Furthermore, the CBT test system due to automatic marking allow teachers to administer as many tests as possible and have the system mark it in record time relieving the teacher the tedium of continuous marking.

Recently, CBTs are designed to enable students take part in either objective, subjective or both examinations. The objective type access the student via multiple choice question and answers, while the subjective examined the study based on essay and allow candidates express their ideas and answers to a question in a more robust way, unlike multiple choice questions found in objective based CBTs.

Some of these CBTs are also incorporated with automated marking scheme which provided the score of the exam instantaneously after the exam is completed and submitted (Mariagowda et al., 2021). These features of the CBTs made it the perfect system to address the aforementioned issues in the current examination system. However, despite the success, there is still room for improvement, especially in the accuracy of grading and flexibility of the user interface during examination.

Overtime, many techniques have been proposed to improve the performance of CBT system using mainly artificial intelligence-based approach like the rule-base optimization technique, cognitive approach, fuzzy logic, latent semantic analysis (Ali, 2015; Nandini et al., 2018; Himani et al., 2016) among others. However, this paper will apply rule-based optimization technique for setting rules and mathematical methods to solve problems in automatic examination marking systems, determine the correct answers to questions and compute their scores accordingly using mathematical computation to grade the student (Nandini et al., 2018). This approach is very cost effective, easy to use, reliable and very fast; however, there is still need to improve the accuracy of the marking and scoring system.

TABLE 1: LITERATURE REVIEW

Author	Title	Technique/ methodology	Work done	Limitation/ gap
Mariagowda et al. (2021)	Comprehensive examination assessment model using machine learning.	Hybrid technique	The system used Item Response Theory (IRT) and machine learning algorithm to develop the examination system	Accuracy of 85% was achieved, but there is still room for improvement
Simsek et al. (2019)	The use of expert system in individualized online exams	Cognitive approach	The study used the cognitive approach to develop a personal test system where questions are arranged randomly	Only objective questions were considered.
Augustine (2013)	Design and implementation of online entrance examination	Structured System Analyses and Design Methodology (SSADM)	The study developed an online system for the management of entrance examination online using HTML and PHP.	The study was limited only to objective questions.
Alla et al. (2018)	Intelligent electronics assessment for subjective exams	Subjective CBT system	The study developed a subjective system for the examination of students performance using Java	The performance can be improved using automated marking scheme
Ejim et al. (2017)	Computer based examination system with multi-factor authentication and message notification features	Web based approach	The system was developed using Object Oriented Analyses and Design and Unified Modeling Language. It allowed real time examination and update of the central database when complete questions are answered and submitted by the students	The system can be improved via the incorporation of the subjective exam scheme.

Kuyoro et al. (2016)	Work on design and implementation of a computer-based testing system	Water fall model based software development Life Cycle	The system developed a CBT software	The system do not have subjective exam platform

2. METHODOLOGY

There are three types of methodologies associated with computer science research and development; they are research methodology; Software Development Life Cycle (SDLC) and software design methodology. Research methodology is set of standard methodology for research in any science investigation, but the one adopted for this research is the experimental research methodology. The SDLC is a process which is focused on the design, development and testing of the software with the aim of producing a high-quality software within the time and budget defined for the research. The SDLC employed is the water fall model after a thoughtful consideration and comparison with other counterparts. The methodology was adopted against other counterparts such as the Agile model, iterative model, V model, etc. due to its capacity to expressly reveal the goal of the study from an early state, thus ensuring that the researcher is in line and do not deviate from the outlined process. Secondly the methodology ensures a direct handshake between the output of a process and then input of another, hence ensuring a holistic information flow, down to the final stage.In the same vein, the software design methodology adopted is the Structure System Analysis and Design Method (SSADM).

3. SYSTEM DESIGN

The system was designed using modeling diagram such as logical flow chart, entity relationship diagrams for the database back-end and architectural diagram to present the high-level model of the new system.

3.1 **Database (Backend) Design**

Database design is concerned with how data is represented and stored within the system. The data are the examination questions, answers, grades, and reviews which are stored. The database stores information of the student and also the examination records, where only the lecturer can have access to them. The system stores the above information in MySQL Database server, which is an open-source tool required for development of online management systems. The data tables presented are the lectures framework which manages the lecturers and course information, student information framework, questions, examination, answers and score tables respectively. **3.2 Development of the Expert System**

This expert system is a computer-based software emulator which can make accurate decision and mimic human behavior and intelligence. This expert system was developed in this research using marking system and scoring system integrated to form the CBT system for subjective examination. The marking system was developed with clustering approach which

employed K-nearest neighbor to search for similar words and match, while the total matched worded are scored using rule base scoring algorithm.

3.3 Development of the Matching System (Marking Scheme)

To develop the computation model for the marking scheme, the K-NN model in Shahadat and Ibtisham (2022) which used Euclidean distance to compute similarities of keywords to determine the correctly answered questions was adopted. The algorithm identified the extracted words from the lecturers' input as class A and then the extracted keywords from the student answers as class B and then used the Euclidean model in equation 1 to match the similarities as shown in the model of figure 1;

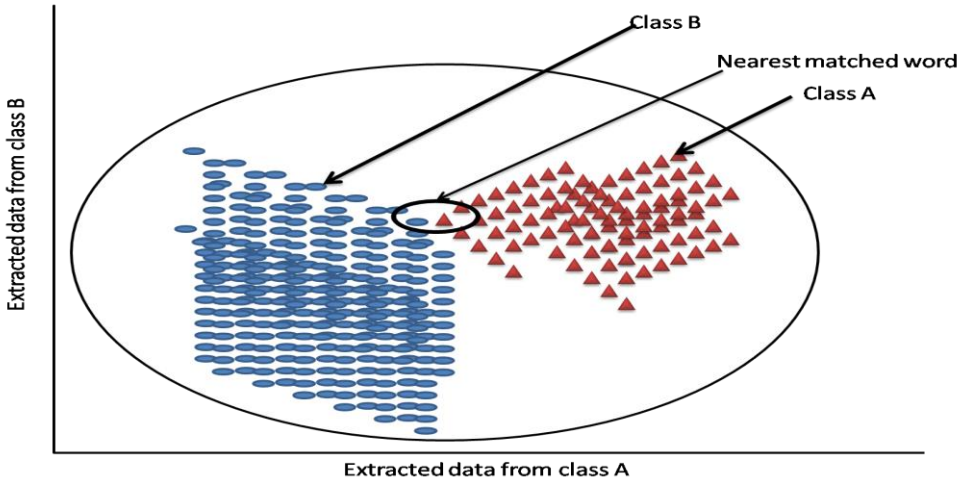

Figure 1: Model of the Matching system

From the figure 1, the extracted keywords were matched using the model in equation 1 and then output presented the correctly answered question by the student.

$$D_e = \sqrt{\sum_{i=1}^{x}(y_A - y_B)^2} \quad (1)$$

Where y_A is the input keywords from the admin (lecturer); y_B is extracted keywords from student answers; x is the total number of correctly classified keywords; D_e is output of student response. The model developed showed how the input from the students and lecturer were cross matched and used to determine the correctly answered question. The algorithm was presented as;

Pseudo Code of the Marking Scheme

1. Start
2. Input questions and label ID as integer
3. Input answer keywords for each question
4. Extract question and their keywords as y_A
5. Select question by students
6. Input answers to questions selected
7. Extract features of answer keywords as y_B
8. Compute similarities between y_A and y_B using equation 1
9. Compute number of correct answered questions
10. Feed to scoring algorithm

11. Return
12. End

3.4 Development of the Rule based scoring algorithm

The model of the scoring system was developed using the input score value assigned by the lecturer for each question and also considering the output of the matching algorithm to determine the total score of the student; the flow chart of the rule-based scoring system was presented in figure 2;

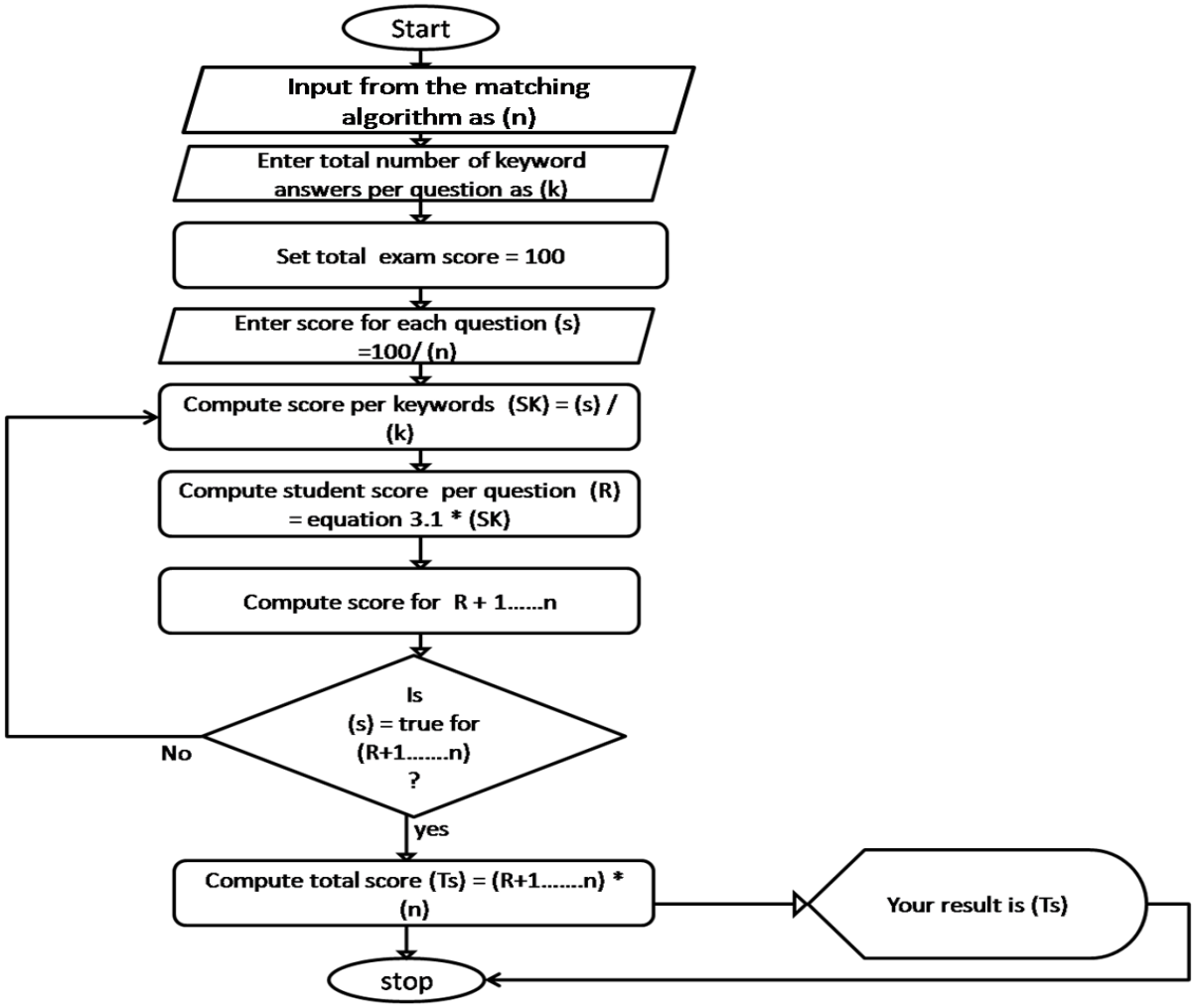

Figure 2: A model of the rule scoring system

From the model in figure 2 the scoring system showed how the scoring system programmed by the setting based on the lecturers input such as the score per questions, number of key words provided per answer, number of questions and total score of the examination. These setting was used to control the input feed by the matching algorithm which matched and presented the number of correctly answered question by the student, then the rule based was used to grade the question based on the appropriate score and then update to accommodate the next question score until

the whole questions are answered and the total score summed and presented as the final score of the student. The system block diagram of the CBT is presented in figure 3;

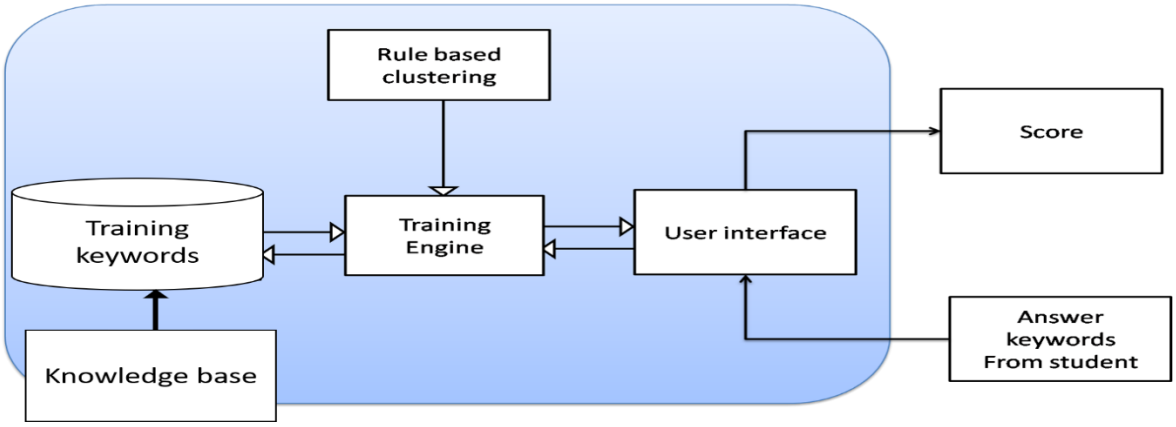

Figure 3: Model of the CBT expert system

The figure 3 showed how the system was developed. The lecturer which is the knowledge-based domain expert provided the key words for the set exam questions as the training keywords, then the rule based which was developed with the scoring and matching algorithm was used mark and score input answered from student and the score output from the user interface.

4. SYSTEM IMPLEMENTATION

The system was implemented using classification application software, Node.JS and MySQL software respectively. The classification app was used to train the matching algorithm developed with K-NN and then developed to the web-based application for front and back-end implementation. The HTML scripts was used to develop the front end based on the scoring and matching algorithm. This was also improved using cascade styling sheets (CSS) to provide a user interactive and friendly system. The back-end which manages the data such as the examination questions, keywords, results and student registration information were developed with NodeJS and MySQL tools. The home page is presented in figure 4.

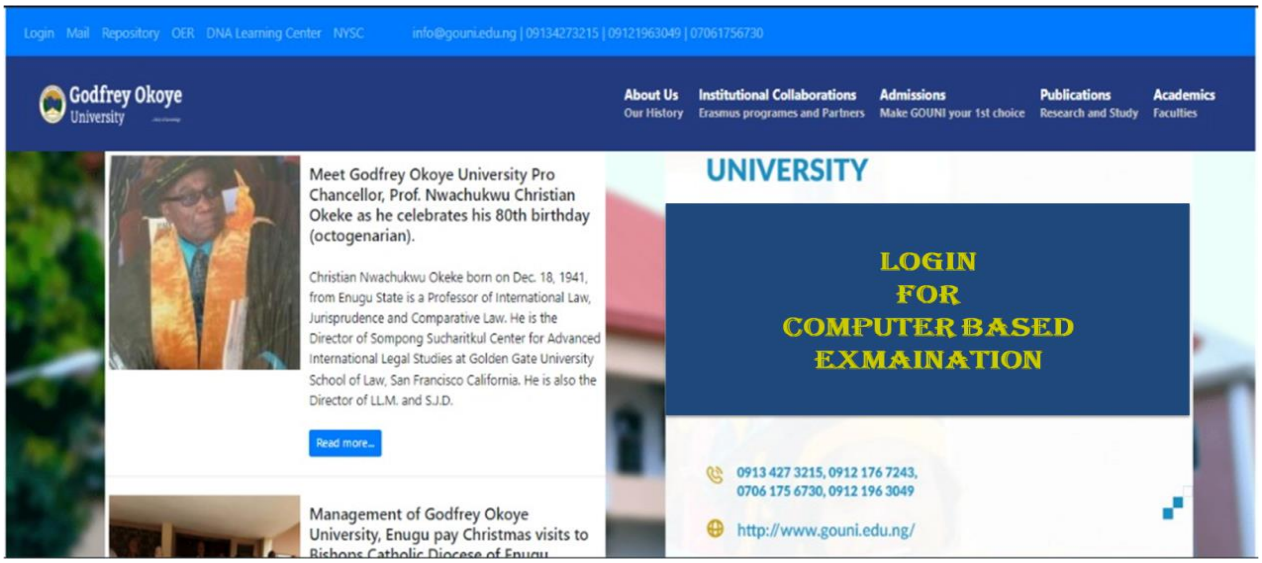

Figure 4: Home page of the implemented system

4.1 Performance of the Algorithm

This section presented the performance of the algorithm developed and trained using the classification app software. The training was used to learn the K-NN based matching algorithm of the features of the lecturer input keywords for every questions so as to be used as a reference point for the classification of the student answers. After the learning, the matching process was evaluated with sample of the input keywords as test data and the performance evaluated using area under curve which considered the relationship between true positive rate and false positive rate.

The aim here is to achieve Area under Curve (AUC) value of equal or approximately 1 which indicated correct learning of the keywords and from the AUC recorded is 0.89. The implication of this result showed that the matching algorithm correctly learn the keywords for the questions and was able to match correctly input keywords by the student at an accuracy of 88.68%. Having trained the algorithm and evaluated, the performance was validated with tenfold cross validation approach which iteratively tested the algorithm ten time and then compute the average accuracy and AUC as shown in table 2;

TABLE 2: VALIDATION OF THE K-NN LEARNING ALGORITHM

Testing Number	Area Under Curve (AUC)	Accuracy (%)
1	0.89	88.68
2	0.87	88.51
3	0.88	88.40

4	0.87	88.50
5	0.86	88.61
6	0.86	89.48
7	0.85	88.64
8	0.89	89.37
9	0.86	87.89
10	0.88	89.03
Average	0.87	88.71

The validation result in table 2 presented the performance of the matching algorithm developed and how reliable it is to be used for the evaluation of the student performance during the exam process. The result showed that the average AUC is 0.87 and the average accuracy of the system is 88.71%. Having tested and validated the system, it is deployed and used to develop a web-based CBT system of which the result was discussed in the next section.

4.2 Results

This section presented the result of the new CBT system developed. The results presented the performance of the user registration system, login and exam setting section, result of the examination system process and the scoring result. The result in figure 5 presented the student registration process;

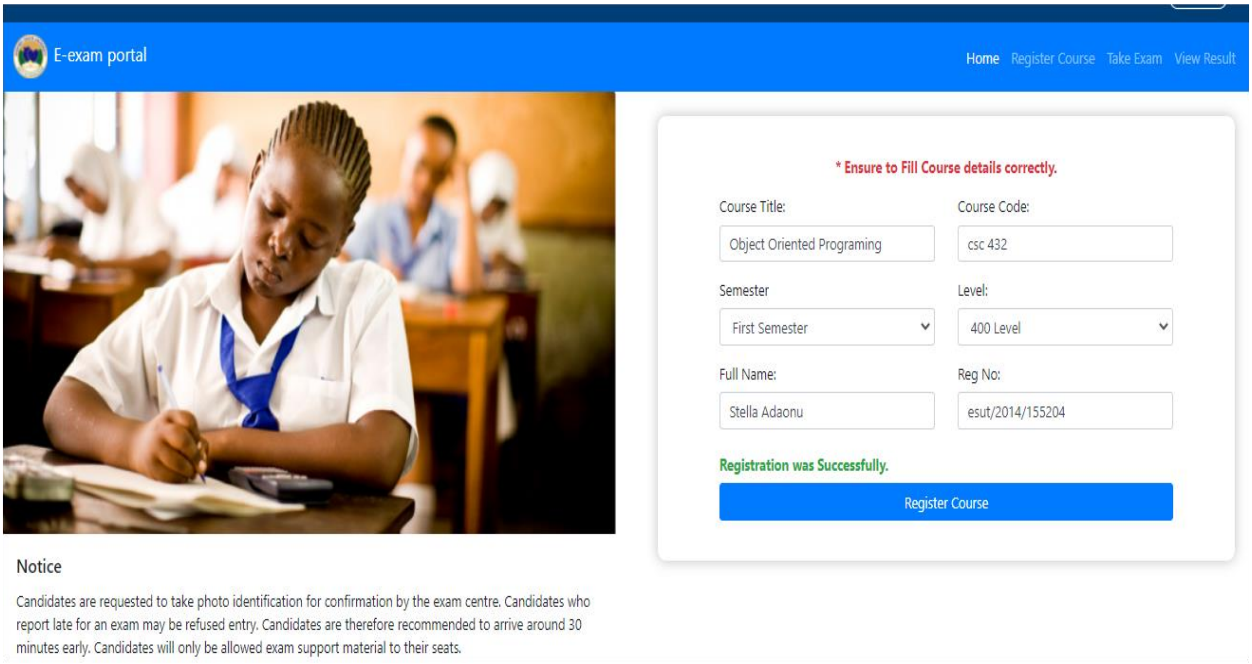

Figure 5: Student registration framework

This section presented the user registration section where the users (student) submit necessary biological details to register for the exam and get the login information which grants them access to the CBT system. In the same way, the lecturer can also register and get login details used for login in figure 6 and figure 7;

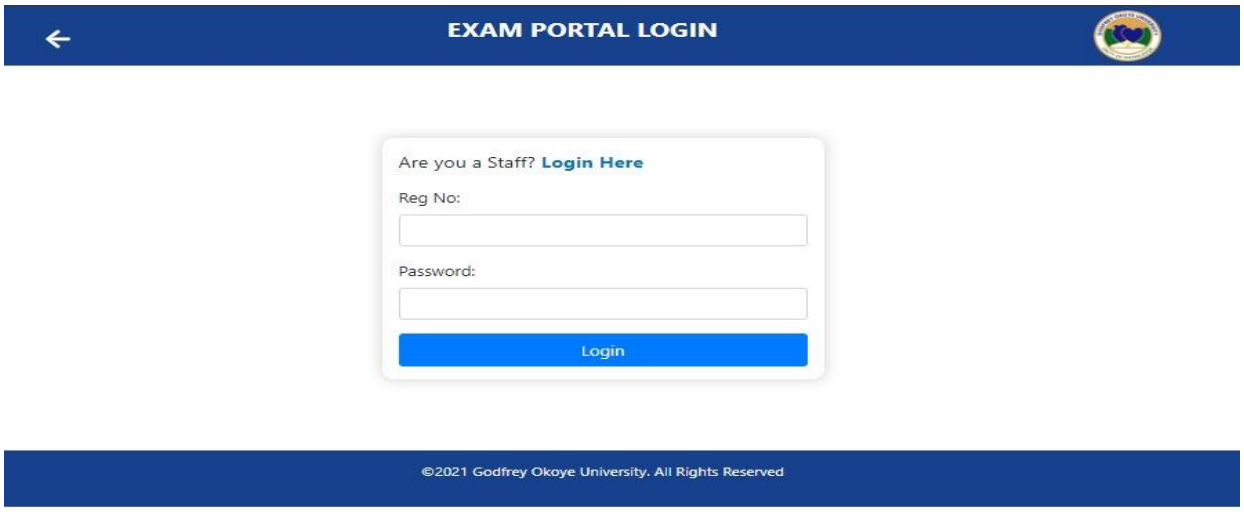

Figure 6: Login section for lecturer

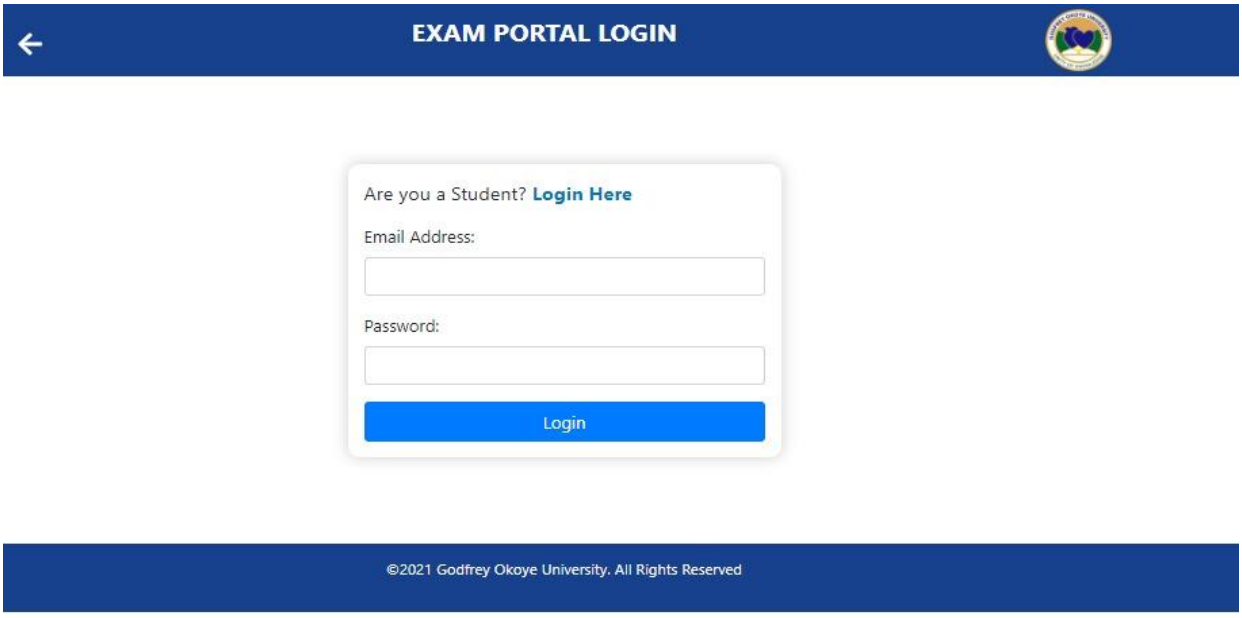

Figure 7: Login section for students

The figure 6 and figure 7 presented the login section of the system developed for users.

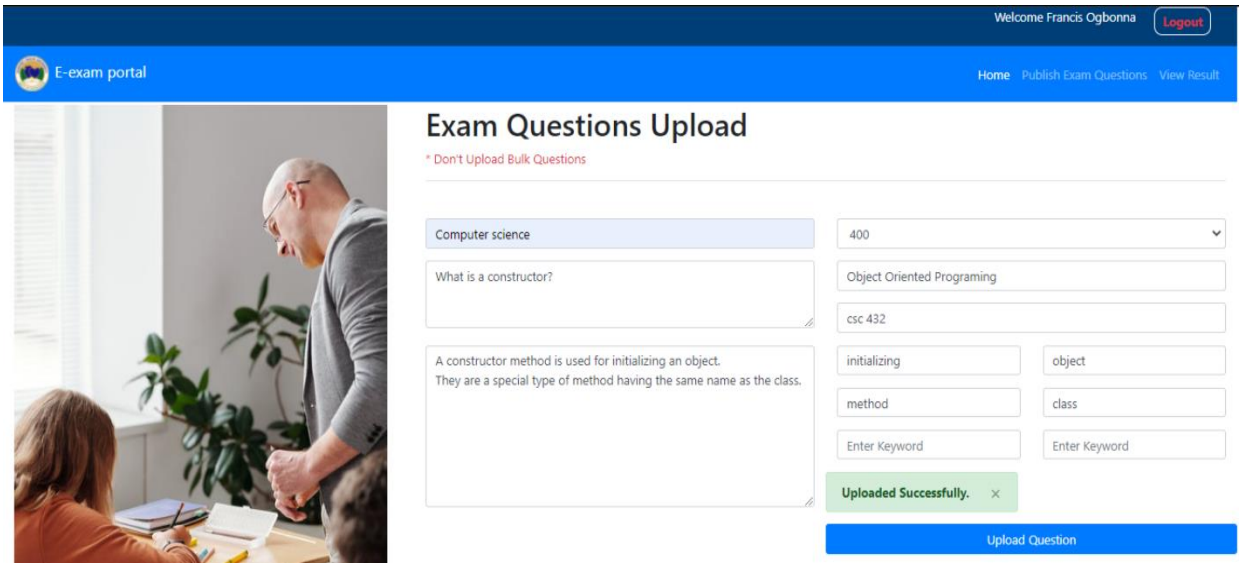

Figure 8: Result for setting exam

Figure 8 presented the lecturer section where exam is setup. After login, the lecturer set the question which in this case as in figure 8 is "what is a constructor?" and the keywords for the answer are input as shown in the framework and then submitted. To answer the question, the student logged into the system and gained access to the question as shown in figure 9;

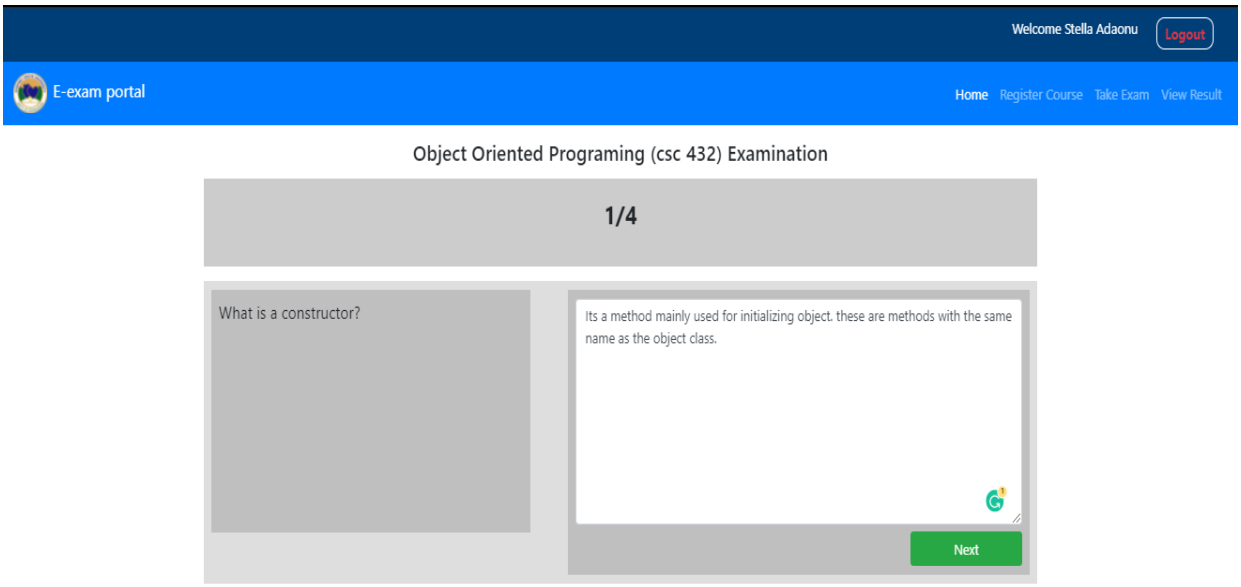

Figure 9: Examination framework

The figure 9 presented the framework where the student answered the question set earlier in figure 8, the answer submitted by the student were extracted by the feature extraction process, alongside the keywords submitted by the lecturer for the question. These two features were categorized based

on the K-NN model and then used to search the similar keywords from both classes and then feed to the scoring algorithm for grading. The figure 10 presented another answer framework where the students submit answers to questions set by the lecturer.

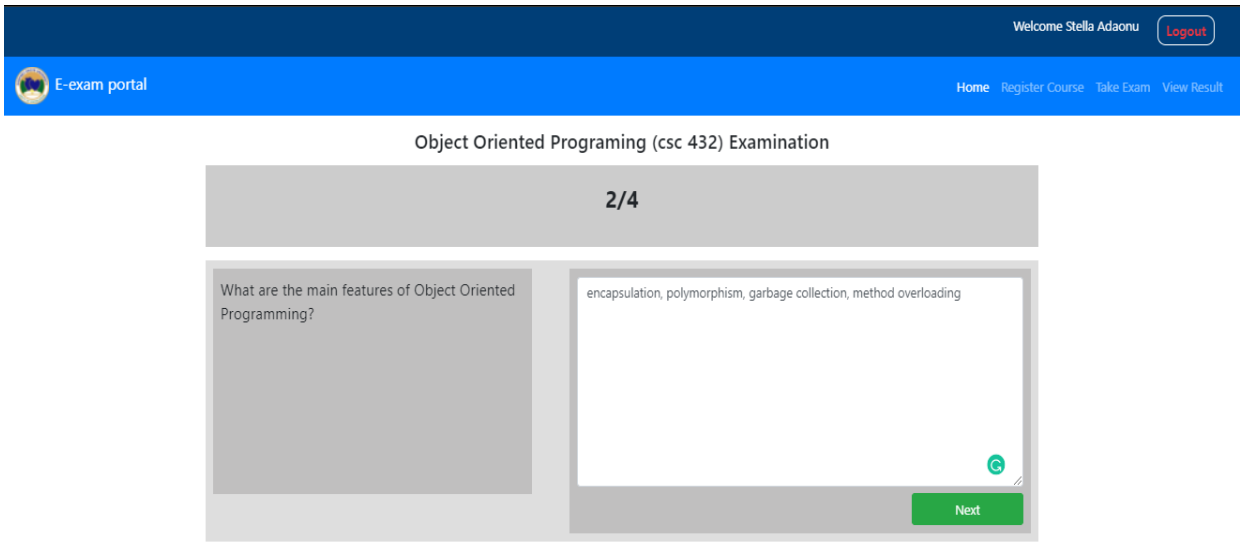

Figure 10: Answer section for next question 2

4.3 Comparative Analysis

This section comparatively evaluated the performance of the new algorithm developed and the existing state of the art algorithms developed for CBT systems. The analysis considered the authors, techniques and accuracy achieved as shown in table 3;

TABLE 3: COMPARATIVE ANALYSIS

Author	Techniques	Accuracy
Nandini et al. (2018)	Cognitive based approach	85%
Maram et al. (2017)	Latent semantic analysis and rhetorical structure algorithm	50%
Mariagowda et al. (2021)	Item Response Theory (IRT) and machine learning algorithms.	85%
Allah	Electronic assessment	89%
New System	K-NN and Rule based	88.7%

The table 3 presented a comparative analysis of the of CBT development technique performance and graphically analysed as shown in figure 11;

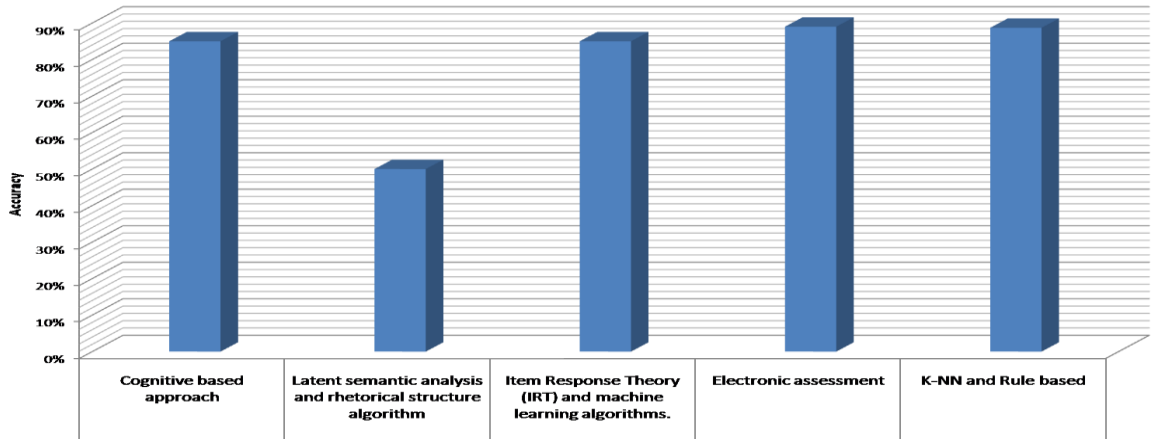

Figure 11: Comparative Analysis

From the result it was observed that the new algorithm performed better than most of the existing algorithms, however the electronic assessment techniques slightly edge the new algorithm developed with 0.3%, nevertheless the electronic assessment techniques is very expensive to implement as against the new system which is cheaper to implement, more reliable and more user friendly.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research has successfully developed an improved computer-based examination and automatic marking system using expert system technique. The research methods are user registration, login, subjective exam setting, feature extraction, time control, answer matching and scoring system. The model of the answer matching system was developed with K-NN algorithm while the scoring system was developed with rule-based approach. The matching algorithm was trained with classification app and then export to JavaScript and PHP for web-based CBT system alongside the rule-based scoring algorithm. When tested the result showed area under curve performance of 0.87 and accuracy of 88.7%. The performance when compared with other CBT algorithm achieved better performance compared with the rest in terms of reliability.

5.2 Recommendation

Having successfully completed this research, the following are recommended;

i. The system should be extended to other departments within the institution for fast exam marking and scoring process.
ii. The system is recommended to other tertiary institutions in Nigeria for adoption

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