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# EMPLOYING BOTH DESCRIPTIVE AND PREDICTIVE ALGORITHMS TOWARD IMPROVING PREDICTION ACCURACY

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## ABSTRACT
The research describes the use of both descriptive and predictive algorithms for better accurate prediction. The current research has focused on the use of either descriptive or predictive algorithm for prediction, but this research work employed the two algorithms. Clustering technique was used in the descriptive stage while classification technique was used in the predictive stage. K-Means and Expected Maximization (EM) were used for clustering while models from three classifiers (Decision Stump, M5P and RepTree) were used for classification. The result of using each of the two algorithms individually was presented as well as the result of combination of both algorithms. It was discovered that utilizing both algorithms for prediction provided more accurate result.

**Keywords**: Data Mining, Clustering, Classification, Expected Maximization, M5P

## 1.0 INTRODUCTION
Accuracy is an important element in prediction. Attempts to predict may do more harm than good. An inaccurate prediction is likely to have worse consequences than if there had been no prediction at all. A successful earthquake prediction for instance, would greatly reduce the loss of life, if not necessarily the economic damage, by permitting dangerous buildings to be evacuated, tsunami-prone areas to be cleared, hospitals and rescue team to be prepared on standby [1].

The goal of Data Mining is to get actionable insights resulting in smarter decisions and better outcomes. Data mining is the process of digging through data and looking for meaningful trends and patterns. It uses sophisticated statistical analysis, neural networks, modeling techniques to explore relationships in the data that more traditional methods may not find. This allows identification of previously undetected relationship among items. In general, data mining builds abstract models of the data to guide understanding of the underlying trends [2]. A data mining technique could be descriptive or predictive. The choice of data mining technique is contingent upon the nature of problem to be solved and the size of the database. Based on the kind of knowledge which can be discovered from databases, data mining techniques can be broadly classified into several categories including

clustering, classification, dependency analysis, data visualization and text mining [3].

When data is first segmented into smaller and logically similar groups, exploring further relationships become more efficient and clearer. Descriptive analysis (clustering) identifies groups of related records that can be used as a starting point for exploring further relationships. It looks at data and analyzes past events for insight as to how to approach the future. Predictive algorithm turns data into valuables, actionable information. It uses data to determine the probable future outcome of an event or a likelihood of an event occurring [4].

The current research has focused on the use of either descriptive or predictive algorithm for prediction but this research work employed the two algorithms to extract information based on the calling behavior of subscribers with high probability of churn in the future. This will be achieved in three stages. Firstly, the predictive algorithm will be applied on the data set which was obtained from a Nigerian telecommunications Service Provider. Secondly, clustering algorithm will also be applied on the same data set. Thirdly, the clusters that are of interest from the second stage are then classified to make future predictions.

## 2.0 MATERIAL AND METHODS

The data examined in this research is from the call records of subscribers in one of the telecommunication service providers in Nigeria. The data were gathered and collected in Microsoft Excel (CSV) format.

### 2.1 Data Selection and Preprocessing

The working data of this research contains the call records of 996 subscribers. The total number of records in the dataset is 228,520. The records covered a period of three months. Mysql was used for the extraction of the 12 RFM (Recency, Frequency, Monetary) Features based on those used by [3], [5], [6] and [7]. The 996 subscriber call records contain the following data which were selected from the call records in order to use them in building the required and targeted features:

a. Phone Number of each subscriber
b. Incoming Calls
c. Incoming Start Time
d. Incoming Duration
e. Outgoing Calls
f. Outgoing Start Time
g. Outgoing Duration

### 2.2 Data Mining

In this work, three methods of prediction were used; firstly, descriptive technique was used, secondly the predictive technique and thirdly, the combination of the two algorithms were used.

In the descriptive technique, the customer was clustered based on their usage behavioural (RFM) feature. K-means and Expected Maximization (EM) clustering methods were used for the clustering.

K-means clustering follows a simple and easy way to classify a given data set through a certain number of clusters fixed apriori. It partitions the objects into K mutually exclusive clusters, such that objects within each cluster are as close to each other as possible, and as far from objects in other clusters as possible. Each cluster is characterized by its centroid, or centre point [8]. Expected Maximization (EM) assigns a probability of it belonging to each of the clusters. EM can decide how many clusters to create by cross validation, or you may specify apriori how many clusters to generate.

For the predictive step, classification techniques were used. Classification is the process of finding a model that describes and distinguishes data classes or concepts for the purpose of being able to use the model to predict the class of objects whose class label is unknown [9] (Han and Kamber, 2006). Decision tree was chosen because it is capable of efficiently generating interpretable knowledge in an understandable form. Models from tree

classifier (RepTree, DecisionStump, and M5P) were used.

RepTree is a fast decision tree learner. It builds a decision/regression tree using information gain/variance and prunes it using reduced-error pruning (with backfitting). The algorithm only sorts values for numeric attributes once. Missing values are dealt with by splitting the corresponding instances into pieces [10].

DecisionStump is a model consisting of a one-level decision tree. That is, it is a decision tree with one internal node (the root) which is immediately connected to the terminal nodes. A decision stump makes a prediction based on the value of just a single input feature [10].

M5P implements base routines for generating M5 Model trees and rules. A learning technique that consistently yields the best result is M5P regression trees [10].

## 2.3 Building the Classification (Predictive) Model

Three measures are commonly used to describe call patterns of a subscriber by aggregating his/her call records (Wei and Chiu, 2002 and Ali, 2009) which are:

a. Minutes of use (MOU): This refers to the total number of minutes of outgoing calls made by the subscriber over a specific period
b. Frequency of use (FOU): This refers to the total number of outgoing calls made by the subscriber over a specific period.
c. Sphere of influence (SOI): This refers to the total number of distinctive receivers contacted by the subscriber over a specific period.

The following features were extracted for every subscriber:

a. $MOU_{initial}$: This represents the MOU of a subscriber in the first sub-period.
b. $FOU_{initial}$: This represents the FOU of a subscriber in the first sub-period.
c. $SOI_{initial}$: This represents the change in SOI of a subscriber in the first sub-period.
d. $\Delta MOU_s$: This represents the change in MOU of a subscriber between the sub-period s – 1 and s (for s=2,..n) and is measured by $\Delta MOU_s = (MOU_s - MOU_{s-1} + \delta)/ (MOU_{s-1} + \delta)$ where $MOU_1 = MOU_{initial}$ and $\delta$ is a small positive real number (e.g. 0.01) to avoid the case when $MOU_{s-1}$ is 0 (i.e. when $\Delta MOU_s$) cannot be calculated.
e. $\Delta FOU_s$: This represents the change in FOU of a subscriber between the sub-period s – 1 and s (for s=2,..n) and is calculated as $\Delta FOU_s = (FOU_s - FOU_{s-1} + \delta)/ (FOU_{s-1} + \delta)$.
f. $\Delta SOI_s$: This represents the change in SOI of a subscriber between the sub-period s – 1 and s (for s=2,..n) and is calculated as $\Delta SOI_s = (SOI_s - SOI_{s-1} + \delta)/ (SOI_{s-1} + \delta)$.

The classification model was constructed for each subscriber using the decision trees algorithms.

## 2.4 Building the Clustering (Descriptive) Model

Weka was used in building the clustering model. SimpleKmeans wrapped up withMakeDensityBased Clusterer and Expected Maximization (EM) was used for the clustering. The following set of 12 RFM related variables for [3] and [7] was constructed by the use of MySql in order to segment the subscriber based on their calling behavior:

1. **Call Ratio:** Proportion of calls which has been made by each subscriber to his/her total number of calls (incoming and outgoing calls).
2. **Max Date:** The last date in our observed period in which a subscriber has made a call.
3. **Min Date:** The first date in our observed period in which a subscriber has made a call.
4. **Average Call Distance**: The average time distance between one's calls.

5. **Life:** The period of time in our observed time span in which each subscriber has been active.
6. **Max-Distance:** The maximum time distance between two calls of a specific subscriber in our observed period.
7. **No-of-days:** Number of days in which a specific subscriber has made or received a call.
8. **Total-no-in**: The total number of incoming calls for each subscriber in our observed period.
9. **Total-no-out:** The total number of outgoing calls for each subscriber in our observed period.
10. **Total Cost:** The total money that each subscriber has been charged for using the services in the specific period under study.
11. **Total-duration-in:** The total duration of incoming calls (in seconds) for a specific subscriber in our observed time span.
12. **Total-duration-out:** The total duration of outgoing calls (in seconds) for a specific subscriber in our observed time span.

### 2.5 Combining both Clustering and Classification Techniques for Better Prediction

Instead of analyzing call records data of subscribers separately as have been considered in the two techniques above, the result from the clustering model was used for the classification stage. The subscribers that have not been responding well based on clustering and are likely to churn in the nearest future now became our interest for the classification stage in order to identify the specific churners from non-churners. The result will now be used for future prediction.

## 3.0 RESULTS AND DISCUSSION

The following presents the results of the predictive model, descriptive model and combination of both models.

### 3.1 Classification (Predictive) Model Result

The WEKA decision tree classifiers were used. Models from tree classifiers (DecisionStump, M5P, and RepTree) were used. Five yardsticks were used in measuring the performance of these classifiers. These yardsticks include:

i. **Correlation coefficient (CC)**: This measures the degree of correlation or relationship among the attributes. It ranges between 1 for high positive correlation to -1 for high negative correlation, with 0 indicating a purely random relationship.

ii. **Mean Absolute Error (MAE):** This is a quantity used to measure how close forecasts or predictions are to the eventual outcomes. As the name suggests, the mean absolute error is an average of the absolute errors. MAE can range from 0 to $\infty$. It is a negatively-oriented score: Lower values are better.

iii. **Root Mean Squared Error (RMSE):** The RMSE is a quadratic scoring rule which measures the average magnitude of the error. In other words, it represents the difference between forecast and corresponding observed values are each squared and then averaged over the sample. Finally, the square root of the average is taken. Since the errors are squared before they are averaged, the RMSE gives a relatively high weight to large errors. This means the RMSE is most useful when large errors are particularly undesirable. It can range from 0 to $\infty$. It is a negatively-oriented score: Lower values are better.

iv. **Relative Absolute Error (RAE):** This takes the total absolute error and normalizes it by dividing by average of the actual values. Lower values are better.

v. **Root Relative Squared Error (RRSE):** Instead of total absolute error as in RAE, it takes total squared error and divides by the average of the actual values. Finally, the square root of the result is taken.

Following the five yardsticks for measuring the performance of the three models (DecisionStump, M5P and RepTree) that were used, it was found out that M5P performed better than both DecisionStump and Reptree.

### 3.1.1 M5P Result on call records of Subscribers

M5 pruned model tree:
(using smoothed linear models)

FOUs <= -0.555 :

| FOUs <= -0.765 :

| | FOUs <= -0.94 :

| | | FOU_FINAL <= 1 : LM1 (3/298.184%)

| | | FOU_FINAL > 1 : LM2 (7/44.547%)

| | FOUs > -0.94 :

| | | SOI_FINAL <= 10.5 :

| | | | MOU_INITIAL <= 1351.5 : LM3 (3/1.237%)

| | | | MOU_INITIAL > 1351.5 : LM4 (5/17.249%)

| | | SOI_FINAL > 10.5 : LM5 (28/6.256%)

| FOUs > -0.765 : LM6 (160/4.132%)

FOUs > -0.555 : LM7 (790/2.746%)

### 3.1.2 Interpretation of M5P Result

No of Rule(s): 7
No of Instances: 996
Prediction: All the subscribers in with a total of 206 that fall under the rules (LM1:LM6) are classified as churners while the remaining subscribers with a total of 790 under the rules (LM7) are classified as non-churners.

**Table 1: Cross Validation Summary all (996) subscribers**

| Performance Measure | |
|---|---|
| Correlation Coefficient | 0.5784 |
| Mean Absolute Error | 3.4649 |
| Root Mean Squared Error | 25.9715 |
| Relative Absolute Error | 83.15% |
| Root Relative Squared Error | 82.08% |

### 3.2 Clustering (Descriptive) Model Result

Both SimpleKMeans and Expected Maximization algorithms were used for the clustering stage. Expected Maximization performed better than SimpleKMeans. The performance measure used was log likelihood which determines how well an algorithm has performed. As a result Expected maximization was used. The analysis of each of the attributes used is presented in graphical form.

### 3.2.1 Call Ratio

Call Ratio is the proportion of calls which has been made by each subscriber to his/her total number of calls (incoming and outgoing calls). Almost all the clusters are having the same call ratio except for cluster 10 with 0.3. The more a subscriber calls the more likelihood he /she is retained and the more turnover for the telecom service provider. Hence, the service provider should intensify effort in deploying strategy that will encourage subscribers in cluster 10 to make more calls.

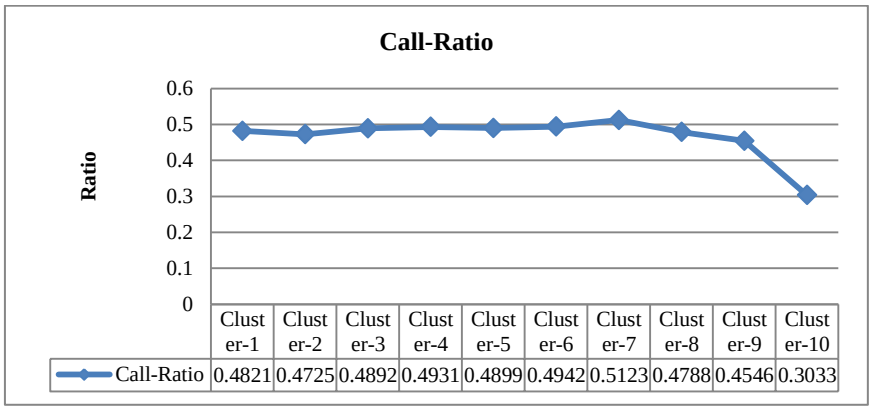



**Figure 1: Graphical Representation of Call-Ratio for each Cluster using EM (Expected Maximization)**

### 3.2.2 Average Call Distance

The Average Call Distance is the average time distance between one's calls. From figure 2, a cluster with high average call distance implies that the subscribers are not making call regularly. Clusters 8 and 9 fell into this category. This might be due to a number of reasons including getting the same service at lower cost from other service provider, quality of service to mention a few. Hence, they are likely to churn in the nearest future. The telecommunications service provider should intensify retention efforts on them so as to win them back.

### 3.2.3 Life

Life represents the period of time in our observed time span in which each subscriber has been active. In figure 3, those subscribers that fall in the category of clusters 8, 9 and 10 are likely to churn which may be due to some factors such as quality of the service, coverage, price, etc. For instance if a subscriber relocates to a location where there is no network coverage, the subscriber will need to go for another network.

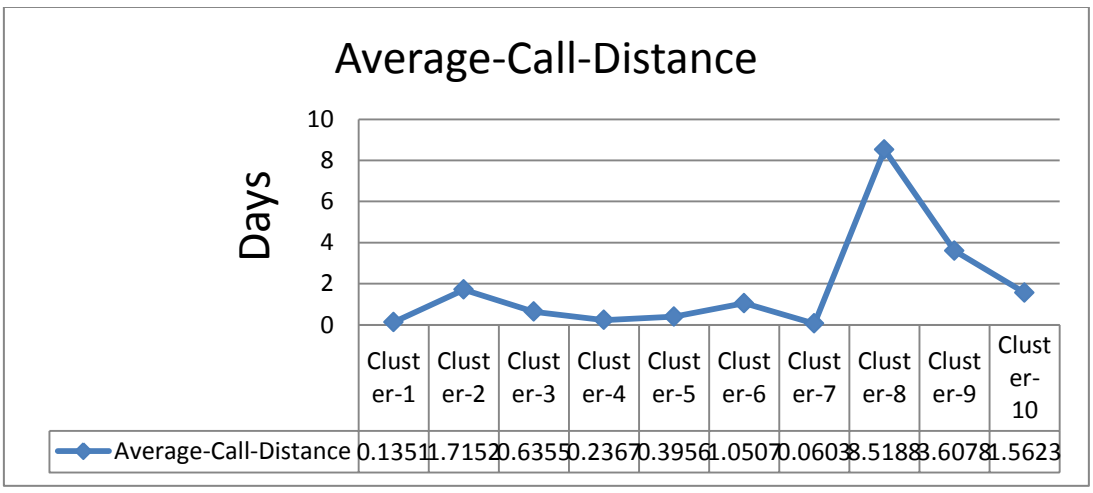
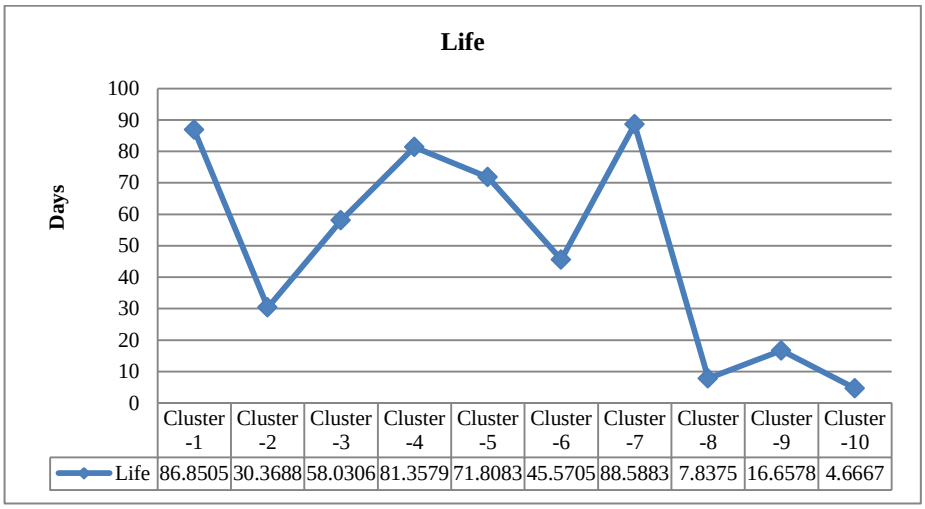



**Figure 2: Graphical Representation of Average-Call Distance for each Cluster using EM (Expected Maximization)**




network.

**Figure 3: Graphical Representation of Life for each Cluster using EM (Expected Maximization)**

### 3.2.4 Max Distance

Max-Distance is the maximum time distance between two calls of a specific subscriber in our observed period. Clusters with high maximum time distance represents the subscribers that have not been calling regularly. The higher the maximum time distance the more tendencies for the subscribers to churn. As a result retention efforts should be focused on the subscribers that fall into clusters 8, 9 and 10 in figure 4.

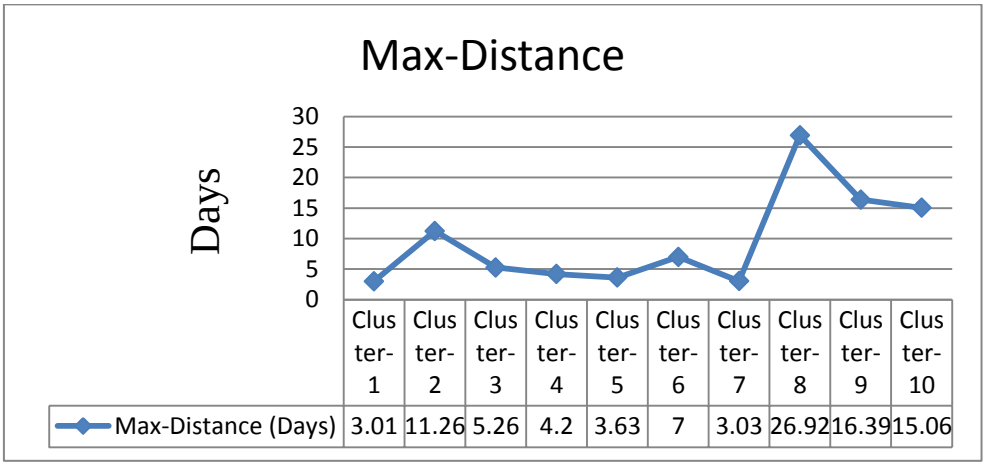



**Figure 4: Graphical Representation of Max-Distance for each Cluster using EM (Expected Maximization)**

### 3.2.5 No of Days

No-of-days stands for the number of days in which a specific subscriber has made or received a call. The total number of days in the observed period was ninety (90) days. Looking at figure 5, number of days for clusters 8, 9 and 10 is far below average and this implies that they have not been active. For them to be won back retention efforts have to be focused on them otherwise in the nearest future they are likely to churn.

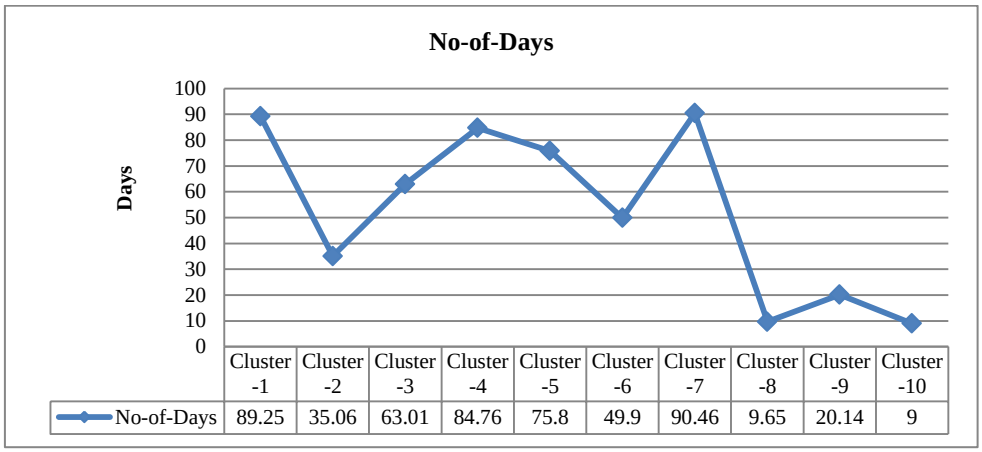



**Figure 5: Graphical Representation of No-of-Days for each Cluster using EM (Expected Maximization)**

### 3.2.6 Total No In

Total-no-in is the total number of incoming calls for each subscriber in our observed period. When a subscriber stops receiving calls through a network; it points to the fact that the subscriber might not be interested in the network again because if he/she is making calls through that network he will definitely be communicated back through that same network. As a result looking at figure 6, subscribers in clusters 2, 6, and especially clusters 8, 9 and 10 should be tracked so as to make investigation of what actually went wrong. From the investigation telecommunications service provider will now be informed of the kind of retention effort to deploy.

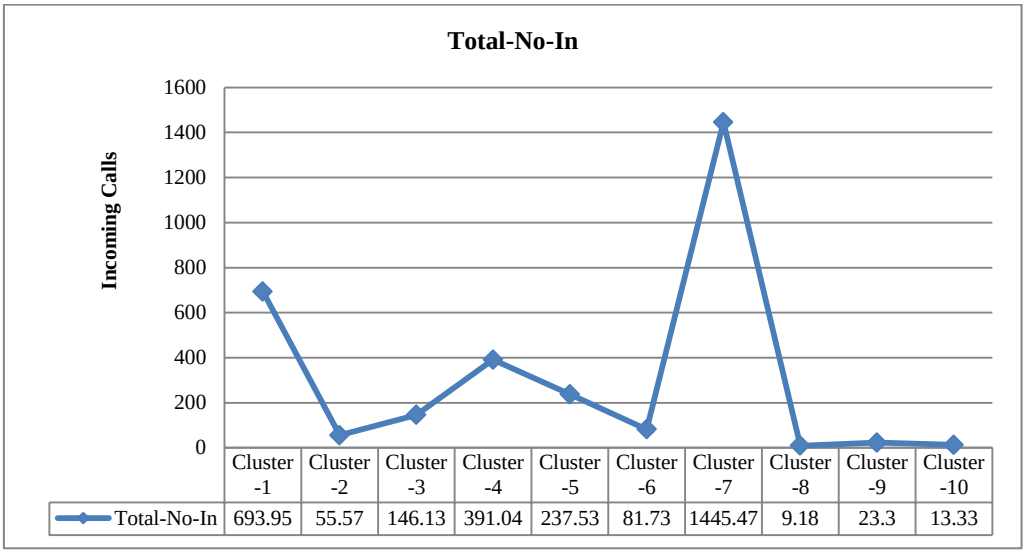



**Figure 6: Graphical Representation of Total-No-In for each Cluster using EM (Expected Maximization)**

### 3.2.7 Total No Out

Total-no-out represents the total number of outgoing calls for each subscriber in our observed period. A subscriber that stops making calls through a network will definitely not be receiving call through that network. In figure 7, the subscribers that form those clusters 2, 3, 6, 8-10 are likely to churn.

### 3.2.8 Total Cost

Total Cost is the total money that each subscriber has been charged for using the services in the specific period under study. The more money spent the likelihood that the subscriber is satisfied with the network services and vice versa. Price is the most determinant factor here because the lower the price the more the total turnover for the service provider and the more calls made by the subscribers. From figure 8, the clusters 2, 3, 6, 8, 9 and 10 have the lowest total cost. Retention efforts should be focused on those subscribers that form those clusters.

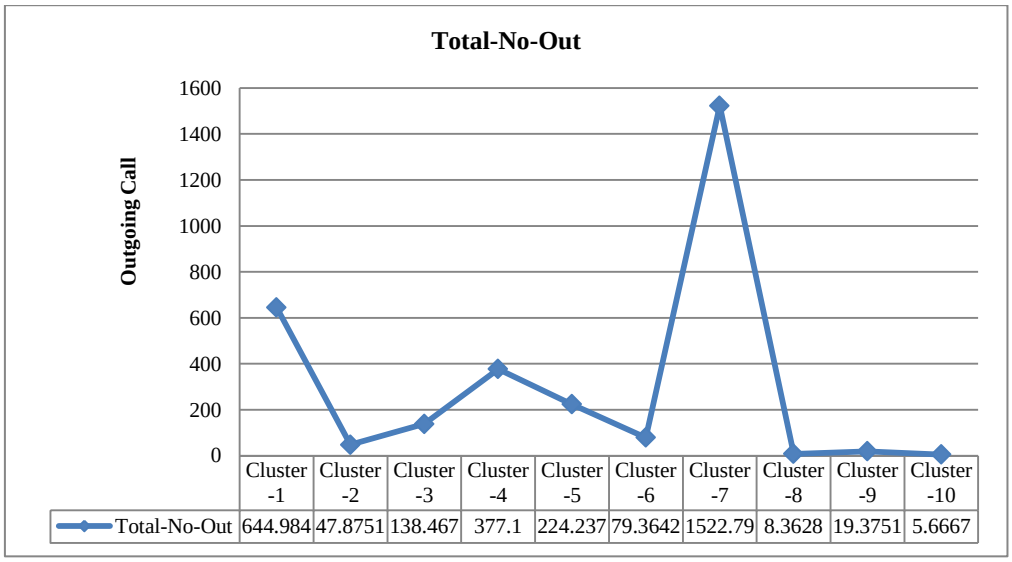



**Figure 7: Graphical Representation of Total-No-Out for each Cluster using EM (Expected Maximization)**

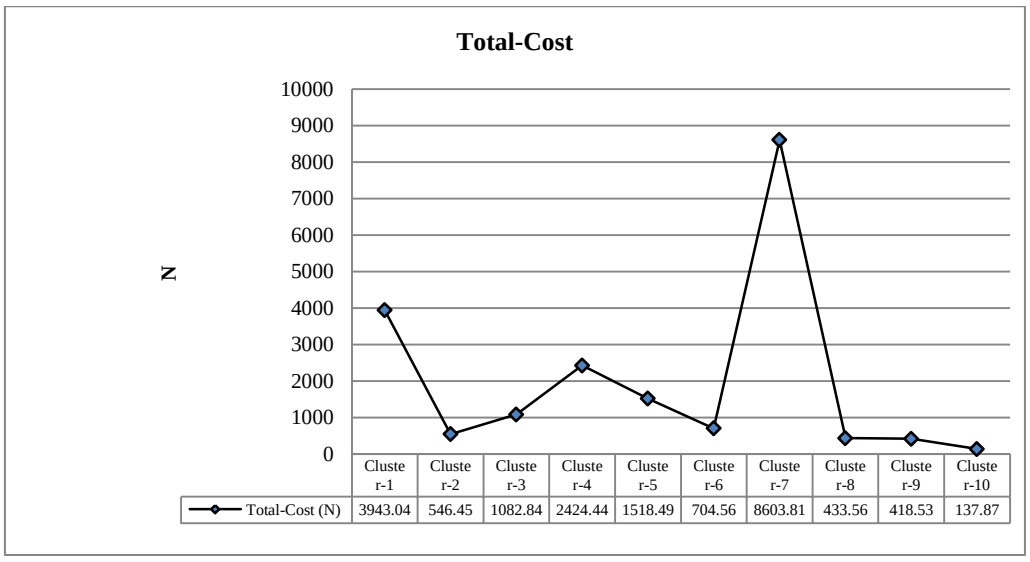



**Figure 8: Graphical Representation of Total-Cost for each Cluster using EM (Expected Maximization)**

**Remarks**

1. Subscribers in clusters 8, 9 and 10 have not been responding well and are very likely to churn in the nearest future. Hence, they should form the focus of targeted campaign in order to win them back.
2. Subscribers in clusters 2, 3 and 6 are slightly different, their call ratio and no of days attributes were still fairly okay. With demographic data further investigation could be carried out. For instance they could be students in school. Therefore, a package could be developed for them in other to encourage them.

### 3.3 Combination of Descriptive and Predictive Models Result

This study has shown the potential of both descriptive and predictive models combined in providing useful information on predicting more accurately the subscribers who are likely to churn. It has also provided solution to the problem of misclassification. Thus, to enhance accuracy elements of a dataset were first grouped by cluster and then applied the classification algorithms successively to clusters that were of interest. In this way each cluster's unique "rules" for relating attributes to classes were learnt and thereby more accurately classify the members of each cluster.

Using the result from clustering stage, subscribers in clusters 8, 9 and 10 became our area of interest. Subscribers that fall to clusters 8, 9 and 10 were regarded as churners due to their calling behavior. This evidence is not sufficient to classify these subscribers as churners because our interest is to identify specifically churners and non-churners from these subscribers that are generally classify as churners. Classification technique was applied to the subscribers in clusters 8, 9 and 10 so as to identify the churners from non-churners.

As it has been earlier discovered in the classification techniques, M5P algorithm performed better than DecisionStump and Rep Tree. As a result M5P algorithm was applied to clusters 8, 9 and 10 for the prediction.

#### 3.3.1 M5P Result on Cluster 8

M5 pruned model tree:
(using smoothed linear models)
LM1 (44/32.324%)

#### 3.3.2 Interpretation of M5P Result on cluster 8:

No of rule(s) : 1
No of instances : 44
Prediction: All the 44 subscribers in cluster are classified as churner.

#### 3.3.3 M5P Result on Cluster 9

M5 pruned model tree:
(using smoothed linear models)
ISOIs <= -0.527 :
| ISOIs <= -0.619 :
| | ISOIs <= -0.742 : LM1 (14/23.19%)
| | ISOIs > -0.742 : LM2 (55/21.703%)
| ISOIs > -0.619 :
| | IMOUs <= -0.09 : LM3 (29/32.134%)
| | IMOUs > -0.09 : LM4 (10/30.915%)
ISOIs > -0.527 :
| FOU_Initial <= 26 :
| | FOU_Final <= 9.5 :
| | | FOU_Initial <= 5 : LM5 (2/52.559%)
| | | FOU_Initial > 5 : LM6 (7/25.64%)
| | FOU_Final > 9.5 : LM7 (29/24.454%)
| FOU_Initial > 26 :
| | FOU_Final <= 24.5 : LM8 (13/2.656%)
| | FOU_Final > 24.5 :
| | | FOU_Initial <= 37.5 : LM9 (14/2.494%)
| | | FOU_Initial > 37.5 :
| | | | FOU_Initial <= 77 : LM10 (18/22.782%)
| | | | FOU_Initial > 77 : LM11 (5/22.962%)

### 3.3.4 Interpretation of M5P Result of on Cluster 9

No of Rule(s): 11
No of Instances: 196
Prediction: All the subscribers in cluster 9 with a total of 108 that fall under the rules (LM1: LM4) are classified as churners while the remaining subscribers with a total of 88 under the rules (LM5: LM11) are classified as non-churners.

### 3.3.5 M5P Result on Cluster 10

M5 pruned model tree:
(using smoothed linear models)
ISOIs <= -0.48 : LM1 (75/15.868%)
ISOIs > -0.48 : LM2 (20/47.175%)

### 3.3.6 Interpretation of M5P Result on Cluster 10

No of Rule(s): 2
No of Instances: 95
Prediction: All the subscribers in cluster 10 with a total of 75 that fall under the rule LM1 are classified as churners while the remaining subscribers with a total of 20 under the rules LM2 are classified as non-churners.

**Table 2: Cross Validation Summary for clusters 8, 9 and 10**

| Performance Measure | Cluster 8 | Cluster 9 | Cluster 10 |
|---|---|---|---|
| Correlation Coefficient | 0.9463 | 0.9283 | 0.9645 |
| Mean Absolute Error | 0.0476 | 0.0811 | 0.0866 |
| Root Mean Squared Error | 0.0613 | 0.1261 | 0.1288 |
| Relative Absolute Error | 38.33% | 35.57% | 39.33% |
| Root Relative Squared Error | 32.32% | 39.91% | 26.64% |

### Remarks

Applying Classification to our clusters 8, 9 and 10 brought out the actual churners and non-churners with better accuracy. This also went a long way to solve the problem of misclassification.

## 4.0 CONCLUSION

This research work proved that using both descriptive and predictive algorithms for predictions yield better accuracy than using either of the algorithms individually. This is evident in the performance measure of classification (M5P algorithm) applied on all the call records of the subscribers directly and on the clustered data (clusters 8, 9 and 10) in Tables 1 and 2 respectively. This work is now advocating that researchers should employ the use of both algorithms in prediction.

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# FORMAL STRUCTURES FOR EXTRACTING ANALYTICALLY JUSTIFIABLE DECISIONS FROM A SET OF AMBIGUOUS KEY PERFORMANCE INDICATORS

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## ABSTRACT

This paper identifies the benefits of transforming business process models into Decision Support Systems (DSS). However, the literature reveals that a business process model "should have a formal foundation" as a major requirement for transforming it into a DSS. The paper further ascertains that formal structures refer to logical representations of the relationships existing between the dependent and the independent variables in a specific architecture description. In view of these requirements, the paper adopts the business process modelling methodology to analyse the instrumentality of a case study, and establishes a lack of logical correlations in the transitions between the inputs and the output. The paper therefore, provides two analytically plausible standards for these transformations. The first of the models, called the EOP, is a mathematical relationship for obtaining justifiable outcomes from the Key Performance Indicators. The second is the Promotability-Index model, which is a formulation using Decision Tables. The paper further affirms that Decision Tables are useful in the specification, analysis, design, and testing stages of the Structured Systems Analysis and Design Methodology (SSADM) for transforming ideas into complex logic. Eventually, with these models, a practically useful information system can be developed easily, driven by the logic embedded within the tables, coupled with the well planned business decisions. The contribution of the paper is to provide models that describe the internal computation mechanisms driving the DSSs at the background, and this works towards improving accuracy in performance evaluation results.

**Keywords:** Formal Structure, Mathematical Model, DSS, Decisions Support System, Business Process Model

## 1.0 INTRODUCTION

Armstrong in [3] identifies the need for continuous research into the strategies for improving accuracy in performance evaluation results. In view of this, many authors recommend the strategy of transforming the performance evaluation business process models into Decision Support Systems [8], [6], and [14]. However, even the few of such systems referenced in the literature, such as [19], do not provide the necessary expository description of the internal computation mechanisms driving the systems at the background. This paper therefore, makes a contribution towards making models of

these internal computation mechanisms available for software developers.

Koole in [11] defines a Decision Support System (DSS) as an interactive model-based computer system that helps humans solve a certain class of business problems. More so, [10] identifies the benefits associated with the implementation of Decisions Support Systems to include: Intelligent behaviors in gathering and incorporating domain knowledge, learning from the acquired knowledge, reasoning about such knowledge and whenever enquired, being able to issue recommendations and justifiable outcomes.

The above benefits are very critical in employees' performance evaluation results, as they will serve to motivate the workforce towards increased productivity and improved quality of output [1]. Consequently, this paper analyses appendix 1, with a view to transforming it into a DSS. Appendix 1 is the business process model used by some organisations in the Nigerian Public Service (NPS) for evaluating the performances of their employees. It is therefore, a very important tool that helps in facilitating management's decisions making [24]. Nevertheless, for the outcome to lead to the making of sound decisions, [2] insists that the fixed sequence of activities that convert inputs to outputs in the business process model must be well defined.

The preceding requirement therefore, motivates the first objective of this paper, which is to analyse the dependencies in Appendix 1, and identify the possible bottlenecks in transforming it into a DSS. The analysis will focus on the characteristics of the Key Performance Indicators (KPIs), which [5] describes as the main objects in a business process model that enable decision makers to specify the performance evaluation aspects against the objectives. The KPIs are therefore, the value drivers used to regulate employees' actions and inactions in the workplace [16]. Subsequently, when the KPIs are developed, they drive all subsequent data collection, analysis, and reporting in performance evaluation business process models [25].

The verification analysis reveals a lack of precise definition in the logical transitions between the independent and the dependent variables, thereby exposing the ambiguity in obtaining justifiable outcomes using the instrumentality of Appendix 1. The presence of ambiguity in the variable dependency transitions therefore, renders Appendix 1 unsuitable for transformation into an employees' performance evaluation Decisions Support System. However, [23] recommend that business process models "should have a formal foundation" because such models do not leave any scope for ambiguity and increase the potential for analysis.

The above recommendation therefore, motivates the second objective of this paper, which is to formulate a set of formal structures from the KPIs, for the purpose of providing analytically plausible standard for transforming inputs to outputs in an employees' performance evaluation business process model. The formal structure of a model is a mathematical representation of the relationships existing between the independent and the dependent variables in the specific architecture description [13]. This paper introduces two models to provide the functionality required in the preceding statement.

The first of the models, called the EOP model, provides a mathematical relationship for determining the overall performance of an employee. The second, called the Promotability-Index model, is a formulation using Decision Tables, which are visual logic structures for determining the eventual outcome of the process. The objects, relations and constraints in the business process model are formally structured in the Decision Tables, so as to provide the rules-templates for obtaining

predictable results, in a format that is visually comprehensible, and therefore, easily verifiable. Eventually, when the business process model is eventually transformed into a DSS, these formal structures represent the possible computations of that program. ReQtest in [18] recommends the construction of Decision Tables during system design, as they provide very vital software development tools for developers, assist the requirements specialist to be more confident that every important element has been documented, and help the tester to create better test cases.

## 2.0 CHARACTERISTICS OF KEY-PERFORMANCE INDICATORS

The World Bank in [25] indicates that Key Performance Indicators could be quantitative or qualitative, but warns that qualitative indicators should be used with caution, since they are harder to verify, because they often make use of subjective judgements. Consequently, [17] advocates for the use of objective, quantifiable, and measurable criteria in evaluating employees' performances, as this will improve fair judgement and perception of equity. This position is in agreement with [9] who defines a KPI as a performance metric for a specific business activity that has an associated business goal.

A performance metric includes three components: the performance measure or metric definition, the weights, and the target [16]. The goal is used to determine whether or not the business activity is performing within accepted limits. The tracking and analysis of the KPIs provide business users with the insight required for business performance optimisation. To be effective therefore, the KPIs of an employees' performance evaluation system should be clearly defined in terms of these components.

The performance measure defines how the metric will be measured in terms of, what quantity is obtained out of the total quantity (such as percentage of, number of, rates, etc.). It could be referred to as the criteria to determine if a particular result has been achieved. The weight is the relative importance of the aspect in the overall function of meeting the performance goals. It is always expressed as a percentage. The target is the desired level of achievement for a given performance aspect. It specifies the range of achievement on a particular measure that signifies that performance has met expectations. The target is the outcome we are aiming at (that is, the result we are trying to achieve). A result that falls above the target exceeds expectations, and the one that falls below, does not meet expectations. The target is always expressed as a range.

## 3.0 ANALYSIS OF THE KEY-PERFORMANCE INDICATORS IN APPENDIX 1

Business process modelling involves identifying and presenting a baseline model of an existing ('as is') process, analysing, and developing a new improved ('to be') model [4]. This paper adopts this methodology, which begins with the verification analysis of the KPIs dependencies in Appendix 1. This is with a view to exposing the bottlenecks in accurately obtaining justifiable outcomes therein. The outcome of this stage will then determine the structure of the proffered solution.

Appendix 1 is the 'as is' model. [4] indicates that an 'as is' model gives an overall picture of how the process works, now. More so, [20] posits that the picture presents what the process looks like as a whole, broken down in terms of the specific activities that must be completed, the order in which they must be completed, and the dependencies between those activities. The dependencies include the relations linking the objects that interact to produce the outcome. However, in a dependency diagram, the independent variables interact to produce the dependent variable, which represents the outcome.

Section 10 of Appendix 1 defines the scope of the independent variables identified as "Aspects of Performance". These are the KPIs used by the supervisors in rating the performances of their subordinates on the various aspects. Consequently, the KPIs in Section 10 (I-IV) interact to determine the value for an employee's overall performance (Overall assessment) in Section 11. The overall performance value, which is the dependent variable, plays a very crucial role, since it is a very significant factor in determining the eventual rewards from the performance evaluation process.

It is therefore, imperative that we analyse these dependencies to ascertain the extent to which the independent variables (inputs) contribute to the dependent variable (outcome). We do this by comparing their characteristics in terms of the three components that should effectively constitute the KPIs in a performance evaluation tool: the performance measure or metric definition, the weights, and the target.

### 3.1 THE PERFORMANCE MEASURE OR METRIC DEFINITION

The following criteria are presented in Section 11 as the performance measures:

**A: Outstanding**. An exceptionally valuable member of the staff; performance is well above the required standard for the job.

**B: Very Good**. Display good all-round level of effectiveness; performance meets requirements in all important tasks.

**C: Good**. A competent member of staff; generally achieves the standards required.

**D: Satisfactory**. Completes all assignments satisfactorily within the agreed dates.

**E: Fair**. Performance does not always reach the required standard; room for improvement.

**F: Poor**. Performance does not meet the standard.

These criteria are determined subjectively. In other words, there is no correlation linking these ratings with those awarded earlier for the same employee. More so, the ratings in Section 11 are supposed to be used in determining the final outcome as presented in Section 15. However, it is also clearly evident that Section 15 does not have a formal relationship with Section 11, thereby having a performance evaluation tool whose outcome may be laden with supervisor biases. In other words, there is no standard for obtaining employee's actual performances using this instrument.

### 3.2 THE WEIGHTS

The supervisor is expected to rate the performances of his subordinate with any of the letter grades: A, B, C, D, E, and F. Furthermore, the letter grades are also attached with the following weights, as found in the introduction of Section 10:

A: 6
B: 5
C: 4
D: 3
E: 2
F: 1

**Observation:** After the definition of these weights, there were no further references made to them till the end of the document. The implication of this observation is that the weights are never applied in determining the outcomes. Meanwhile, the performance weights help in driving organisational mission and vision, by depicting the relative importance of the performance aspects. The non-utilisation of the performance weights therefore, will impact negatively on the performance evaluation outcome, which will in-turn affect the effective attainment of the mission and vision.

### 3.3 THE TARGETS

We can weakly refer to: Sections 12 (Training Needs), 13 (General Remarks),

14 (Suggestions for Redeployment), and 15 (Promotability) as constituting the targets in Appendix 1. However, the performance target serves as the major driver that motivates the employees in the workplace, as they try to meet up with the benchmark for work attributes. Consequently, we view Section 15 as the major value driver, while Sections 12, 13, and 14 are additional incentives that may not necessarily be determined through the instrumentality of Appendix 1. Therefore, we hinge our observations on the characteristics of Section 15.

## Observation:

Section 15, the Promotability index that determines the reward awarded to employee does not make any reference to any of the ratings that have been awarded in the preceding sections, which constitute the independent variables. Rather, the section provides Checkboxes that allows the supervising officer to select one of the rewards from among the list to which the employee appraise will be awarded. This is an indication of subjective rating, which does for any correlation between the independent and the dependent variables.

The implication of this is that the supervisor is at liberty to award any of the overall ratings to the subordinate, irrespective of what was awarded at the preceding sections. This is part of the reasons why employee performance ratings in many organisations could be far above average, while the organisational performance falls far below average. This is contradictory, since the performances of the employees in an organisation should determine, to a large extent, the performance of the organisation.

## 3.4 SUMMARY OF FINDINGS

It is observed that there is no standard for obtaining employee's actual performances using this instrument. More so, the performance weights are defined but never utilised in determining employees' performance outcomes. Finally, the Promotability index that determines the target in Appendix 1, and represents the reward awarded to the employees does not make any reference to any of the ratings that have been awarded in the preceding sections, which constitute the independent variables. We therefore, summarise the characteristics of the KPIs in the baseline model as presented in Figure 1.

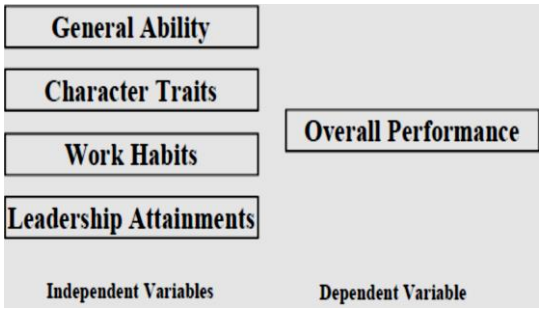


**Figure 1: Baseline Model of the KPIs in Appendix 1**

Figure 1 is a picture of the KPIs in Appendix 1 broken down into the dependent and independent variables. These variables are the core value drivers, and are therefore, used in determining the high level performance metrics embedded in the instrument. Figure 1 reveals the disconnect between the dependent and the independent variables. In other words, the dependent variable is not determined as an outcome from the independent variables. The implication of this feature is that the supervising officer is at liberty to award the highest overall performance score even when the appraisee had scored very lowly in the majority of the value drivers.

Based on these features, we posit that the baseline model is:

i. Incommensurable, as the Employee Overall Rating is determined subjectively (ambiguously) without a computational formula for comparison, and cannot therefore, be used for the development of a Decision Support System.
ii. Inequitable, as there is no Computational Associativity between the Employee Actual Performance and

the Key Performance Indicators used for determining an Employee's Reward.

iii. Therefore, inconsequential, as some employees could be positively rewarded without recourse to performance achievements. This position derives from the fact that the promotability index is ignored. The promotability index associates the Employee Overall Rating with the constraints for determining the final outcome of an employee's reward. Consequently, performance evaluation decisions are largely dependent on the satisfaction of the constraints as well as supervisor's tendencies.

In the following sections, we present the structures that will provide a set of common standard that will minimise the ambiguities associated with the KPIs in Appendix 1.

## 4.0 DERIVING THE FORMAL STRUCTURES FROM THE KEY PERFORMANCE INDICATORS IN APPENDIX 1

Formal models are the ones in which process concepts are defined rigorously and precisely, so that mathematics can be used to analyse them, extract knowledge from them, and reason about them [23]. It is safe therefore, to assert that a formal model is a mathematical model, and is a representation of a system using mathematical concepts and language [21]. One advantage of using them is that they can be verified mathematically, and can be checked for consistency and other properties [12].

To obtain a mathematical model, mathematical modelling principles have to be applied to solving a specific real life problem. Mathematical modelling replaces components or variables in the specified real-life system with symbols, which are further related mathematically. In fact, [15] lists four steps of mathematical modelling to include:

i. **Draw a picture**: if possible, draw a picture of the situation.
ii. **Use Variables**: assign a letter for each variable mentioned in the problem.
iii. **Describe the situation**: use the given information to try and find equations for the desired quantity.
iv. **Evaluate**: solve the system of equations for the desired value.

These steps will guide us in developing the mathematical model for the Overall performance, which has been presented in the earlier sections as the dependent (output) variable. Figure 2 is a reinvention of Figure 1. However, Figure 2 clearly depicts the dependencies.

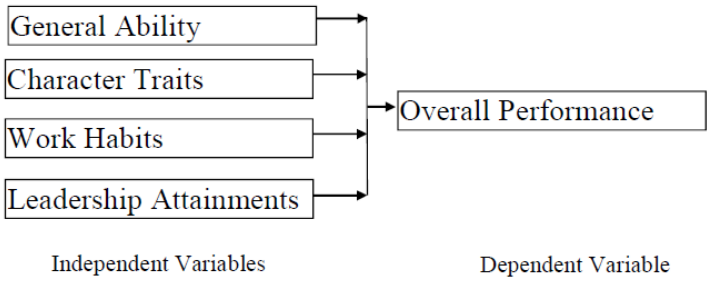


**Figure 2: Framework for obtaining the Overall Performance Model showing the Dependencies**

From Figure 2, it could be seen that there are four performance aspects (drivers) to be considered in obtaining the Overall performance, including: General Ability, Character Traits, Work Habits, and Leadership Attainment. These four parts put together, therefore, constitute the independent variables.

Mathematically, therefore, we assign each of the variables in Figure 2 with a symbol, in order to make its representation clearer, as follows:

$X_1$ = General Ability
$X_2$ = Character Traits
$X_3$ = Work Habits
$X_4$ = Leadership Attainment

## 4.1 OBTAINING THE EMPLOYEE OVERALL PERFORMANCE (EOP) MODEL

Let $X_1$, $X_2$, $X_3$, and $X_4$ denote the independent variables representing the inputs, and EOP denote the dependent variable, representing the output. The relationship therefore, between the inputs and the output can be represented, as shown in Equation 1.

$$EOP = f(X_1, X_2, X_3, X_4) \quad 1$$

The structure in Figure 2 indicates that the independent variables have additive property. In other words, they add up together to produce the EOP.

This additive characteristics is presented in Equation 2

$$EOP = X_1 + X_2 + X_3 + X_4 \quad 2$$

Equation 2 is the EOP without the associated performance weights. In order to associate the performance aspects with the level of importance to which the organisation perceives their contributions, we attach the variables with their derived constants. This produces the relationship in Equation 3.

$$EOP = \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 \quad 3$$

Equation 3 possesses the characteristics of a multiple regression model, and should therefore have a constant variable to take care of the slight deviations in the quality of data. Introducing the constant variable into Equation 3 produces Equation 4.

$$EOP = a + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 \quad 4$$

where :
a = constant variable
$\beta$ = associated weights of the independent variables
$X_1$ = General Ability
$X_2$ = Character Traits
$X_3$ = Work Habits
$X_4$ = Leadership Attainments

Equation 4 is the final EOP model that can be used for prediction, depending on the input values supplied for $X_1$, $X_2$, $X_3$, and $X_4$. The actual values for "a" (the constant variable) and "β" (the weights variables) will be generated by a Computer System using actual data and a multiple regression analysis software.

## 4.2 OBTAINING THE PROMOTABILITY-INDEX MODEL

The second index in Appendix 1 is the Promotability-Index model. The model is obtained using a framework that integrates the EOP value and the constraints. Since the structure for obtaining the EOP value has been established, we proceed in this section to present the structure for the constraints, and subsequently, develop the Decision Tables for determining employees' rewards. To be eligible for promotion to the next rank, [7] stipulates that an employee satisfies three conditions, including: performance, due date, and qualifications.

The performance constraint is the motivation behind the measurement of work attributes. It is used as a benchmark to compare the level of attainment in employee's actual performance. It should be attainable and associated with special incentives. However, the highest level in the target range should be able to encourage employees to work harder because of the associated incentives. In consideration of these positions, we devise the conventions in Table 1 as the range of values that determines the group an employee's performance should belong.

**Table 1: Employee Overall Performance Constraints**

| ***Employee Overall Performance*** | ***Group*** | ***Reward*** |
|---|---|---|
| *80% and above* ***(GROUP I)*** | *High Performer (s)* | *Promotion depending on the other constraints, and a Commendation Certificate.* |
| *Less than 80% but more than or equal-to 60%* ***(GROUP II)*** | *Medium Performer (s)* | *Promotion depending on the other constraints.* |
| *Less than 60% but more than or equal-to 40%* ***(GROUP III)*** | *Average Performer (s)* | *No Promotion, advised to improve performance.* |
| *Less than 40%* ***(GROUP IV)*** | *Low Performer (s)* | *Queried, to ascertain the cause (s) of low performance.* |

Furthermore, [7] stipulates the following provisions as constraints for the purpose of promotion to a higher rank:

i. The minimum number of years that an officer must spend in a post before being considered eligible for promotion is as shown in Table 2.

**Table 2: Employee Due-Date Constraints**

| ***Grade Level of Staff*** | ***Number of Years in Post*** |
|---|---|
| *06 and below* | *Minimum of 2 years* |
| *07-14* | *Minimum of 3 years* |
| *15-17* | *Minimum of 4 years* |

ii. The minimum qualifications that an employee should have in order to be qualified to be promoted to a post are as shown in Table 3.

**Table 3: Employee Qualifications Constraints**

| ***Grade Level of Staff*** | ***Minimum Qualifications*** | ***Quali-fications ID.*** |
|---|---|---|
| *1-3* | *FSLC* | *1* |
| *4-5* | *SSCE/GCE/Equiv.* | *2* |
| *6-7* | *ND/NCE/ Equiv.* | *3* |
| *8 and above* | *HND/BSC/BA/Equiv.* | *4* |

The values in Table 1, Table 2, and Table 3 represent the constraints for determining the Target of the referred performance evaluation business process model. The next step is to formulate the values in these tables so as to obtain the logical relationships for the Promotability-Index. The Promotability-Index (Outcome) attribute is a value which determines the recommended decision for each employee. The number of variables combinations derivable from the constraints presented above demonstrates a complexity in the relationships between the inputs and the outputs. A good way to deal with such representations is to use Decision Tables, since they make it easy to see that all possible combinations of conditions have been considered and when conditions are missed, it is easy to see [18].

A decision table is a "tabular representation used to describe and analyse decision situations, where the state of a number of conditions determines the execution of a set of actions. Not just any representation, however, but one in which all distinct situations are shown as columns in a table, such that every possible case is included in one and only one column (completeness and exclusivity)" [22]. In a Decision Table, logic is modeled with rules, combination of conditions, and then the action entries that will correspond to an action in decision making. Finally, the action of each rule is the evaluation of the formula.

However, in order to minimise the risk of the tables being so large, and therefore, more difficult to manage, [18] advocates for the creation of many smaller decision tables instead of fewer larger ones. This recommendation is adopted in this paper in organising the Decision Tables. Consequently, the tables are organised according to employee's grade levels, since the constraints are presented in this pattern.

The Decision Tables are therefore, presented in terms of their corresponding grade levels, as shown in Tables 4, 5, 6, 7, 8, and 9.

**Table 4: Decision Table for Grade Level 1-3 Staff**

| *Grade Level* | *EOP (%)* | *Due-Date (years)* | *Qualifications ID* | *Promo-tability* | *Outcome* | *Recommendation* |
|---|---|---|---|---|---|---|
| *1-3* | *>= 80* | *>=2* | *1* | *Yes* | *8* | *Promotion and Commendation Certificate* |
| | *>= 80* | *<2* | *1* | *No* | *7* | *Commendation Certificate. Not due for promotion* |
| | *< 80 >= 60* | *>=2* | *1* | *Yes* | *6* | *Promotion Only* |
| | *< 80 >= 60* | *<2* | *1* | *No* | *5* | *Satisfactory. Not due for promotion* |
| | *< 60 >= 40* | *>=2* | *1* | *No* | *4* | *Denied Promotion. Advised to improve performance* |
| | *< 60 >= 40* | *<2* | *1* | *No* | *3* | *Not due for promotion. Advised to improve performance* |
| | *< 40* | *>=2* | *1* | *No* | *2* | *Denied Promotion. Queried to ascertain the cause of poor performance* |
| | *< 40* | *<2* | *1* | *No* | *1* | *Not due for promotion. Queried to ascertain the cause of poor performance* |

**Table 5: Decision Table for Grade Level 4-5 Staff**

| *Grade Level* | *EOP (%)* | *Due-Date (years)* | *Qualifications ID* | *Promo-Tability* | *Outcome* | *Recommendation* |
|---|---|---|---|---|---|---|
| *4-5* | *>= 80* | *>=2* | *2* | *Yes* | *8* | *Promotion and Commendation Certificate* |
| | *>= 80* | *<2* | *2* | *No* | *7* | *Commendation Certificate. Not due for promotion* |
| | *< 80 >= 60* | *>=2* | *2* | *Yes* | *6* | *Promotion Only* |
| | *< 80 >= 60* | *<2* | *2* | *No* | *5* | *Satisfactory. Not due for promotion* |
| | *< 60 >= 40* | *>=2* | *2* | *No* | *4* | *Denied Promotion. Advised to improve performance* |
| | *< 60 >= 40* | *<2* | *2* | *No* | *3* | *Not due for promotion. Advised to improve performance* |
| | *< 40* | *>=2* | *2* | *No* | *2* | *Denied Promotion. Queried to ascertain the cause of poor performance* |
| | *< 40* | *<2* | *2* | *No* | *1* | *Not due for promotion. Queried to ascertain the cause of poor performance* |

**Table 6: Decision Table for Grade Level 6 Staff**

| *Grade Level* | *EOP (%)* | *Due-Date (years)* | *Qualifications ID* | *Promo-tability* | *Outcome* | *Recommendation* |
|---|---|---|---|---|---|---|
| *6* | *>= 80* | *>=2* | *3* | *Yes* | *8* | *Promotion and Commendation Certificate* |
| | *>= 80* | *<2* | *3* | *No* | *7* | *Commendation Certificate. Not due for promotion* |
| | *< 80 >= 60* | *>=2* | *3* | *Yes* | *6* | *Promotion Only* |
| | *< 80 >= 60* | *<2* | *3* | *No* | *5* | *Satisfactory. Not due for promotion* |
| | *< 60 >= 40* | *>=2* | *3* | *No* | *4* | *Denied Promotion. Advised to improve performance* |
| | *< 60 >= 40* | *<2* | *3* | *No* | *3* | *Not due for promotion. Advised to improve performance* |
| | *< 40* | *>=2* | *3* | *No* | *2* | *Denied Promotion. Queried to ascertain the cause of poor performance* |
| | *< 40* | *<2* | *3* | *No* | *1* | *Not due for promotion. Queried to ascertain the cause of poor performance* |

**Table 7: Decision Table for Grade Level 7 Staff**

| *Grade Level* | *EOP (%)* | *Due-Date (years)* | *Qualifications ID* | *Promo-tability* | *Outcome* | *Recommendation* |
|---|---|---|---|---|---|---|
| *7* | *>= 80* | *>=3* | *3* | *Yes* | *8* | *Promotion and Commendation Certificate* |
| | *>= 80* | *<3* | *3* | *No* | *7* | *Commendation Certificate. Not due for promotion* |
| | *< 80 >= 60* | *>=3* | *3* | *Yes* | *6* | *Promotion Only* |
| | *< 80 >= 60* | *<3* | *3* | *No* | *5* | *Satisfactory. Not due for promotion* |
| | *< 60 >= 40* | *>=3* | *3* | *No* | *4* | *Denied Promotion. Advised to improve performance* |
| | *< 60 >= 40* | *<3* | *3* | *No* | *3* | *Not due for promotion. Advised to improve performance* |
| | *< 40* | *>=3* | *3* | *No* | *2* | *Denied Promotion. Queried to ascertain the cause of poor performance* |
| | *< 40* | *<3* | *3* | *No* | *1* | *Not due for promotion. Queried to ascertain the cause of poor performance* |

**Table 8: Decision Table for Grade Level 8-14 Staff**

| *Grade Level* | *EOP (%)* | *Due-Date (years)* | *Qualifications ID* | *Promo-tability* | *Outcome* | *Recommendation* |
|---|---|---|---|---|---|---|
| *8-14* | *>= 80* | *>=3* | *4* | *Yes* | *8* | *Promotion and Commendation Certificate* |
| | *>= 80* | *<3* | *4* | *No* | *7* | *Commendation Certificate. Not due for promotion* |
| | *< 80 >= 60* | *>=3* | *4* | *Yes* | *6* | *Promotion Only* |
| | *< 80 >= 60* | *<3* | *4* | *No* | *5* | *Satisfactory. Not due for promotion* |
| | *< 60 >= 40* | *>=3* | *4* | *No* | *4* | *Denied Promotion. Advised to improve performance* |
| | *< 60 >= 40* | *<3* | *4* | *No* | *3* | *Not due for promotion. Advised to improve performance* |
| | *< 40* | *>=3* | *4* | *No* | *2* | *Denied Promotion. Queried to ascertain the cause of poor performance* |
| | *< 40* | *<3* | *4* | *No* | *1* | *Not due for promotion. Queried to ascertain the cause of poor performance* |

**Table 9: Decision Table for Grade Level 15-17 Staff**

| *Grade Level* | *EOP (%)* | *Due-Date (years)* | *Qualifications ID* | *Promo-tability* | *Outcome* | *Recommendation* |
|---|---|---|---|---|---|---|
| *15-17* | *>= 80* | *>=4* | *4* | *Yes* | *8* | *Promotion and Commendation Certificate* |
| | *>= 80* | *<4* | *4* | *No* | *7* | *Commendation Certificate. Not due for promotion* |
| | *< 80 >= 60* | *>=4* | *4* | *Yes* | *6* | *Promotion Only* |
| | *< 80 >= 60* | *<4* | *4* | *No* | *5* | *Satisfactory. Not due for promotion* |
| | *< 60 >= 40* | *>=4* | *4* | *No* | *4* | *Denied Promotion. Advised to improve performance* |
| | *< 60 >= 40* | *<4* | *4* | *No* | *3* | *Not due for promotion. Advised to improve performance* |
| | *< 40* | *>=4* | *4* | *No* | *2* | *Denied Promotion. Queried to ascertain the cause of poor performance* |
| | *< 40* | *<4* | *4* | *No* | *1* | *Not due for promotion. Queried to ascertain the cause of poor performance* |

In the Decision Tables above, each row is a rule, and each column in that row is either a condition or action for that rule towards arriving at a decision. The clear tabular representation in the tables are meant to prevent software developers from making avoidable mistakes that may happen when studying loosely organised business documents. More so, Decision Tables offer a simple, visual aid that can be applied in the development of knowledge-based systems to perform verification processes efficiently.

Furthermore, Decision Tables are efficient for describing situations where varying conditions produce different test actions. They are equally powerful for finding faults both in implementation and specifications. In software development, Decision Tables help test-teams manage complex logic in software applications.

With these benefits, coupled with the well planned business decisions, a practically useful information system can be

developed easily. In summary therefore, Decision Tables are found to be useful in the specification, analysis, design, and testing stages of the Structured Systems Analysis and Design Methodology (SSADM) of transforming ideas into complex logic. The tables developed here are therefore, to be embedded within the logic that will drive the eventual computer programs.

## 5. CONCLUSIONS

This study posits that a business process model "should have a formal foundation" as a major requirement for transforming it into a DSS. The paper further identifies indicates that a formal model is any model which the process concepts are defined rigorously and precisely, so that mathematics can be used to analyse them, extract knowledge from them, and reason about them [23].

The analysis of Appendix 1, based on the above requirements, establishes a lack of precise definition in the logical transitions between the independent and the dependent variables, thereby exposing ambiguity in obtaining justifiable outcomes using the instrumentality of this business process model. The presence of ambiguities in the variable dependency transitions of Appendix 1 therefore, renders it unsuitable for transformation into an employees' performance evaluation Decisions Support System.

The paper therefore, provides formal structures from the KPIs in Appendix 1, for the purpose of providing analytically plausible standard for transforming the inputs to outputs in an employees' performance evaluation business process model. The first of the structures, called the EOP model, provides a mathematical relationship for determining the overall performance from the Key Performance Indicators. The second is the Promotability-Index model, which is a formulation using Decision Tables.

The paper further indicates that Decision Tables are useful in the specification, analysis, design, and testing stages of the Structured Systems Analysis and Design Methodology (SSADM) of transforming ideas into complex logic. Eventually, with these models, a practically useful information system can be developed easily, driven by the logic embedded within the tables, coupled with the well planned business decisions.

Finally, the paper makes a contribution towards improving accuracy in performance evaluation results, by providing models that describe the internal computation mechanisms driving the systems at the background. An empirical study to validate the impact of the models on field data is ongoing. We recommend the models for further independent validation in order to establish the reliability of our claims.

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# APPENDIX I

## RELEVANT SECTIONS OF A TYPICAL ANNUAL APPRAISAL FORM USED IN SOME ORGANISATIONS IN THE NIGERIAN PUBLIC SERVICE

**PART THREE**

*(To be completed by the Reporting Officer under whom the Officer has been serving during the year)*

***9. Assessment of Performance***

(a) Did you and the person reporting upon agree on the targets set? YES/NO.

(b) Did you and the person reported upon agree on the main duties performed and the order of importance under the target set? YES/NO. (If no, please discuss the changes with him and record any unresolved differences here).

.....

.....

.....

***10. Aspects of Performance***

In assessing performance you are to consider some or all the following aspects and comment on as well as assess them separately. Each aspect is described in terms of "Outstanding (A) and poor (F)". The four intermediate ratings (B,C,D,E) represent behavior between these extremes as generally described in the notes at the end of this Form.

Rating 'A' or 'F' should be given if you believe it is a generally true statement. Either of the two ratings however, must be supported in paragraph 14 on General Remarks.

If you feel that an aspect of performance not in the lists under Sub-Section (I) to (IV) calls for special comments, mention it at the end of the relevant Section.

The following weights are attached to the gradings:

*(i) A.....6*

*(ii) B.....5*

*(iii) C.....4*

*(iv) D.....3*

*(v) E.....2*

*(vi) F.....1*

***Assessment of Actual Performance Standards/General Ability***

***(I) Job Assessment/General Ability***

(Assess objectively how the Officer has performed his set tasks. This may include)

*(Tick only one Box)*

| | A | B | C | D | E |
|---|---|---|---|---|---|
| (a) How well he/she understands, organize and does his/her job..... | | | | | |
| (b) How much he/she applied his/her professional/technical/ administrative or any other acquired knowledge..... | | | | | |
| (c) How much he/she was able to accomplish within a set time frame... | | | | | |
| (d) Judgement (quality of his/her decisions and contributions) where relevant..... | | | | | |
| (e) Work speed and accuracy..... | | | | | |

*Effectiveness of communication*

| | A | B | C | D | E |
|---|---|---|---|---|---|
| (f) Expression on paper..... | | | | | |
| (g) Oral Expression..... | | | | | |

*Human Relations*

| | | | | | |
|---|---|---|---|---|---|
| (h) Relations with staff..... | | | | | |
| (i) Relations with public..... | | | | | |

| A | B | C | D | E | F |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

(j) Management of Staff.....
(k) Quality of work.....
(l) Productivity.....
(m) Effective use of figures/other data.....
(n) Initiative.....
Please justify the gradings.....
.....

*(11) Character Traits*

In assessing character traits, considerate on should be given to:

| A | B | C | D | E | F |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

(a) Dependability (whether he/she is able to work consistently) without close supervision, inspection or compulsion).....
(b) Loyalty to the Organisation.....
(c) Honesty:.....
(d) Reliability under pressure.....
(e) Sense of responsibility.....
(f) Appearance.....
Please justify the gradings:.....
.....

*(iii) Work Habits*

| A | B | C | D | E | F |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

(a) (i) Punctuality at work.....
(ii) Attendance at work.....
(iii) Drive and Determination.....
(iv) Resource Utilization.....
Please justify the gradings.....
.....
.....

*(b) Sanctions:*

Has any disciplinary action been taken against the officer during the period covered by this report? YES/NO.
If Yes, give details of sanctions.....
.....

*(c) Reward:*

Has the Officer received any special commendation (WRITTEN) during the year for outstanding Performance? If YES, give details:
.....
.....

*(Tick only one Box)*

*(IV) Leadership Attainment:*

| A | B | C | D | E | F |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

(i) Does he/she encourage his/her subordinates to define agreed standards and measures for effectiveness before hand?.....
(ii) Does he/she encourage and train his/ her subordinates to avoid late assessments of goals?.....
(iii) Does he/she show good example in terms of punctuality, Efficiency and high degree of responsibility in whatever he/she does?
.....
(iv) Did he make suggestions for changes/adjust methods/procedures that significantly contribute to his own work or that of any associate/ subordinate?.....

**11. Overall Assessment**

From the above assessments, indicate the overall performance of his/her duties by ticking the appropriate box below

| | | | |
|---|---|---|---|
| A | Outstanding | | An exceptionally valuable member of the staff; performance is well above the Required standard for the job. |
| B | Very Good | | Display good all-round level of effectiveness; performance meets requirement In all important tasks. |
| C | Good | | A competent member of staff; generall achieves the standards required. |
| D | Satisfactory | | Completes all assignment satisfactorily within agreed date. |
| E | Fair | | Performance does not always reach the required standard; room for improvement |
| F | Poor | | Performance does not meet the standard |

**12. Training Needs**

Indicate training needs necessary to improve the performance or potential of the officer.

.....

.....

.....

**13. General Remarks**

Please provide any additional relevant information here drawing attention to any particular strengths or weaknesses and indicate special aptitudes (if any) demonstrated by the officer:

.....

.....

.....

.....

.....

**14. Do you suggest the officer for:**

(a) A different job in the same grade? Yes/No

(b) Transfer to a job at similar level in another occupational group or cadre? YES/NO

If you have answered YES to either question, say which kind of job and give reasons below:

.....

.....

.....

**15. Promotability**

A. Exceptionally well qualified the officer already seems likely to stand out in the next higher post..... ☐

B. Ready for promotion..... ☐

C. Has promotion potentials; has completed the required number of years ☐

D. Not yet entitled to promotion (for non-fulfilment of conditions prescribed for promotion in line with the Guidelines in Civil Service Reforms)..... ☐

E. No evidence of promotion potential at present ☐

F. Unlikely to qualify as he/she seems to have reached the limit of his/her capability..... ☐

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# FUZZY ANALYSIS AND ADAPTIVE ANTHROPOMETRY MODEL FOR OBJECT IDENTIFICATION IN SURVEILLANCE SYSTEM

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**ABSTRACT**
The proof of identity in many cases like road traffic accidents, bomb blasts and other terrorists' attacks are most frequently achieved by comparing the individual's appearance to a previously captured image. This process is however cumbersome thus necessitating us to propose a system that automatically detects and focuses on the human face and inputs it to the face recognition system for further processing. The methodology uses a combination of temporal differencing and background subtraction method for object detection. It is then followed by a template-matching classification algorithm which uses the object silhouette followed by the contour tracing algorithm. After object detection and classification, we compute the anthropometric measurements of the human silhouettes in frame. We also carried out performance analysis based on run time and time performance of algorithms. A fuzzy based analysis was carried out. The results show that our algorithms give a better performance than existing ones. The system works under existing infrastructures and ISPs without any modification, so as to reduce the level of complexity of the system.
**Keywords:** Segmentation algorithms, Surveillance systems, Anthropometry, Object Identification, Object classification and Face localization.

## 1.0 INTRODUCTION

Video surveillance has long been in use to monitor security sensitive areas such as banks, department stores, highways, crowded public places and borders. The advances in computing power, availability of large-capacity storage devices and high speed network infrastructure have paved the way for cheaper, multi sensor video surveillance systems. Traditionally, the video outputs are processed online by human operators and are usually saved to tapes for later use only after a forensic event. The increase in the number of cameras in ordinary surveillance systems overloaded both the human operators and the storage devices with high volumes of data and made it infeasible to ensure proper monitoring of sensitive areas for long times. In order to filter out redundant information generated by an array of cameras, and increase the response time to forensic events, assisting the human operators with identification of important events in video by the use of "intelligent" video surveillance systems has become a critical requirement. The making of video surveillance systems "intelligent" requires fast, reliable and intelligent algorithms for

moving object detection, classification, tracking and Object recognition [1].

Most surveillance systems operate using single modality and lack robustness because they are limited to a particular situation. The existing systems only emphasizes on certain aspects of surveillance. Existing systems trigger an alarm when an object is detected but is not sufficient for an intelligent system. It is a necessity for modern surveillance systems to incorporate object recognition in order to reduce the number of false positives and false alarm. Such a system authenticates the violator using a biometric authentication system based on face recognition to alerts the user of an unauthorized access.

More so, a sizeable number of threats to lives and properties are caused by human and not disaster like fire. There is therefore a need to recognize human threats by an intelligent surveillance system. Face detection is the entry point of the face recognition process. The general aim of face detection is the task of determining whether or not there are any faces in a given image, and if present returns the image location of each face. Hence, there is need to develop a face localization algorithm to perform this task.

Intelligent algorithms for performing segmentation of moving objects as well as feature extraction have already been developed and successfully implemented in software. Unfortunately, very few of these algorithms have been incorporated into today's video surveillance systems. Real time video Surveillance requires fast and accurate algorithms which is computationally efficient. It is necessary to analyze previously existing algorithm to find a suitable one for real-time video surveillance or to develop one that will perform effectively with high detection quality. This research is targeted at adapting the use of anthropometry and fuzzy analysis for building a surveillance system, which can intelligently and continuously monitor a chosen environment.

## 2.0 RELATED WORKS

It has been established that increase in the number of cameras in ordinary surveillance systems overloaded both the human operators and the storage devices with high volumes of data making it cumbersome to ensure proper monitoring of sensitive areas over a period of time. In a bid to filter out redundant information generated by an array of cameras, and increase the response time to forensic events, assisting the human operators with identification of important events in video by the use of "smart" video surveillance systems has become a critical requirement. However, making a video surveillance systems "smart" requires fast, reliable and robust algorithms for moving object detection, classification, tracking and activity analysis [4].

Pfinder uses a simple scheme, where background pixels are modeled by a single value, and foreground pixels are explicitly modeled by mean and covariance, which are recursively updated. It requires an empty scene at start-up. It is a real-time system for tracking a person which uses a multi-class statistical model of color and shape to segment a person from a background scene. It finds and tracks people's head and hands under a wide range of viewing condition. There is a general purpose system for moving object detection and event recognition where moving objects are detected using change detection and tracked using first-order prediction and nearest neighbour matching. Events are recognized by applying predicates to a graph formed by linking corresponding objects in successive frames [9].

Onifade et al [3], developed a system that proposes that the detection of motion essentially requires the user to perform two major steps. The first step is to setup the hardware for acquiring the video data in which the motion is to be detected and the

second step is to actually develop an algorithm by which the motion will be detected. A video stream is stored as a series of frames occurring in an ordered sequence one after the other.

The system is initialized to take a snapshot of an image which is referred to as Old. With the system's inbuilt timer, the next image taken will be referred to as Current. If there exists a difference in the Old and Current images' RGB values, the motion is said to occur which is detected by the Sensors. Here motion detection algorithm is based on frame difference calculation in terms of RGB values and brightness threshold values stored in byte arrays. The algorithm compares two consecutive frames Old and Current, pixel by pixel to generate a difference value. If the difference value is greater than a fixed value (randomly taken), then motion is detected. Else if, there is no difference between previous and current frame's byte arrays then Old is set to Current. The process repeats according to the program's set timer [3].

Md. Junaedur [4] related to the broad subject of automatic motion detection and analysis in video surveillance image sequence. Besides, proposing the new unique solution, some of the previous algorithms are evaluated, where some of the approaches are noticeably complementary sometimes.

In real time surveillance, detecting and tracking multiple objects and monitoring their activities in both outdoor and indoor environment are challenging task for the video surveillance system. In presence of a good number of real time problems limits scope for this work since the beginning. The problems are namely, illumination changes, moving background and shadow detection. In this work, an improved background subtraction method has been followed by foreground segmentation, data evaluation, shadow detection in the scene and finally the motion detection method. The algorithm is applied on to a number of practical problems to observe whether it leads us to the expected solution. Several experiments were done under different challenging problem environment. Test result shows that under most of the problematic environment, the proposed algorithm shows the better quality result.

Anthropometric analyses of faces play an important role in reconstruction of face in forensic and medico-legal investigations. With the introduction of new technologies like CCTV cameras and video surveillance system, rare and common features of face help in the identification of CCTV footage. Recently published work [12] has analyzed different human faces using anthropometry and anthroposcopy in Indian and African population respectively. Whenever, there is a video or image available from crime scene, the facial identification is one of the most important task forensic scientists carry out manually during their investigation. Forensic scientists perform manual examination of facial images or videos for a match with huge database of mug shots (Along with fingerprints, law enforcing agencies universally and routinely use photographs for criminals' records. These images have become commonly referred to as 'mug shots' and are characterized by two photographs, one from photograph of the face and the other a profile picture). The proof of identity in many cases like road traffic accidents, bomb blasts and other terrorists' attacks, is most frequently achieved by comparing the individual's appearance to a previously captured image. This may be a passport photograph in the case of immigration, a photograph on any type of identity card and driving license, credit card or a still from CCTV footage in forensic settings [12].

## 3.0 SYSTEM METHODOLOGY

In this research, we employ temporal differencing (very adaptive to dynamic environments) and Background subtraction (provides the most complete feature data) for the development of our algorithm. The

aim is to get the advantage of the two techniques and thus a more efficient system. It is also very important to employ an algorithm whose run time is minimal since the system is expected to work in real time.

The proposed algorithm used in developing this work is mathematically represented below. Temporal difference is the simplest method to extract moving objects and adapt to dynamic environments, but cannot detect the entire shape of a moving object with uniform intensity. In this paper, subsequent images $I(x, y, t)$ and $I(x, y, t+1)$ are subtracted and the difference image is set on threshold to get the region of changes. The threshold $d\ T$ can be derived from image statistics. In order to detect cases of slow motion or temporally stopped objects, a weighted accumulation with a fixed weight for the new observation is used to compute the temporal difference image $I(x, y, t)$ *difference* as shown in following equations:

$$I_{difference}(x,y,t+1) = \begin{cases} 1, \text{ if } (1_{accum}(x, y, t+1) > T_d \\ 0, \text{ otherwise} \end{cases}$$

And

$$I_{accum}(x, y, t+1) = (1 - W_{accum})\, I_{accum}(x,y,t) + W_{accum}\, I(x, y, t+1) - I(x, y, t),$$

where *accum W* is the accumulation parameter which describes the temporal range for accumulation of difference images. $I(x, y, t+1)$ *accum* is initialized to an empty image.

This is then hybridized with the background subtraction model below.

Control Variable: K $V_0 \propto T_a$

Initialization $\forall_{f-d\ldots K}$ $W_f - 0$

$\mu_f - \inf$ $\sigma_f - V_0$ $c_f - 0$

While new data x(t)

$\forall_{f-d\ldots K}$

$$P_f - \begin{cases} w_f\, g_f(x, \mu_f\, \sigma_f) \ldots\ldots\ldots If & |x - \mu_f| \\ 0 \ldots Otherwise \end{cases}$$

*If* $\sum_{f-1}^{k} P_1 > 0$ *Then*

//at least one match is found

For $(K - 1; k < K; k + +)$

$q_k - P_k\, {}^{f}\sum_{f-1}^{k} P_f$

//expected posterior of $G_k$

*If Winner – take – all Then*

$$q_k - \begin{cases} 1 \ldots\ldots\ldots\ldots if - k - \text{argmax}_f\{p_f\} \\ 0 \ldots\ldots\ldots\ldots\ldots Otherwise \end{cases}$$

*End If*

$W_k(t) - (1 - \alpha).\ W_k(t-1) + \alpha.q_k$

*If* $q_k > 0$ *Then*

//for matched Gaussians

$1 - \propto$

$c_k - c_k + q_k$

$7_k - q_k\ (\quad c_k \quad + \propto)$

$\mu_{k(f)} - (1 - 7_k)\ \mu\ (t - 1) + 7_k\, x$

$\sigma^2_k(f) - (1 - 7_k)\ \sigma^2_k\ (t - 1) + 7_k\, (x - \mu_k(t-1))^2$

*End If*

*End For*

*Else*

$\forall_{f-d\ldots K}$ $W_k\ (f) - (1 - \alpha).\ W_k\ (t-1)$
$k - \text{argmin}_f \{W_f\}$ $W_k - \propto \mu_k - x\ \sigma - V_0$ $C_k - 1$
*End If*
*Normalize w*
*End While*

### 3.1 Proposed Face Localization Algorithm

Face detection is the entry point of the face recognition process. We firstly developed basic system architecture as shown below in Figure 1. In order to localize a human face, we developed an anthropometry-based face detector algorithm tagged **ANTHROBLOG**.

Our algorithms' approach to face localization is found to be a coarse-to-fine approach. We effectively split the problem into two important stages:
1. Classify each image in the video frame into humans and non-humans;
2. Locate the face in any human imagery using an anthropometry-based face detector

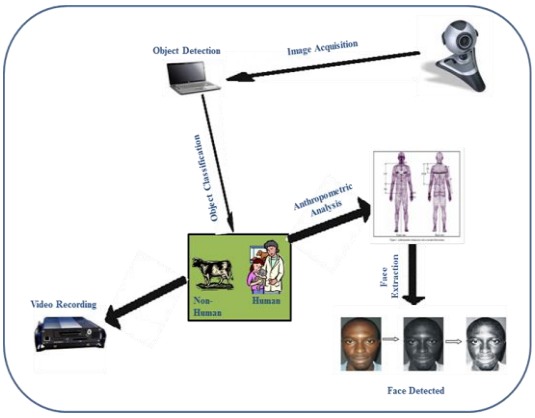


Fig. 1: Proposed Anthropometry-Based Face Localization Module

Our proposed algorithm proceeds by breaking the human parts into six pre-defined label. We then measure the various lengths of the human body parts. This is obtained by first capturing the raw data of the human length from the video frame. This is then scaled and normalized. The measured normalized data for the six labelled parts are then compared. It is proposed that the shortest length on the various human body parts in the head region.

Our image-based system was designed to transform 2D digitization into linear anthropometric measurements. The shortest length is expected to be the head region. The cameras will then zoom on the region to extract the human face for the face recognition system. The extraction of the face from the scene will require some adjustments for changes in rotation, illumination, scale and pose. Here, face images are normalized or enhanced to improve the recognition performance of the system. If we avoid pre-processing, we stand a chance of getting a low performance by the system, thus we apply histogram equalization, automatic rescaling and manual face cropping. After this has been done we extract the chosen features and appropriately rank them.

## 4.0 RESULTS AND EVALUATION

In this section, we present the test environment and the experimental results of our algorithms. We also present the various experiments conducted to verify the claims on the proposed system. The model comparison is also highlighted in this section.

Result for Object Detection Algorithm

Algorithm analysis is carried out on four major algorithms based on three different techniques. The first algorithm is denoted as basic background subtraction (BBS) algorithm. It computes the absolute difference between the current image and a static background image and compares each pixel to a threshold. All the connected components are computed and they are considered as active regions if their area exceeds a given threshold. This is perhaps the simplest object detection algorithm one can imagine. The second method is the detection algorithm used in the W4 system. Three features are used to characterize

each pixel of the background image: minimum intensity, maximum intensity and maximum absolute difference in consecutive frames. The third method assumes that each pixel of the background is a realization of a random variable with Gaussian distribution (SGM - Single Gaussian Model). The mean and covariance of the Gaussian distribution are independently estimated for each pixel. The fourth algorithm represents the distribution of the background pixels with a mixture of Gaussians. Some modes correspond to the background and some are associated with active regions (MGM - Multiple Gaussian Model).

For this work, we classify each of the algorithms based on their methodology as adaptive background subtraction, temporal differencing or adaptive background mixture models as shown in Table 1.

**Table 1: Classification of Object Detection Algorithm**

| S/N | ALGORITHM | TEMPORAL DIFFERENCE | BACKGROUND SUBTRACTION | GAUSSIAN MIXTURE MODEL (MGM) |
|---|---|---|---|---|
| 1 | Basic Background Subtraction (BBS) | | ❖ | |
| 2 | W4 | ❖ | | |
| 3 | Single Gaussian Model (SGM) | | | ❖ |
| 4 | Multiple Gaussian Model (MGM) | | | ❖ |

### 4.1 Runtime Analysis for Object Detection

We tested the computational performance of the three different object detection algorithms approach - adaptive background subtraction, temporal differencing and adaptive background mixture models. The runtime analysis of the algorithms is shown in Table 2 while the time performance analysis, which is the per-frame processing time of these algorithms for an image size of is shown in Table 3

The runtime analysis shown in Table 2 of various object detection algorithms was obtained by executing a 'dry run' of each algorithm on implementation.

**Table 2: Runtime Analysis of Object Detection Algorithm**

| OBJECT DETECTION ALGORITHM | RUNTIME OF ALGORITHMS |
|---|---|
| Adaptive Background Subtraction | 3 Sec |
| Temporal Diffencing | 3 Sec |
| Adaptive Background Mixture Models | 12 sec |

The time performance analysis was carried out by first executing each of the algorithms using a limited number of video frames. This was achieved by applying the conditional statement below for the temporal differencing algorithm.

```
While (vid.FramesAcquired<=50) % Stop after 50 frames
   data = getdata(vid,2);
   diff_im = imabsdiff(data(:,:,:,1),data(:,:,:,2));
   imshow(diff_im);
end
```

Our method enabled us to measure the time taken to process a specified number of frames. The result is then fuzzified and defuzzified via the fuzzy inference system.

The result of the fuzzy time performance Analysis is shown below in figure 2

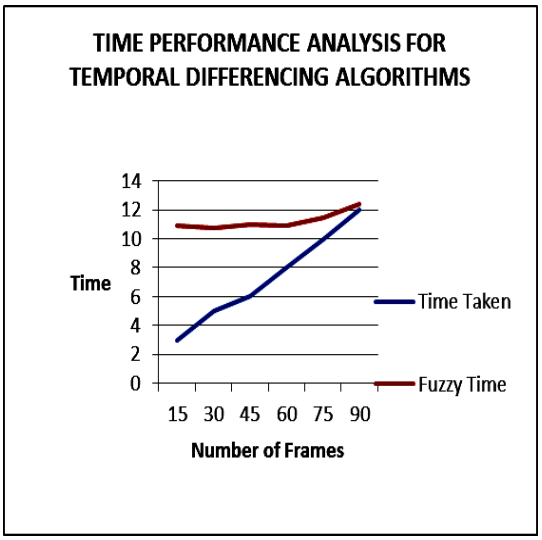


Figure 2: Time performance result for Temporal differencing

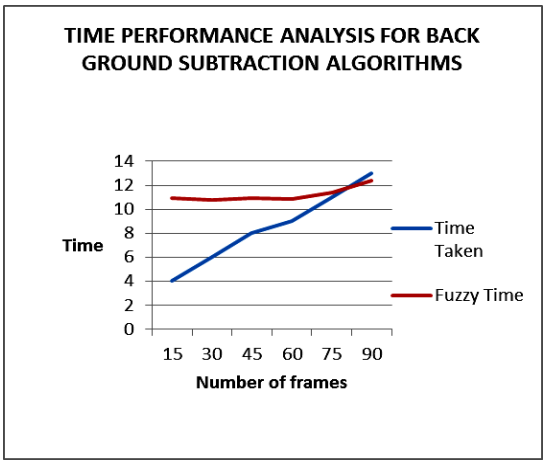


Figure 3: Time performance result for Background Subtraction

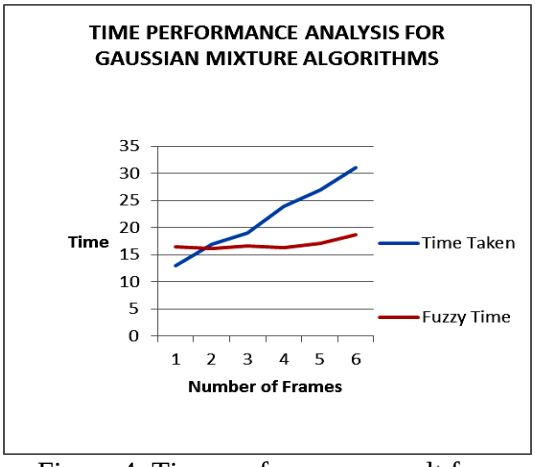


Figure 4: Time performance result for Gaussian Mixture

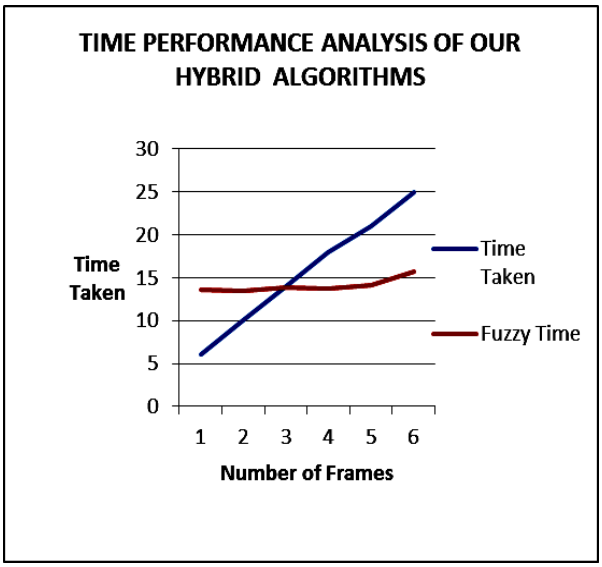


Figure 5: Time performance result for our Hybrid Model

The results in figure 2 to figure 5 show the 2-D representation of the measured time analysis and the fuzzy time analysis. We observe that the measured time simply follows a linear model while the fuzzy models an overall average result within a time frame for each algorithm.

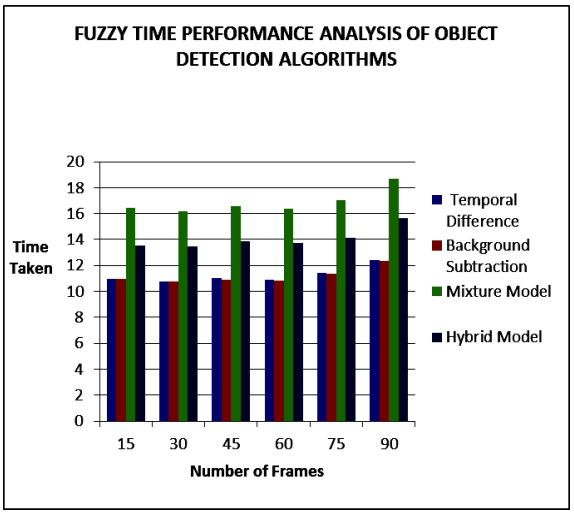


Fig. 6: Fuzzy Time Performance Analysis of Object Detection Algorithms

Figure 6 above shows the comparison of the fuzzy time performance for the various algorithms modeled in our work. From the result in fig. 6 above, the average time to process a frame is given below in Table 3 below.

**Table 3: Time Performance Analysis of Object Detection Algorithm**

| OBJECT DETECTION ALGORITHM | FUZZY AVERAGE TIME TO PROCESS A FRAME |
|---|---|
| **Temporal Difference** | 11.25033333 |
| **Background Subtraction** | 11.19818333 |
| **Mixture Model** | 16.87103333 |
| **Hybrid Model** | 14.06873333 |

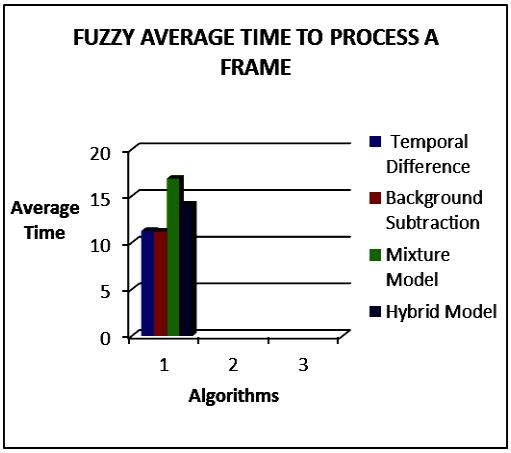


Figure 7: Fuzzy Average Time to process a Frame

The result shows that our hybrid model gives a better time performance than the Gaussian mixture model. We also observed that our hybrid model proves to be better algorithm than each of the other models – temporal difference and background subtraction model since it combined both of their advantages.

### 4.2 Anthropometry-Based Face Localization Algorithm (ANTHROBLOG)

In order to measure the performance of our ANTHROBLOG algorithm, we tested it on the four sample video clips used in section 4.1 that contains only humans with different postures. We expect the algorithm to return the faces of the detected human imagery. The result of the evaluation is shown below in Table 4.

**Table 4: Performance Evaluation of Face Localization Algorithm**

| | HUMAN | FACES DETECTED | CORRECT (%) |
|---|---|---|---|
| Movie Clip 1 | 0 | 0 | 100 |
| Movie Clip 1 | 1 | 1 | 100 |
| Movie Clip 1 | 2 | 2 | 100 |
| Movie Clip 1 | 4 | 3 | 80 |

The result gives an overall average performance of 95% which is considerably acceptable. The cameras will then zoom on the region to extract the human face for the face recognition system.

## 5.0 CONCLUSION

In this work, we implemented three different object detection techniques and compared their detection quality and time-performance with our developed Hybrid model. The Fuzzy analysis carried out helped to measure the degree of each technique's capabilities. Our Hybrid model's temporal differencing gives better runtime result for dynamic scene changes and detecting motion while the adaptive background subtraction scheme gives the most promising results in terms of detection quality and computational complexity to be used in a real-time surveillance system.

Our anthropometry based face localization algorithm (ANTHROBLOG) extracts human face from human classified silhouette. In addition, our tests in sample applications show that using human anthropometry gives promising results and no complicated methods are necessary for face detection in human imagery.

In the future, we hope to extend the object detection algorithm to solve the mirror object problem resulting from panning, tilting and zooming which results into great deflection of the background. Also, work should be done to detect each object during a cluster of detected objects. Other areas include false alarm detection using neural network or Fuzzy Logic paradigm.

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# AN EFFICIENT IMAGE CRYPTOSYSTEM BASED ON WOLFRAM SEQUENCE AND RNS

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## ABSTRACT
In this paper we propose a novel encryption algorithm for digital images using the moduli set {2n+2, 2n+1, 2n}. The technique uses the Wolfram sequence for resizing, bitwise-XOR for pixel scrambling and modulus operation for pixel encoding. In the proposed scheme, a digital image is first segmented into many parts. A quarter (the upper most left part) of the segmented image is used to perform the scrambling and the modulus processes. Experimental results reveal that the proposed scheme can effectively encrypt/decrypt images with good compression ratio and a very minimal distortion. Simulation analyses also show that the scheme has a large key space, high information entropy, low correlation coefficient, highly sensitive to change in secret keys and efficient in both bit representation and internal memory requirement

**Keywords**: Moduli set, XOR operation, pixel scrambling, Wolfram sequence, encryption algorithm.

## 1.0 INTRODUCTION
Digital images are composed of discrete units called pixels (picture elements). A pixel is a small square representing some color value. Digital images are usually represented as two-dimensional (2D) $r \, x \, c$ array, where $r$ represents the number of rows of pixels and $c$ represent the number of columns of pixels, with each entry in the matrix being a numeric value representing a given color [2, 3, 4]. The recent advancement in digital techniques for processing and distributing data over the internet has made the accusation of digital images easier. However, these techniques are inefficient when sensitive and confidential images are involved. When plain-images fall into wrong hands, their confidentiality, integrity and authenticity may be compromised. Two major approaches for protecting digital images are: information hiding which includes watermarking, anonymity, steganography, covert channel, and encryption [5-14].
Due to their bulky and redundant nature, traditional cryptosystems (such as the Rivest-Shamir-Adleman (RSA) and Digital Signature Algorithm (DES) cryptosystems) widely used for text may not be appropriate for digital image encryption. Also the characteristic of human perception permits a decrypted image to contain small distortion. This violets the requirements of text encryption (i.e. recovered text should exactly much that of the plain-text)[21].

The Residue Number System (RNS) is an integer system which speeds up arithmetic computations by splitting numbers into smaller parts in such a way that each part is independent of the other [16]. RNS has the following interesting inherent features: parallelism, modularity, fault tolerance, and carry free operations. These features make RNS to be widely used in Digital Signal Processing (DSP) applications such as digital filtering, convolution, fast Fourier transform, and image processing [1, 15, 16, 17].

The application of RNS in image processing is well documented in literature [1, 22, 28, 30]. These applications encourage the encoding of pixels to achieve smaller data size and bit representation for fast transmission and memory conservation [30].

This paper is inspired by the work in [30] where a recommendation for future work was to find a way of reducing the amount of internal memory allocation for cipher-images. In this paper we propose a new cryptosystem for digital images that addresses this need and also increase the key space. Sensitive digital images could be highly secured through the application of this system. In the proposed system, a digital image is first resized using an algorithm based on the Wolfram sequence, it is then scramble using a bitwise XOR operation and finally encoded using the moduli set {2n+2, 2n+1, 2n}. Experimental results show that the proposed technique can successfully encrypt/decrypt digital images with minimal distortion of decrypted images.

The rest of the paper is structured as follows: a brief discussion of Wolfram sequence and RNS are presented in Section 2. A detailed discussion of the proposed scheme is covered in Section 3. Section 4 presents experimental results and discussion on the scheme. Finally, Section 5 presents the concluding remarks.

## 2.0 BACKGROUND

### 2.1 Wolfram Sequence

The Wolfram sequence is defined for a set of integer as [20];

$$w_n = \begin{cases} \frac{3}{2} w_{n-1} & for\ w_{n-1}\ even \\ \frac{3}{2}(w_{n-1}+1) & for\ w_{n-1} odd \end{cases} \quad (1)$$

This is a modification of the sequence related to the Collatz problem. The first ten iterations of the sequence starting with $w_1$ to $w_{10}$ is shown in Table 1.

**Table 1: First ten iterations of the Wolfram sequence start with $w_1$ to $w_{10}$**

| $w_i$ | Iteration | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| **1** | **1** | **2** | **6** | **9** | **15** | **24** | **36** | **54** | **81** | **123** |
| **2** | **2** | **3** | **6** | **9** | **15** | **24** | **36** | **54** | **81** | **123** |
| **3** | **3** | **6** | **9** | **15** | **24** | **36** | **54** | **81** | **123** | **186** |
| **4** | **4** | **6** | **9** | **15** | **24** | **36** | **54** | **81** | **123** | **186** |
| **5** | **5** | **6** | **15** | **24** | **36** | **54** | **81** | **123** | **186** | **279** |
| **6** | **6** | **9** | **15** | **24** | **36** | **54** | **81** | **123** | **186** | **279** |
| **7** | **7** | **12** | **18** | **27** | **42** | **63** | **96** | **144** | **216** | **324** |
| **8** | **8** | **12** | **18** | **27** | **42** | **63** | **96** | **144** | **216** | **324** |
| **9** | **9** | **12** | **24** | **36** | **54** | **81** | **123** | **186** | **279** | **420** |
| **10** | **10** | **15** | **24** | **36** | **54** | **81** | **123** | **186** | **279** | **420** |

From Table 1, it can be clearly seen that the Wolfram sequence is the same for $w_i\ odd$ and $w_{i+1}\ even$ except for the first iteration values.

Given $w_1$ and $w_n$ of the Wolfram sequence, we define the reversal sequence $w_{n-1}$ as follows;

$$w_{n-1} = \begin{cases} \frac{2}{3}w_n - 1 & for\ w_n\ even \\ \frac{2}{3}w_n & for\ w_n odd \end{cases} \quad (2)$$

where $w_{n-1}$ is decided as follows

if $(w_{n-1} + 1 = w_1)\ or\ (w_{n-1} - 1 = w_1)\ or(\ w_{n-1} = w_1)$ then
$w_{n-1} = w_1$
else if $|w_{n-1}|_3 \neq 0$ then
if $|w_{n-1} + 1|_3 = 0$ then
$w_{n-1} = w_{n-1} + 1$
else if $|w_{n-1} - 1|_3 = 0$ then
$w_{n-1} = w_{n-1} - 1$

## 2.2 Overview of RNS

RNS is defined for a set of $N$ relatively prime moduli set $\{m_1, m_2, \dots, m_N\}$, such that the greatest common divisor of $m_i$ and $m_j$ is one (i.e. $\gcd(m_i, m_j) = 1$ and $i \neq j$) and $M = \prod_{i=1}^{N} m_i$ is the dynamic range. Every integer $X < M$ has a unique representation $|X|_{m_i}$(where $|X|_{m_i}$ denotes $X$ mod $m_i$ ) in the system [16, 18].

Given the residue$(x_1, x_2, x_3, \dots, x_N)$, its decimal equivalent $X$ is computed through the Chinese Remainder Theorem (CRT) as [16];

$$X = \left|\sum_{i=1}^{N} M_i \left|M_i^{-1} x_i\right|_{m_i}\right|_M \quad (3)$$

where $M_i = \frac{M}{m_i}$ and $M_i^{-1}$ is the multiplicative inverse of $M_i$ with respect to $m_i$.

A modification of Eq. (3) for moduli set with common factors is presented in Eq. (4) [16].

$$|X|_{M_L} = \left|\sum_{i=1}^{n} \alpha_i x_i\right|_{M_L} \quad (4)$$

where $M_L$ is the Lowest Common Multiple (LCM) of the $\{m_i\}_{i=1,N}$, the set of moduli sharing a common factor, $X$ is the decimal equivalent of $\{x_i\}_{i=1,N}$, $\alpha_i$ is an integer such that $|\alpha_i|_{\frac{M_L}{\mu_i}} = 0$and$|\alpha_i|_{\mu_i} = 1$, and $\{\mu_i\}_{i=1,N}$ is a set of integers such that $M_L = \prod_{i=1}^{N} \mu_i$ and $\mu_i$divides $m_i$. It should be noted that $\alpha_i$ may not exit for some $i$. A modified version of Eq. (4) is shown in Eq. (5) [16].

$$|X|_{M_L} = \left|\sum_{i=1}^{N} \beta_i \left|\beta_i^{-1}\right|_{\mu_i} x_i\right|_{M_L} \quad (5)$$

where $M_L = LCM\{m_i\}_{i=1,N} = \prod_{i=1}^{n} \mu_i$ , $\beta_i = \frac{M_L}{\mu_i}$, $\left|\beta_i^{-1}\right|_{\mu_i}$ is the multiplicative inverse of $\beta_i$ with respect to $\mu_i$.

The decimal equivalent of the RNS number $(x_1, x_2, x_3)$ with respect to the moduli set {2n+2, 2n+1, 2n} is simplified as follows [16];

$$X = (x_2 - x_1)m_1 + x_1 + m_1 m_2 \left|\frac{(x_1 + x_3)}{2} - x_2\right|_{\frac{m_3}{2}} \quad (6)$$

For instance, given the moduli set $\{8, 7, 6\}$, we compute the decimal equivalent of the residue representation $(2, 3, 4)$ using Eq. (6) as;

$$X = (3-2)8 + 2 + (8 \times 7)\left|\frac{(2+4)}{2} - 3\right|_{\frac{6}{2}}$$
$$X = (1)8 + 2 + 56|3 - 3|_3$$
$$X = 10 + 56|0|_3$$
$$X = 10 + 56(0)$$
$$X = (1)8 + 2 + 56|3 - 3|_3$$
$$X = 10.$$

Thus, the residue representation of the decimal number 10 using the moduli set {8, 7, 6} is (2, 3, 4).

## 3. PROPOSED SCHEME

The proposed encryption algorithm has three major parts: an image is first resized using an algorithm based on the Wolfram sequence, then scrambled through a bitwise-XOR operation and finally encoded through a modulus operation.

### 3.1 The Proposed Encryption Algorithm

Let $I_o(x, y)$ be an $r\ x\ c$ plain-image, $n \geq 4$ an integer for the moduli set, $w_0 \geq 1$ the initial Wolfram sequence and $p \geq 1$ the number of iteration to perform. The encryption algorithm is defined as;

1. input the parameters $I_o, n, w_0$ and $p$

2. resize $I_o$into $I_r$ as follows

2.1 let $w_i = w_0$ for $0 \leq i \geq r - 1$

a. for each row and column of $I_o$

b. shuffle pixels upward if $w_i$ is even

c. otherwise shuffle pixels leftward

d. generate $w_{i+1}$ using Eq. (1) and loop step b.

2.2 let $w_i = w_0$ for $0 \leq i \geq r - 1$

a. for each row and column of $I_o$

b. shuffle pixels leftward if $w_i$ is even

c. otherwise shuffle pixels upward

d. generate $w_{i+1}$ using Eq. (1) loop step b.

3. isolate the upper most left part of $I_o(x, y)$ as an $\frac{r}{2}\ x \frac{c}{2}$ reduce plain-image $I_r(\bar{x}, \bar{y})$

5. scramble the pixel position of $I_r(\bar{x}, \bar{y})$into $I_{scr}$ as follows;

a. for each iteration $p$

b. for each row and column of $I_r$

$$x' = (m_1 * i \ \oplus m_3 * j) * p \ mod\ r$$
$$y' = (m_2 * i \ \oplus w_0 * j) * p \ \ mod\ c$$
$$I_{scr}(x, y) = I_r(x', y') \quad (7)$$

where $i = 1,2, \ldots, r$ and $j = 1,2, \ldots, c$

c. for each row of $I_{scr}$

$$I_{scr}(i, j) = I_{scr}(i, j) \oplus g \quad (8)$$

where

$$g = \begin{cases} 2i + 1 & if (s_i mod w_0) = 0, \\ 2i & otherwise \end{cases}$$

and $s_i$ is the sum of pixels in $i$th row

6. using the moduli set {2n+2, 2n+1, 2n} encode $I_{scr}$ and concatenate column-wise (dimension 2) into $I_{en}(\bar{x}, \bar{y} \times 3)$ as follows;

$$I_{en} = cat(2,\ |I_{scr}|_{m_1},\ |I_{scr}|_{m_2},\ |I_{scr}|_{m_3}) \quad (9)$$

where $m_1 = 2n + 2, m_2 = 2n + 1, m_3 = 2n$

7. save $I_{en}$as the cipher-image

### 3.2 The Proposed Decryption Algorithm

Let $I_{en}(x, y)$ be an $r\ x\ c$ cipher-image, $n \geq 4$ an integer for the moduli set, $w_0 \geq 1$ the initial Wolfram sequence and $p \geq 1$ the number of iteration to perform.

1. input the parameters $I_{en}, n, w_0$ and $p$

2. split $I_{en}$ into three residual images as follow;

$$I_{en1} = I_{en}\left[r, \frac{c}{3}\right]$$
$$I_{en2} = I_{en}\left[r, \left(\frac{c}{3} + 1\right) : \left(\frac{c}{3} 2\right)\right]$$
$$I_{en3} = I_{en}\left[r, (\tfrac{c}{3} 2) + 1 : c\right] \quad (10)$$

where $I_{en1} = |I_{scr}|_{m_1}$, $I_{en2} = |I_{scr}|_{m_2}$ and $I_{en3} = |I_{scr}|_{m_3}$

3. reconstruct $I_{scr}$as follows;

a. let $(x_1, x_2, x_3)$ be the residue of $I_{scr}$ with respect to $\{m_2, m_2, m_2\}$

b. for each column and row of $I_{en1}$, $I_{en2}$ and $I_{en3}$

$$(x_1, x_2, x_3) = \big(I_{en1}(i, j), I_{en2}(i, j), I_{en3}(i, j)\big) \quad (11)$$

c. obtain $I_{scr}(x, y)$ using Eq. (11) and Eq. (6)

4. scramble the pixel position of $I_{scr}$ into $I_r(x, y)$follows;

a. for each iteration $p$ counting downwards

b. for each row and column of $I_{scr}$ counting downwards

c. scramble $I_{scr}$ using Eq. (8) and Eq. (9) into $I_r$

2. resize $I_r$ into$I_o$as follows

2.1 let $w_i = w_0$ for $0 \leq i \geq r-1$

a. for each row and column of a copy of $I_r$ (i.e.$I_{rc}$)

b. shuffle pixels upward if $w_i$ is even

c. otherwise shuffle pixels leftward

d. generate $w_{i+1}$ using Eq. (1) and loop step b.

e. fuse $I_r$ and $I_{rc}$vertically into $I_{rv}$

2.2 let $w_i = w_0$ for $0 \leq i \geq r-1$

a. for each row and column of a copy of $I_{rv}$(i.e. $I_{rvc}$)

b. shuffle pixels leftward if $w_i$ is even

c. otherwise shuffle pixels upward

d. generate $w_{i+1}$ using Eq. (1) and loop step b.

e. fuse $I_{rv}$ and $I_{rvc}$ into $I_o$

7. save $I_o$as the plain-image

The block diagram of the proposed scheme is shown in Figure. 1.

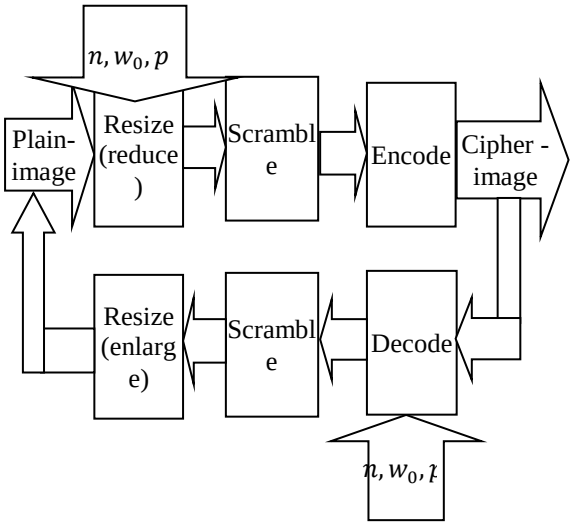



**Figure 1: A block diagram of the proposed scheme**

## 4. EXPERIMENTAL RESULTS

This section discusses experimental results obtained through simulation with MATLAB to assess the efficiency and security of the proposed algorithm. In some instances, experimental results will be compared those obtained by [30]. Our focus is on visual testing, encoding and security analyses.

### 4.1 Visual Testing

Three digital images (cameraman, peppers and rice) of varying sizes were used for visual testing. In this analysis we sought to compare the visual perception of plain-image and cipher-image to assess whether they bare any resemblance. Figure. 2 confirms that there is no perceptual similarity between the plain and cipher images.

Cipher-image should greatly differ from its plain form. Two difference measures used to quantify this requirement are the Number of Pixels Change Rate (NPCR) and the Unified Average Changing Intensity (UACI). The NPCR measures the percentage of different pixels between two images while the UACI measures the average intensity of differences in pixels between two images [24]. Let $I_o(i,j)$ and $I_{en}(i,j)$be the pixels values of plain and cipher images, $I_o$and $I_{en}$, at the $ith$ pixel row and $jth$ pixel column, respectively. NPCR and UACI are defined in Eq. (12) and Eq. (13) respectively [23].

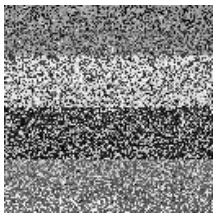
$$NPCR = \frac{\sum_{i=i}^{r}\sum_{i=1}^{c} D(i,j)}{r \times c} \times 100 \quad (12)$$

where

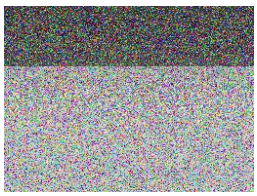
$$D(i,j) = \begin{cases} 0 & if I_o(\mathrm{i,j}) = I_{en}(i,j), \\ 1 & otherwise. \end{cases}$$

$$UACI = \left[\sum_{i=i}^{r}\sum_{i=1}^{c} \frac{I_o(\mathrm{i,j}) - I_{en}(i,j)}{255}\right] \times \frac{100\%}{r \times c} \quad (13)$$


(a) cameraman (plain)


(b) cameraman (cipher)


(c) peppers (plain)


(d) peppers (cipher)


(e) rice (plain)

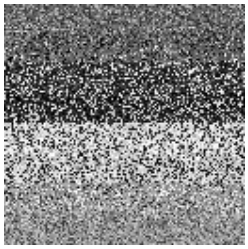

(f) rice (cipher)

**Figure 2:Plain and cipher images with $n = 50, w_0 = 3$ and $p = 15$**

We use the scramble cipher-image to perform difference measure since at that point the images (plain and cipher) have the same dimension. Table 2 depicts the difference measure analysis of the proposed algorithm. The high percentage values of the NPCR measure indicate that the pixels positions have been randomly changed. Also, the UACI values show that almost all pixel gray-scale values of the cipher-images have been changed from their values in the plain-images, making the plain and cipher image pixels more difficult to decipher.

**Table 2: Difference measure between plain-images and cipher-images**

| Image | NPCR (in %) | UACI (in %) |
|---|---|---|
| cameraman | 99.55 | 11.87 |
| peppers | 99.57 | 16.82 |
| rice | 99.69 | 12.32 |

## 4.2 Encoding Analysis

In this analysis we sought to measure the rate of reduction in pixel value and the size of plain-images. For $n = 4$ the proposed technique efficiently produces cipher-images with smaller bit representation and size. The technique recorded a 33% reduction in size and a 25% reduction in memory requirement for cipher-images. Through this reduction, the speed of computational operations and data transmission across networks are enhanced. In [30] disk space reduction is estimated at 90% (for n=3), which is better than our obtained value of 33% (for n=4). However, our memory management is better than that of [30]. Table 3 shows a comparison of plain and cipher images.

**Table 3: Encoding analysis of proposed technique**

| Image | Size(disk space) | | Memory requirement | |
|---|---|---|---|---|
| | Plain-image | Cipher-image | Plain-image | Cipher-image |
| cameraman | 64.00 kb | 49.00 kb | 65536 Bytes | 49152 Bytes |
| peppers | 281.00 kb | 205.00 kb | 589824 Bytes | 442368 Bytes |
| rice | 44.00 kb | 23.00 kb | 65536 Bytes | 49152 Bytes |

## 4.3 Security Analysis

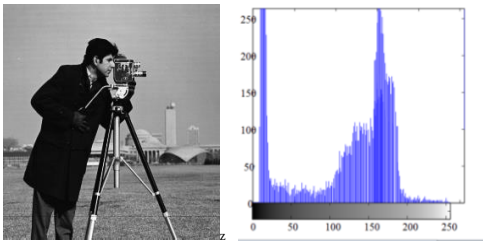
The major goal of any cryptosystem is to provide the maximum security to the plain-image. A good image encryption scheme should resist various attacks such as known plain text attack, cipher-text-only attack, statistical analysis attack, and brute-force attacks. In this section, a security analysis on the proposed image encryption algorithm is conducted. The security assessment has been conducted on key space analysis and statistical analysis.

### 4.3.1 Key Space Analysis

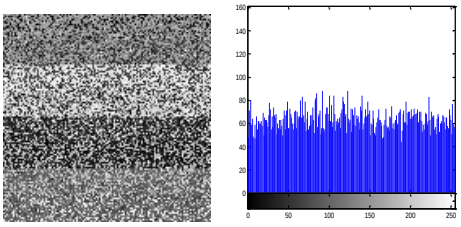
The security of a cryptosystem is enhanced against the brute-force attack if the key space is reasonably large. The proposed technique utilizes three cipher keys: $n > 3$, $p > 0$ and $w_0 > 0$. For effective encoding, we take $n$ to be an 8 bit key and adapt a 56 bit key for $p$and $w_0$. Thus, the number of possible key combination for the proposed technique is$2^8 \times 2^{56} \times 2^{56} = 2^{120}$. Obviously, this is a key space large enough to resist the brute-force attack. This key space is also fairly larger than $2^4 \times 2^{56} \times 2^{56} = 2^{116}$ obtained by [30].

### 4.3.2 Histogram Analysis

The histogram of an image refers to a histogram of the pixel intensity value. It is a graph that shows the number of pixels in an image at each different intensity value found in that image. A cipher-image is secure against statistical attack when its histogram defer completely from that of its plain form [30]. Figure. 3 depicts the histograms of a plain-image and its corresponding cipher-image. It is clear from Figure. 3 that the two histograms are completely different and thus the histogram of the cipher-image does not give any clue about its plain-image. This implies that the proposed scheme is secured against histogram attack.



(a) cameraman (plain) (b) cameraman (histogram)



(c)cameraman (cipher) (d) cameraman (histogram)

**Figure. 3: Histogram of plain and cipher images with $n = 128, w_0 = 3$ and $p = 15$**

### 4.3.3 Information Entropy Analysis

Entropy is a statistical measure of randomness that can be used to characterize the texture of an image. The entropy H of a symbol source S can be calculated as follows [11];

$$H(S) = -\sum_{i=1}^{N} p(s_i) \log_2 p(s_i) \qquad (14)$$

where $p(s_i)$ represents the probability of symbol $s_i$and theentropy is expressed in bits. If the source $S$emits $2^8$ symbolswith equal probability, i.e. $S = \{s_1, s_2, \ldots, s_{256}\}$, then theresult of entropy is $H(S) = 8$, which corresponds to a truerandom source and represents the ideal value of entropy for message source $S$. Information entropy of a cipher-image can show the distribution of gray value. The more the distribution of gray value is uniform, the greater the information entropy. If the information entropy of a cipher-image is significantly less than the ideal value 8, then, there would be a possibility of predictability which threatens the image security [11]. To perform this analysis we use the extreme value of $n = 128$ so as to cover the range of pixel values while compromising on effective encoding. Table 4 compares the entropy values of plain and cipher images.

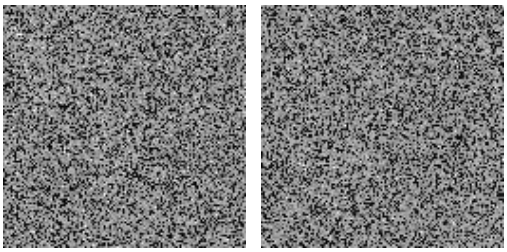
The entropy values of plain-images are far from ideal value since information sources are highly redundant and thus rarely generate uniformly distributed random messages. On the other hand, the entropy values of the cipher-images are very close to the ideal value of 8, which means that the proposed scheme is secure against entropy attacks.

**Table 4: Entropy values for plain and cipher images with $n = 128, w_0 = 3$ and $p = 15$**

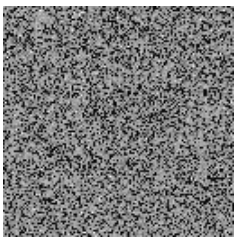
| Image | Entropy | |
|---|---|---|
| | Plain | cipher |
| Cameraman | 7.009716 | 7.987798 |
| Peppers | 7.378534 | 7.917714 |
| Rice | 7.011500 | 7.987780 |

### 4.3.4 Key Sensitivity Analysis

Key sensitivity analysis was also conducted to test the sensitivity of the technique to a small change in any of the cipher keys. A good cryptosystem should be highly sensitive to a small change in any of the cipher keys. A slight change in key should result to a significant change in either the encrypted or decrypted image. In this respect, we tried recovering the plain-image of Figure. 1(b) with three sets of keys that defer in only one bit position from the encryption keys used. Thus $k1 = (n + 1,\ w_0,\ p), k2 = (n,\ w_0 + 1,\ p)$, and $k3 = (n,\ w_0,\ p + 1)$. It can be seen from Figure. 3 that we are unsuccessful in recovering the plain-image with the change in key. Hence the proposed technique is highly sensitive to a small change in the key value.



(a) $k1 = (51, 3, 15)$ (b) $k1 = (50,\ 4,\ 15)$



(c) $k1 = (50, 3, 16)$

**Figure. 4: Key sensitivity analysis of proposed technique**

### 4.3.5 Correlation Coefficient Analysis

Digital images appeals to human vision because of the high correlation among its adjacent pixels. Disturbing this relationship conceals information about the images. Among the requirements of an effective encryption scheme is creating cipher-images that have very low correlation coefficient values. In this analysis, we calculated the correlation coefficients of randomly selected 1000 pairs of two adjacent pixels (horizontal, vertical and diagonal) of both plain and cipher images. Table 5 shows the respective correlation coefficient values for $n = 50, w_0 = 3,\ p = 15$ .

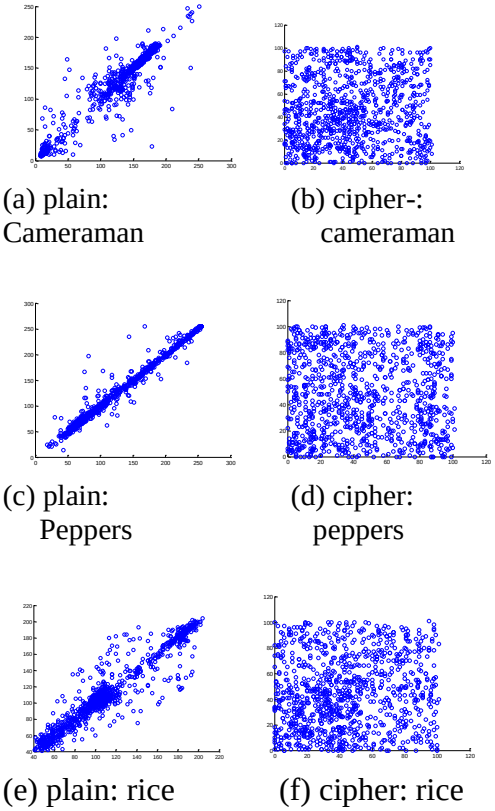
Table 5 reveals that plain-images have very high correlation coefficient values (close to one) confirming the strong relationship among the pixels. On the contrary, the values for cipher-images are very low (close to zero) which confirms that the pixels are very weakly related.

**Table 5: Correlation coefficient values of pairs of adjacent pixels**

| Correlation | Horizontal | Vertical | Diagonal |
|---|---|---|---|
| Plain-image: cameraman | 0.942172 | 0.951023 | 0.899040 |
| Cipher-image: cameraman | 0.131060 | 0.071964 | 0.043871 |
| Plain-image: peppers | 0.995038 | 0.988976 | 0.991090 |
| Cipher-image: peppers | 0.007145 | -0.027523 | -0.003584 |
| Plain-image: rice | 0.930336 | 0.944565 | 0.896171 |
| Cipher-image: rice | 0.111732 | 0.111700 | 0.091718 |

Figure. 5 illustrates the correlation distributions of the horizontal adjacent pixels of plain-images and the corresponding cipher-images using the proposed technique. Figure. 5 confirms the

fact that adjacent pixels in cipher-images are indeed very weakly correlated.



(a) plain: Cameraman (b) cipher-: cameraman

(c) plain: Peppers (d) cipher: peppers

(e) plain: rice (f) cipher: rice

**Figure. 5: Distribution of two horizontal adjacent pixels in the plain and cipher images for $n = 50, w_0 = 5,\ p = 15$**

## 5. CONCLUSION

In this paper, we presented a new cryptosystem for digital images. The system is based on the concept of resizing, scrambling the pixel positions and changing the gray values of the pixels. The resizing process is achieved with the segmentation of plain-image into several parts of which the upper most left part is isolated as a reduce image. In the scrambling process we employed the bitwise-XOR operator on every row and column of the image and finally encoding the pixel values with modulus operation. The simulation and experimental analyses through MATLAB show that the proposed scheme achieves the following;

a) It has a very large key space.
b) It is highly sensitivity to small change in secret keys.
c) It has information entropy values close to the ideal value of 8.
d) It has low correlation coefficient value close to the ideal value of zero (0).
e) It reduces the number of bits require to represent pixels by 4 bits.
f) It reduces the amount of internal memory requirement for cipher-images by 25%.
g) It reduces the number of disk space require to store cipher images by 33%.
h) It encourages fast transmission of data across networks.
i) It enhances high speed computation due to low value of pixels.

Hence, we conclude that the proposed scheme is ideal for image encryption and decryption due to its high security, effectiveness and robustness.

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# A WEB-BASED PLATFORM FOR MOBILE LEARNING MANAGEMENT SYSTEM

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**ABSTRACT**
The rapid spread and penetration of mobile devices to every layer of society has exposed the educational community to many new opportunities and responsibilities. As mobile computing and its disruptive aftermath enter the education arena, the challenge becomes how to harness the potential in ways that are beneficial to the educational community at large and the learners in particular. The traditional and formal way of teaching adopted in most institutions is the use of lecture room and in this type of learning environment it is possible for a student to miss lecture due to some reason beyond his control and also not able to learn at his own pace. Making learning mobile and informal can actually provide the required solution. This work presents a Web-based platform solution for Mobile Learning Management System (WEMOLEMAS) for addressing these problems. The architecture of WEMOLEMAS consists of four main layers namely Presentation layer, Business logic layer, Data Access layer and Data Storage layer. The presentation layer is the user interface which is made up of the system user, the mobile devices, the mobile applications used to access the internet and also context discovery and content delivery. The Business Logic layer is made up of the mLearning Management System (mLMS), Communication Module and Course Learning Module. The Data Access layer is made up of the links and the search engine. Finally, the Data Storage layer is made up of several tables in the database. The implementation was carried out using Adobe Dreamweaver and Wamp server. The evaluation of the system shows that the practise of mLearning will actually improve learning system in various citadel of learning.

**Keywords**: Management System, Mobile Learning, Traditional Education, Web-based

## 1.0 INTRODUCTION

The traditional forms of education do exist, but the growth and expansion of Information and Telecommunication Technology (ICT) is so tremendous that it paved the way for the rapid development of Internet-based learning. The Internet has radically reshaped higher education. Today Internet-based teaching is an opportunity for millions of students to receive their education. It is not too expensive to use the Internet for study and the courses provide

excellent tools like message boards, chat rooms, etc.

The traditional education is made in classrooms where the teacher presents the learning material to a group of students.. Regardless of obvious advantages as a direct contact between a teacher and students and immediate feedback, the traditional classroom education has many disadvantages. For example if the student doesn't take part in some lesson he/she will miss the training material. This disadvantages lead to search for new and more effective educational methods. The rapid growth of information and communication technologies and rising computer knowledge of the students make possible appearance of these new educational forms. In 15 years ago the main accent has been on Computer Based Training which used primary CD and local area networks as information medium, 5 years ago the accent was moved to the use of Internet and Learning Management Systems. The E-learning as new term appeared. Nowadays extremely actual and perspective is mobile learning.

Mobile learning projects are blooming all over the world. They range from the use of Personal Digital Assistants (PDAs) and tablet computers in classrooms, through mobile phones to support learning between schools and museums, to context-aware technology for field trips and tourist visits. One issue that becomes clear is that mobile learning is not just about learning using portable devices, but learning across contexts.

Many communities have defined it based on their own particular experiences, uses and backgrounds. This has led to a fertile proliferation of views and perspectives. However, the downside is that the unique nature of mobile learning is becoming very difficult to characterize. Worst still, mobile learning, as a concept, is currently ill-defined; it seems to be all things to all people. Formal definitions from European and Government agencies espouse its relationship to e-learning. Technologists place a high emphasis on novelty and the functionality of the devices (phones, PDAs, iPods, PSPs) themselves. Some researchers focus on the mobility of the learner. Yet others focus on learning in informal settings, leading to juxtaposition between mobile learning and formal education.

Furthermore, mobile learning applications are underpinned by many different theories of learning. While this breath of perspectives is to be welcomed because it leads to many possibilities for development, it poses problems when trying to develop a theory of mobile learning, the desire to utilise the technology in the hands of everyone to enhance their learning experiences. [3] suggested that usage of mobile learning technologies in education is the most important of required technologies to provide main goals in distance education. [4] were of the view that modern technologies like 3G, Edge and HSDPA facilitates have rapid access to Internet and to mobile platforms using high performance Pocket PCs and PDAs.

This work examined a student-student and student-lecturer collaboration model for mobile learning. It also considered the design and delivery of educational contents to mobile users remotely.

### 1.1 The impact of using Mobile Technologies for Teaching and Learning

According to [2], using mobile technologies in teaching and learning can:

(i) encourage and support learning at any time of day, in any location including in college or school, at home, in the workplace, on field trips and in transit.
(ii) make learning more convenient, accessible, inclusive and sensitive to learners' individual needs and circumstances.
(iii) make learning more interesting, more enjoyable and therefore more attractive to learners.
(iv) encourage non-traditional learners and learners who have not succeeded in traditional education to engage in learning and to improve their self-confidence and self-esteem.
(v) enable lecturers to maintain a supportive dialogue (synchronous and/or asynchronous) with learners regardless of their location and including learners who attend college infrequently.
(vi) enable technological support for teaching and learning in the normal learning location (which could be a classroom) in contrast to the previous experience of learners having to go elsewhere to use computers.
(vii) improve access to learning resources and guidance for learners in remote settings
(viii) enable embedding of e-learning into work-place and work-based learning threatening than paper-based activities improve the speed and quality of feedback to learners during learning.
(ix) improve the speed of completion and quality of coursework and assignments.
(x) improve learners' concentration, focus and behavior.

## 2.0 LITERATURE REVIEW

[6] in their work addresses a device-independent architecture for mobile learning, which creates adaptive contents for mobile learners based on characteristics of mobile learners and mobile device. The authors were unable to address the learning preferences and interest of learners based on social networks and contextual learning situation of learners.
[4] proposed an architecture which offers a solution for m-learning course formation with the use of LO, a solution that combines recent technologies and that is comprehensive from the point of view of the analysis. The architecture presents an adaptive system for content delivery in m-learning, in the context of reusing existing learning object, but integrating news ones as well. In their architecture there was no module focusing on student assessment and the development of the student interaction with the teacher and the course, allowing him to make annotations, stock information locally and send feedback. Also, there was no community for the users, groups and interaction features as well.
A Cloud Computing Network platform for the M-Learning system and Expert system which provide knowledge on how test, examination and assignment are marked and provide the feedback via e-mail to the student was proposed by [1]. In the authors design, the students enjoyed doing assignments and accessing materials through their mobile device and get the feedback via their e-mail but in the design there is no provision for the student to express their feelings by sending feedback on any course material.
[5] makes use of the concept of Myers Briggs Type- Indicator (MBTI). The FRAME model provides a basic yet comprehensive guidance for the understanding of mLearnig and is often being used as a framework for research review of the literature on mLearnig. In this

model, the authors were able to examine the possible relationships between the dispositional factors measured by MBTI and the main construct of mobile learning environments. In the authors work, it was discover that the mobile learning environment constructs did not matched with students' learning.

[7], in their approach used Wireless Universal Resource File (WURFL) and an Adaptive Content Delivery Engine (ACDE) to implement Mobile Mathematics Tutorial (MoMT). The authors work shows that students that combine mobile learning and text book pas well than student that uses only textbook for studying and this reflects in the graph but the system was not implemented on real e-learning system to evaluate the features in ubiquitous learning environment.

## 3.0 METHODOLOGY

The proposed architecture focused on a web-based platform solution for a mobile learning management system (WEMOLEMAS). The architecture of WEMOLEMAS is presented in figure 6. WEMOLEMAS consists of four main layers namely Presentation layer, Business logic layer, Data Access layer and Data Storage layer.

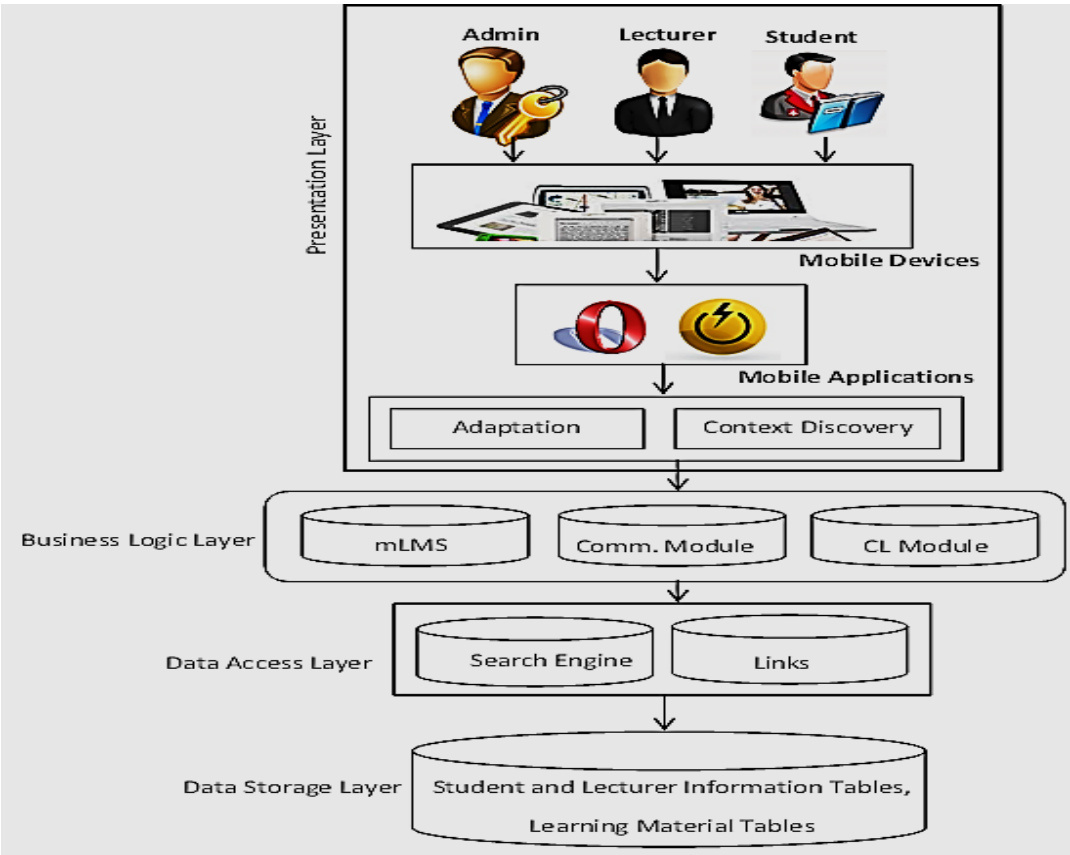



**Figure 1: Architecture of a Web-based Platform Solution for a Mobile Learning Management System**

### 3.1 Presentation Layer

The presentation layer is an interactive interface between users and the system. Its responsibility is to deal with the dialog between users and system. The presentation layer provides separate different user interfaces for students, lecturers and administrators. It also contains the following functional modules: mobile device, mobile application, adaptation, and context discovery.

#### 3.1.1 Users

The m-learning system allows three different types of users to interact with the system according to given privileges. They are the administrator, lecturer and student. Each of them can login in the system with a related identity, possessing different operating authority and functions. The M-learning System Users and Functionality is shown in figure 2.

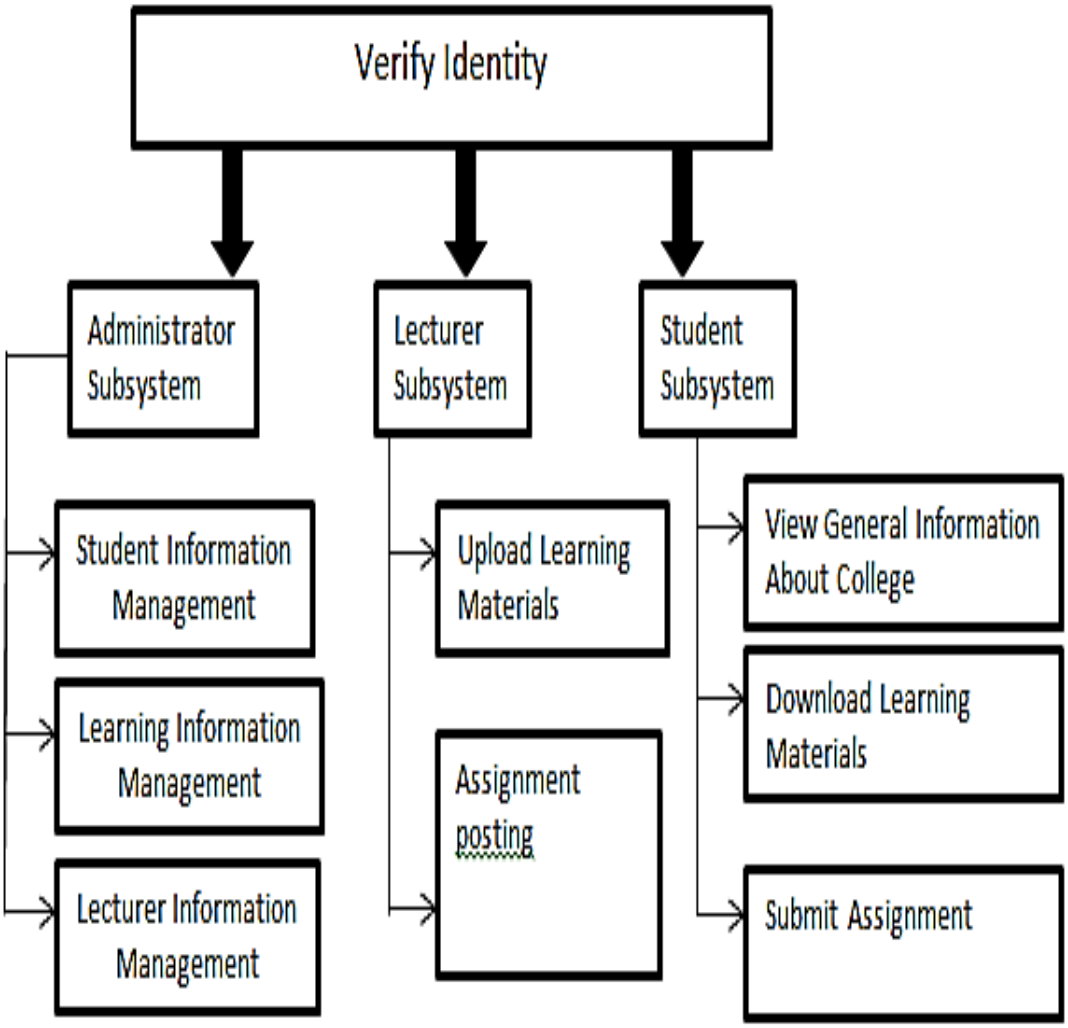



**Figure 2: M-learning System Users and Functionality**

**(i) Administrator Subsystem**

The administrator subsystem plays an important role in keeping the system management. This subsystem provides the administrator with web-based services to manage the information of the m-learning system and other services provided by the system. These are lecturers' information, students' information and learning resources.

**(ii) Lecturer Subsystem**

Lecturer primary goal in the m-learning system is to upload learning material, post assignments and view assignment submission. This subsystem provides the lecturer with web-based tools to manage the information required.

**(iii) Students Subsystem**

The m-learning system is majorly intended for students. They can perform various activities like downloading the learning materials and also view their assignments. The students can send feedback to the lecturer on a particular course for evaluation.

### 3.1.2 Mobile Devices

The client device could be in the form of smart mobile phones, tablets or a PDA.

### 3.1.3 Mobile Application

For the modules using application programs of a smart device, the client software is mainly client application programs of the mobile equipment operating systems and browsers. Users visit the mobile learning system server through the browsers and return the data to the browser according to their requests. The communication between users and results is implemented by running JavaScript in browsers.

### 3.1.4 Adaptation

One of the challenges associated with the use of mobile devices for learning is the size of the screen. Content management must be carefully considered to be suitable for different types of devices. To facilitate this type of management, the delivery of learning material is adaptive to better suit the learner and the mobile device used. Adaptability can be performed in multiple ways and for this purpose various techniques can be used to get all needed data. In the proposed system the profile of the user is retrieved and the mobile device specifications are sensed at each new session. The specification of the mobile device used is also gathered and accordingly, the contents are displayed on the user's mobile screen. For instance, the size of a picture will be chosen according to the dimensions of the mobile device's screen. This will ensure that the information delivered to the learner is properly displayed. The adaptation gathered information about the learner profile and the mobile specifications which are the key elements for content adaptation and delivery, and it also offer the learner a personalized experience of learning. The presentation adaptation can include adaptation of the structure, adaptation of the media format, quality or even type, etc.

### 3.1.5 Context discovery

By context we mean here identity, spatial information (i.e. location), temporal information, environmental information (i.e. noise level), availability of resources

(i.e. battery, display, network, and bandwidth) and etc. The context information could be used for specific m-learning services, but also for adapting the services offered by the mLMS (m-Learning Management System) for the mobile device.

### 3.2 Business Logic Layer

Business logic layer is the heart of the m-learning system. It manages the various services of the m-learning system. It receives request from the presentation layer, process it and pass it down to the data access layer and to the data storage layer. The result is sent back to the presentation layer. Business logic layer is like the transport and network layer in the OSI (Open System Interconnect) model. The three modules in business logic layer that interact within the m-learning system and their functions are Mobile Learning Management System (mLMS), Course Learning Module and Communication Module.

#### 3.2.1 Mobile Learning Management System (mLMS)

The mLMS is the central point of the m-learning system for the administration, documentation reporting and delivery of m-learning education courses. The mLMS offers foreground and background services. The foreground comprises services that do not require management, which are mobile application programs like Opera, UCweb or the mobile device browsers used to access the internet. The background services are majorly handled by the administrator. The mobile Learning Management System (mLMS) provides several services which are:

(i) It handles all aspect of the learning process which makes the environment comfortable for mobile learners.
(ii) It delivers and manages instructional content, identifies and assesses individual and organizational learning goals, tracks the progress towards meeting those goals, collects and present data for supervising the learning process of the organization.
(iii) It handles both students and lecturers registration information.

#### 3.2.2 Course Learning Module (CL Module)

The function of this module is to allow for uploading of learning material by the lecturers and at the same time downloading the learning material by the students. It also makes the administrator to delete unneeded uploads to free memory in the database.

#### 3.2.3 Communication Module

This module allows the users of the m-learning system to communicate with each other. It provides access to asynchronous communication tools such as email, and Short Messages Service (SMS) which allow disseminating information as notices e.g. grades and assignments.

### 3.3 Data Access Layer

It is located on the database server. It contains the data processing logic. Its main task is to receive requesting information from the web server, then complete the function of querying, refreshing and changing data in the database. Thereafter, it returns the results to the web server (Business Logic Layer). Data layer provides data sources for the applications of the m-learning system through the search engine and links. It includes user

information tables, learning resource tables, teaching database, report and tutorial sheet database and questions database.

### 3.4 Data Storage Layer

Data Storage (Database) constitutes a core element in the m-learning system design. The learning system comprises detailed records and tables related to users and learning courses. In addition processed data concerning students learning and instructors are managed in the database. The Database Management System (DBMS) used is MySQL 5.5.8 embedded inside wamp server.

The database design incorporates the tables of records and the relationships among tables. Tables in m-learning system can be classified into three categories: learning resources tables, tables for various level and users' information tables.

### 3.5 Design Algorithm

The following is the pseudo code for the implementation of the recommender system, ordered with respect to the phases in the solution:

**(i) Phase 1**

1. Start
2. Get the requesting student's ID from UI as student_Matric.
3. Get the requesting student's password from UI as student_password.
4. Get the number of registered students in database as count
5. FOR I = 1 to count DO
6. IF (studentMatric no at record(I) == studentMatric no AND password at record(I) == student_password) DO
7. Grant the user access to the web resources
8. ELSE sign-up
9. End IF
10. End FOR
11. End

**(ii) Phase 2**

1. Begin
2. Get the requesting lecturer's ID from UI as lecturer ID.
3. Get the requesting student's password from UI as lecturer_password.
4. Get the number of registered lecturers in database as count
5. FOR I = 1 to count DO
6. IF (lecturer id at record(I) == lecturer ID AND password at record(I) == lecturer_password) DO
7. Grant the user access to the web services.
8. ELSE sign-up
9. End IF
10. End FOR
11. End

**(iii) Phase 3**

1. Begin
2. Get the requesting administrator ID from UI as identifier
3. Get the requesting administrator password from UI as passkey
4. IF (administrator id in the record == administrator ID AND password in the record == administrator password)
5. Grant the user access to the web services.
6. End IF
7. End

## 4.0 IMPLEMENTATION AND RESULTS

The proposed scheme was implemented on a Pentium IV Intel microprocessor with WampServer 2.1 and Adobe Dreamweaver CS 5.5. The program codes were written in

Hypertext Preprocessor (PHP), JavaScript and Hypertext Markup Language 5 (HTML5). Figure 3 shows the login interface of the prototype of the proposed system during testing phase. On login, the students enters his matric no and password which has already been stored in the database, so as to discourage any kind of permutation while the lecturer enter his staff identity, as shown in figure 4a and 4b respectively. Figure 5 shows the Lecturers activities area where they can upload learning/course materials and assignments for student to download.

Students' activities area where they can download their course material based on their level, view their assignments, make use of the search engine, forum, links to important materials and also send feedback to their lecturer on course material are also shown in figure 6(a,b,c&d) .

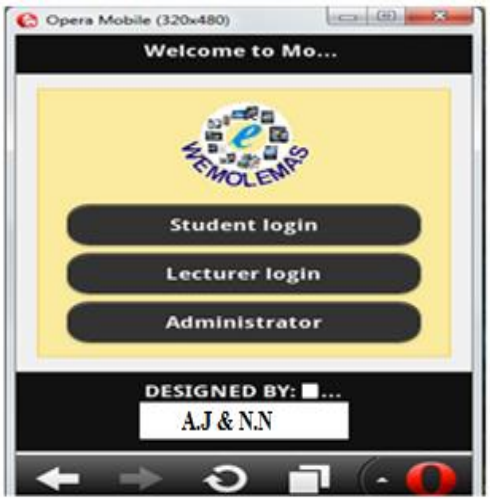
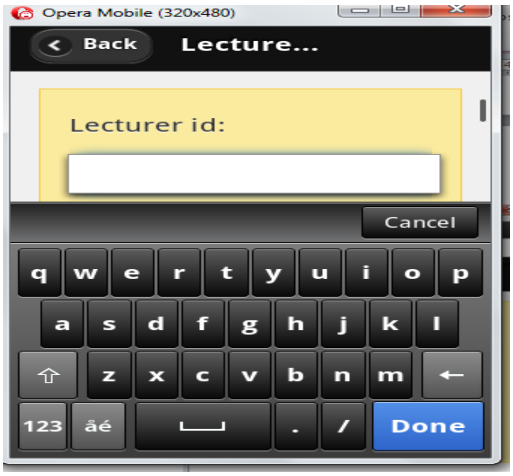


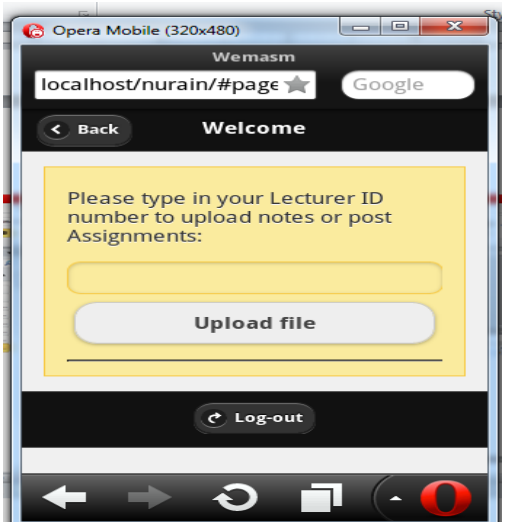

**Figure 3:** The homepage for the Students, Lecturers and Administrator


**(a) Student's Login Area**




**(b) Lecturer's Login Area**

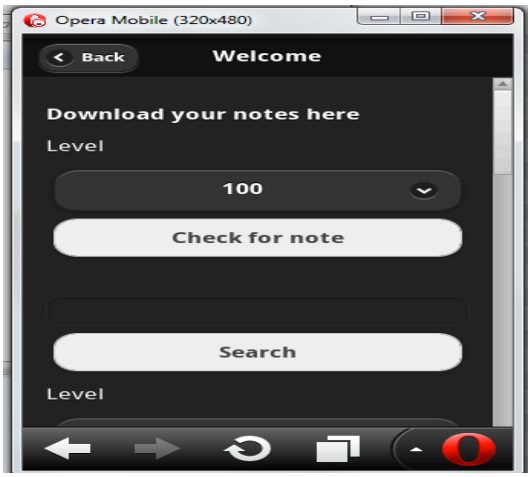
**Figure 4(a & b): Student's and Lecturer's login area**



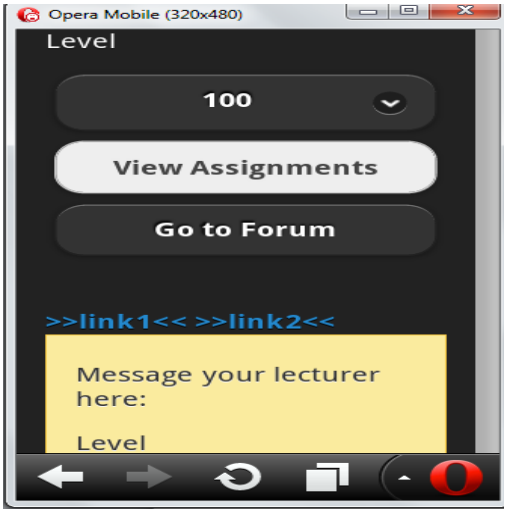

(a) Upload File


(b) Uploaded Materials and Assignments

Figure 5(a &b): Lecturer Activities

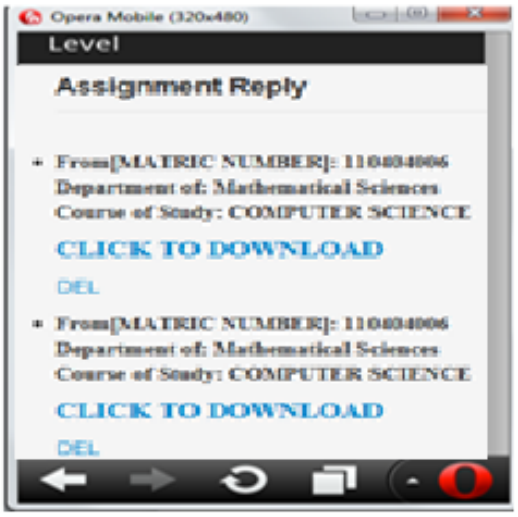



(a)




(b)


(c)




**(d)**

**Figure 6(a, b, c & d): Student Activities**

## 5.0 CONCLUSION

mLearning covers learning with portable technologies, where the focus is on the technology (which could be in fixed location such as classroom), learning across contexts, where the focus is on the mobility of the learner, interacting with portable or fixed technology and learning in mobile society, with a focus on how society and its institution can accommodate and support the learning of an increasingly mobile population. Making Learning mobile will be of more benefits to individuals. In this paper we proposed a model called WEMOLEMAS. WEMOLEMAS consists of four main layers namely Presentation layer, Business logic layer, Data Access layer and Data Storage layer. The proposed system was implemented on an Android phone and jQuery mobile which was used to develop the backend of the application is one of the best mobile application builders.

In future, this system will be hosted in the mobile cloud so that the mobile devices can work with little memory space.

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# NATURAL LANGUAGE PROCESSING TECHNIQUES FOR AUTOMATIC TEST QUESTIONS GENERATION USING DISCOURSE CONNECTIVES

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## ABSTRACT

This paper presents an Automatic Question Generator from narrative text using Natural Language Processing (NLP) techniques, by paying particular emphasis on discourse connectives. Discourse connectives are words or phrases that indicate relationships between two logical sentences or phrases and suggest the presence of mutually related extended verbal expression. A detailed design and development issues are discussed in this work. The system formulates questions from a student's lecture material and displays it to the user in the form of test questions. It also makes provision for the user to answer the questions in essay format and on submission of the answer, the system grades the user and returns the score obtained to the user. The questions were generated by first extracting the text from the materials supplied by the user using text processing concept of NLP. The discourse connectives in each of the sentences are identified and questions are generated from the sentence based on the peculiarity of the connective contained in the sentence. The marker checks the submitted answer to see if it contains 50% of the expected answer. If it does, the user's answer against a particular question is marked as being correct, otherwise it is marked wrong. The end result is an Automatic system which generates test questions for the user and allows him/her to submit essay answers back into the application system. Evaluation results with the system show that the generated questions achieved average accuracies of 87.5% and 88.1% by two human experts.

**Keywords**: Discourse Connectives, Machine Learning, Automatic Test Generation E-Learning.

## 1.0 INTRODUCTION

Natural Language Processing (NLP) is a theoretically motivated range of computational techniques for analyzing and representing naturally occurring texts at one or more levels of linguistic analysis for the purpose of achieving human-like language processing for a range of tasks or applications [1]. This is a very useful concept with respect to independent study

and self-assessment by student outside the normal classroom or online interaction with the teacher. With NLP features, in eLearning materials, students will prepare better for examinations by familiarizing themselves with their notes and study materials at their own pace. The research thus looks at developing an Automatic Test Generator using NLP techniques to help them in preparing for examinations or tests as the case may be. A user will need to feed in his/her lecture notes into the application. The application uses NLP algorithms to generate questions from the note by laying specific emphasis on discourse connectives. Discourse connectives are words or phrases that indicate relationships between two logical sentences or phrases and suggest the presence of mutually related extended verbal expression. Examples of such words are moreover, therefore, because, when, etc. and can indicate numerous relationships between sentences. [2] affirmed that their automatic disambiguation, i.e. the labeling of the correct sense of each occurrence, is important for discourse parsing, but could also serve a useful purpose in machine translation. This has been examined within the coherence theory framework and has proved to link elements of discourse and context [3]. This work takes advantage of discourse relationships within the context of grammar to evolve an Automatic Test Generator (ATG) system that helps students prepare adequately for their exams by solving possible exam questions being generated from their lecture notes and course materials. The student supply essay answers which is accessed for level of correctness by the system. It is hoped that the ATG system will make students to be more familiar with their lecture notes and materials and ensure better performance from students in examinations and tests. This system generates questions with Natural Language Processing techniques using manipulations around the discourse connectives contained in the uploaded text of the note.

## 2.0 BACKGROUND

Natural Language Processing (NLP) refers to the use and ability of computer systems to process sentences in a natural language such as English, rather than in a specialized computer language such as C++. The first NLP application to be developed was a dictionary look-up system developed at Birkbeck College, London in 1948. Since then, NLP has been used widely in the Information Technology world to develop various applications. One of the major uses of NLP is in Question Generation; that is, used to generate questions automatically from a sentence or a group of sentences. Question Generation is an important element of learning environments, help systems, information seeking systems and a myriad of other applications [4]. The ultimate goal of NLP is to build intelligence into software so that they will be able to process a natural language as skillfully and artfully as humans and make computers "understand" statements written in human languages [5], [6].

Typical applications for natural language processing include the following.

- A better human-computer interface that could convert from a natural language into a computer language and vice versa.
- A program that could translate from one human language (e,g English) to another (e.g. French).

- Programs that could check for grammar and writing techniques in a word processing document.
- A computer that could read a human language could read whole books to stock its database with data.
- Information Extraction (IE) systems which concentrates on the recognition, tagging, and extraction into a structured representation, certain key elements of information, e.g persons, companies, locations, organizations, from large collection of text.

A dive into the aforementioned goals will show that the goal of NLP is to achieve true Natural Language Understanding (NLU); Liddy [1] Accounts that this goal is yet to be accomplished owing to the fact that a system with NLU should be able to:

1.) Paraphrase an input text
2.) Translate the text into another language
3.) Answer questions about the contents of the text
4.) Draw inferences from the text

Despite the fact that NLP has made remarkable achievements in the first three goals, the fact that NLP systems, cannot of themselves, draw inferences from text still makes NLU a serious challenge in NLP.

### 2.1 Challenges of Question Generation Systems

Challenges faced by question generation can be categorized into four different categories [7]

- Lexical challenges
- Syntactic challenges
- Discourse related challenges
- Other challenges related to the use of question generation tools in classrooms.

Lexical challenges in question generation has to do with issues relating to lexical semantics i.e the meaning of words and short phrases. Heilman [7] explained that the semantics of the answer to a question affects the question's form. According to Him, the answer determines whether a question will be a "who" question, a "what" question etc.

For example: Alao won the election (Answer)

Who won the election? (Right Question)

What won the election? (Wrong question)

The 'what' question is wrong here because Alao is a person.

The syntactic challenges are further analysed in [7] and indicate that to generate questions, question generation systems need to model some of the complexities of natural language syntax: for example, they involve activities like identification of phrasal boundaries (e.g, which words are part of an answer), identification of predicates and their arguments, and extraction of information from nested structures such as relative clauses. Regrettably, most current parsers are far from perfect and the mistake of parsers also affect question generator systems. Any question generator relying on an incorrect parser is likely to produce ungrammatical questions such as "Who arranges are table, chair, books?" etc. The challenge of solving ambiguity and irregularity in Question Generation is therefore is a worthwhile enterprise, which is still open to serious research.

## 3.0 PROBLEM STATEMENT

The performance of Nigerian students in examinations (both internal & external) has been on the decline in recent years. Statistics show that an average of 72%, 74%, 74% and 75% failure were recorded in the WAEC and NECO examinations conducted in the years 2008, 2009, 2010 and 2011 respectively (The Economy magazine, 2009). Statistics also show that an average of less than 40% of students get a credit and above in a particular subject (The Economy Magazine, 2009). This worrisome trend is not only common with external examinations but teachers have also cried out at the performance of students in examinations conducted for them internally within the local school system. This situation is not peculiar to secondary schools alone as students are being withdrawn from the University for poor performances on a yearly basis. A recent development in the University of Ibadan saw about 440 final year students of the 2012 set bagging an extra year for failure to meet the basic departmental/university's graduation requirements [8]. This is becoming a major issue of concern to the government, especially in view of the nation's goal to be one of the top 20 economies by 2020. One problem faced by the typical Nigerian student is that he/she is not familiar with his/her study materials and questions that could be generated from them. Hence, the need for additional and personalised means for students to familiarize themselves with course notes or materials and conduct personal assessment of their performance through generation of questions from these notes and materials.

Several research have been done in automatic test generation but majority concentrate on objective questions or "fill in the gap" questions, most of which run over the web. This is also a major challenge for an average Nigerian student who is faced with expensive bandwidth overhead. The system presented in this work provides questions to which the user is required to supply essay answers in a desktop application, thereby limiting the bandwidth overhead usually encountered by individual students in web based applications.

## 4.0 RELATED WORK

Automatic Test Generation (ATG) or Question Generation (QG), as a field of NLP, has received increased attention from researchers in recent years, thereby bringing up various approaches to question generation systems with varying differences. QGSTEC is a which makes use of predicate argument structures of sentences and semantic roles for generating questions from texts [9]. In QGSTEC, semantic role labels are first used to identify the relevant parts of text before developing the questions, and then generated questions are then ranked in order to pick the final six best questions. The problem of automatically generating questions from topics was addressed in [10] whereby they considered the fact that each topic is associated with a body of texts that includes useful information about the topic. As a result, they generated their questions by exploiting the named entity information and the predicate argument structures of the sentences within the text. By concentrating on multiple-choice questions, fill-the-gap questions and error-correcting questions, a system that generates exercises of various levels according to students' achievement

level, marks his/her answers and returns them to him/her was proposed in [11].

ArikIturri, an automatic question generator system for Basque language, based on corpora and NLP techniques was presented in [12]. The information source for this question generator consists of linguistically analyzed real corpora, represented in XML markup language. By using innovative ideas in Machine Learning for generating multiple-choice questions, a real-time multiple-choice question generation for language testing was developed in [13]. The questions generated are simply fill-in-the-blank types and do not encompass translation of declarative phrases. Though the system could be competent in many areas and is easily adaptable, the straightforwardness of the question types, makes the method to be language dependent and was limited to testing the students' proficiency in a foreign language.

G-Asks is an intelligent automatic question generation system for academic writing support which generates specific trigger questions as a form of support for students' learning through writing [14]. By using 24 human supervisors and 33 research students, in an engineering research method course, [14] compared questions generated by G-Asks with human generated questions and the results indicate that G-Asks can generate as useful as human supervisors while significantly outperforming human peer and generic questions in most quality measures after filtering out questions with grammatical and semantic errors.

A form of text-to-question generation task, where the input text are sentences was considered in [15]. The QG system generates a set of questions for which the sentence contains, implies, or needs answers.

In [16], a question generator system whose main objective is to generate all the possible questions or related questions of a given sentence using Stanford Parsing was proposed. The system principally uses five modules, which are: Syntactic and semantic analysis, Sentence analyzer, Entity recognition, Transformation Process and Grammar checker. By using a methodology that combines statistical, structural and semantic methods of natural language processing and rule-based AI solution for concept extraction and test item creation, [17] describes an Enhanced Automatic Question Creator (EAQC) which extracts most important concepts out of textual learning content and creates single choice, multiple-choice, completion exercises and open ended questions on the basis of these concepts. EAQC is designed to deal with multilingual learning material and in its recent version, English and German are supported.

## 5.0 METHODOLOGY

Our approach was to gather statistics on the distributions of discourse connectives in natural language texts by sourcing out for words with high level of occurrence in 5 randomly selected literature books being used for in Nigeria secondary schools. We were able to identify 7 discourse connectives out of the estimated 100 discourse connectives in English Language as provided by [18]. The words include "because", "when", "since", "although", "As a result", "For example", and "for instance". These connectives were carried into our design and implementation. Sections 5.1 to 5.4 present a full detail of our design

**5.1 Use Cases**

Use cases are used to identify the external and the internal factors influencing the system. Figure 1 is the use case diagram for feeding in lecture notes to the system. Its description is as follows:

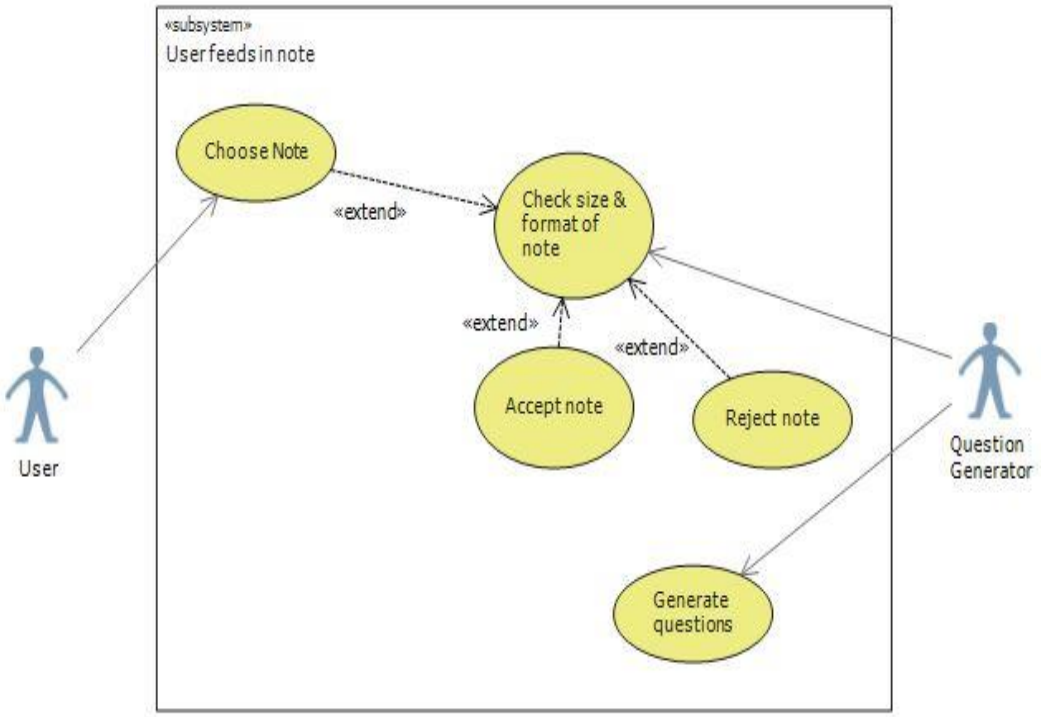


**Figure 1: Use Case 1: diagram of User Feeds in Note**

**Use Case ID:** Use Case 1
**Use Case Name**: User feeds in note
**Use Case Actors**: User and Application
Listed below are the basic course of events in Use Case 1

1.) The user starts the application as shown in figure 1
2.) The user sets path to the location on the local disk where the material is located and selects the material by clicking on it
3.) The application checks the size and format of the note the user has selected
4.) The application rejects the material if it doesn't meet the laid-down specifications by the developer, in terms of size of the material and the format of the material. Otherwise, it accepts the material and passes it on to the question generator
5.) The Question Generator generates questions from the text contained in the material submitted by the user

**Pre-condition:** The application is started
**Post-condition:** Questions are generated by the question generator

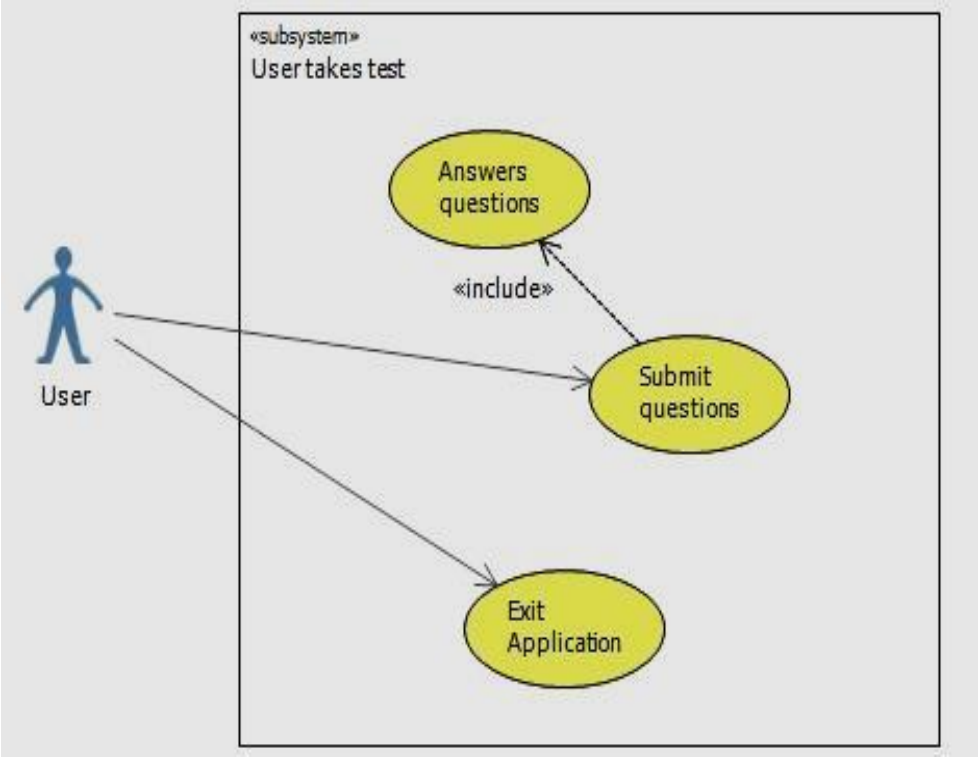


**Figure 2: Use Case 2: User Operation**

The user operation Use-Case is shown in figure 2. A description of the User Operation Use-Case diagram is presented below:

**Use Case ID:** Use Case 2
**Use Case Name:** User Operation
**Use Case Actors:**User

The followings are the basic course of events in the Use-Case

1. The user attempts the questions generated by the application as shown in figure 2
2. The user submits the attempted questions
3. The user can exit the application after submitting the solution to the questions

**Pre-condition:** Questions are displayed for the user to answer

**Post-condition:** The user answers the questions generated by the application.

The system proceeds to evaluate the correctness of the answered questions by using the Solution Explores subsystem as shown in Use-Case 3

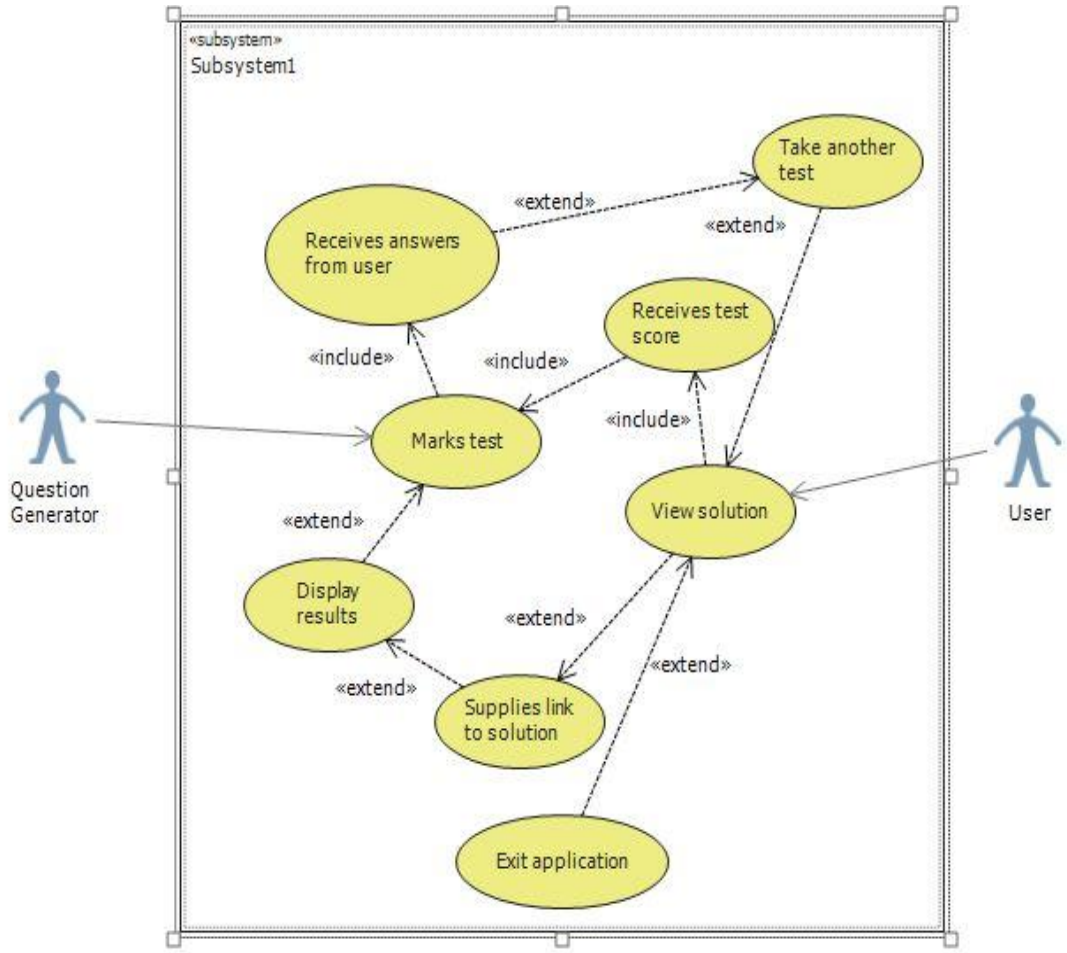


**Figure 3: Use Case 3: Solution Explorer**

A description of activities in Use-Case 3 is shown below:

**Use Case ID:** Use Case 3

**Use Case Name:** Solution explorer

**Use Case Actors:** User and QG

The basic course of events in the solution explorer involve:

1. The application receives the attempted questions with answers supplied by the user as shown in figure 3
2. The application grades the answers
3. The application readies the results for the user to know how he/she fared in the test
4. The application also provides the user with a link to view the correct answer for each of the questions
5. The user receives the test score by viewing the results prepared by the application
6. The user can decide to view the correct answer for each of the questions generated by the application
7. The user can decide to take another test by clicking on the "take another test" button, otherwise, the user clicks on the exit button to quit the application

**Pre-condition:** The user has submitted the solution to the questions

**Post-condition:** The application is exited having graded the answers submitted by the user and supplied the solution to the questions attempted by the user

### 5.2 Context Diagram

A context diagram identifies actors or user roles from any documentation available. It also identifies the information that each external entity sends to the system and receives from the system. Figure 4 shows the context diagram for the Automatic Test Generator System:

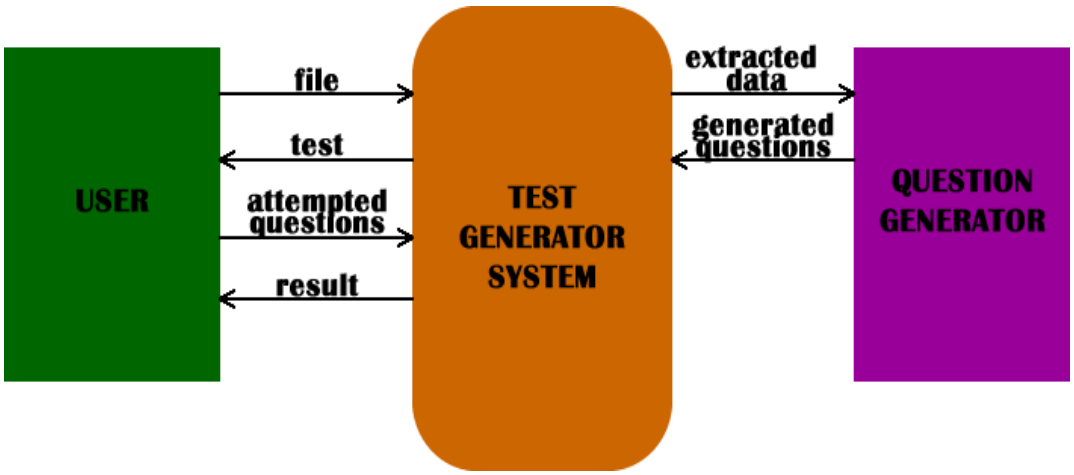


**Figure 4 Context Free Diagram for ATG**

As illustrated in Figure 4, the user selects the file and passes it to the Automatic Test Generator system. The system then passes the text contained in the file to the question generator (as NLP works with only text). The question generator then processes the text and comes out with the generated questions. It passes the questions to the Automatic Test Generator System which the user interacts with. The system outputs the generated questions to the user in form of a test. The user attempts the questions and sends them back to the system. The system then processes the submitted answers and then outputs the result to the user.

### 5.3 UML CLASS DIAGRAM

Class diagrams are used to describe the classes of the system and the relationship that exists among them. Our design recognizes four main tasks for the system: File Validation, Question Generation, Page Indexer and Marker. Figure 5 shows the classes and the relationships between them.

#### 5.3.1 File Validation Class

This class contains the function of the application which checks the type of file that is about to fed into the application by the user. It checks whether the file format is amongst the pre-listed formats compatible with the application. It also checks the size of the material to be fed into the application. It checks if the size of the material is within the maximum limit. If not, it rejects the material. The file name too is verified by this class.

#### 5.3.2 Question Generator Class

The Question Generator is responsible for generating questions from the text contained in the file fed into the application by the user. NLP is used to generate questions from the text in the material submitted by the user into the application. This is done by extracting the

discourse connectives in the text. The discourse connectives are then used to generate questions according to their peculiarities.

### 5.3.3 Marker Class

This Marker class contains the codes that are used to grade the answers the user has supplied and prepare the report of how the user fared during the test.

### 5.3.4 Page Indexer Class

This Page Indexer handles the outlining of the test questions into different pages. It is possible that the test is made up of different pages of questions. This class sees to it that the questions are properly relayed into different pages.

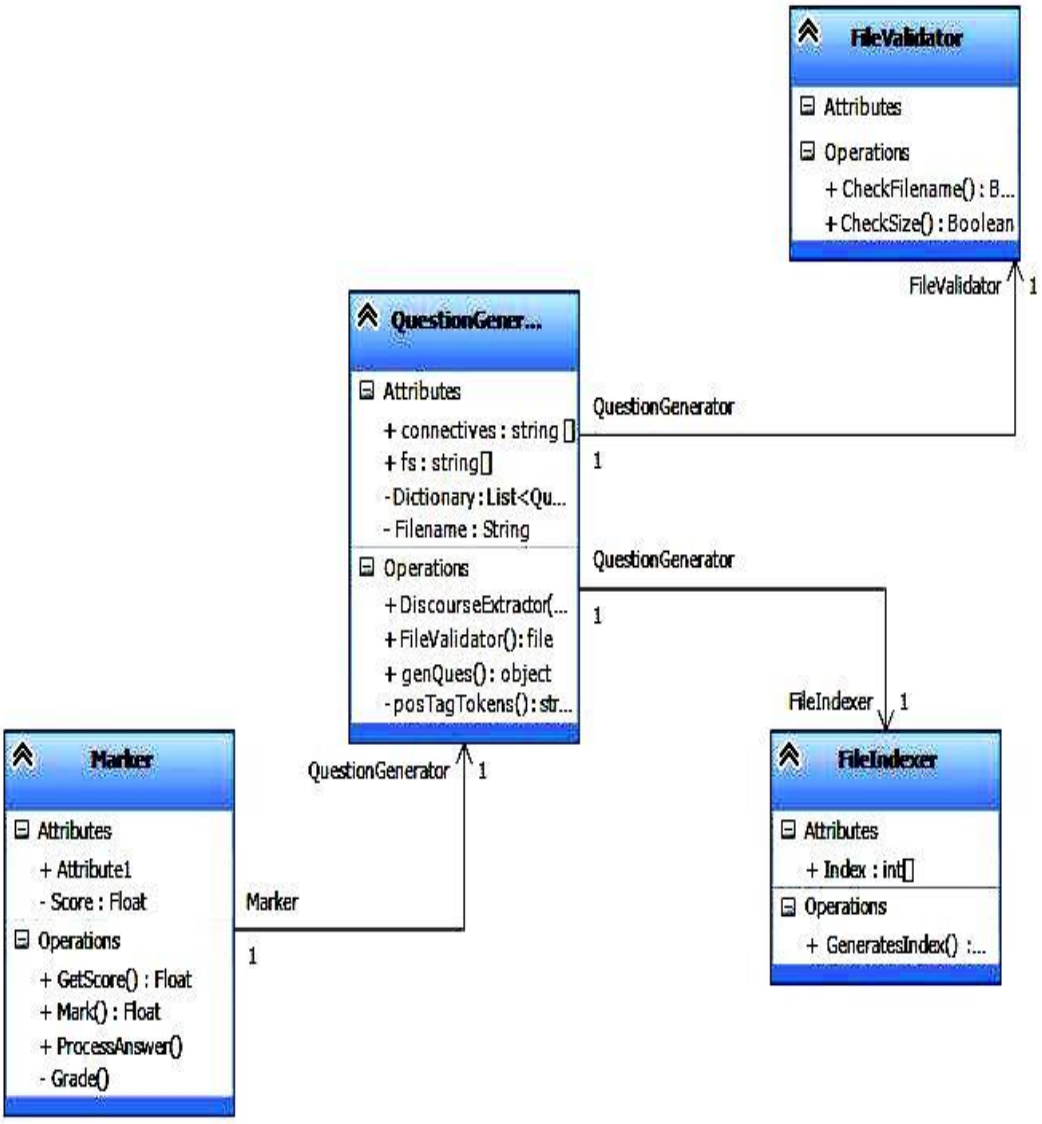


**Figure 5: UML Class Diagram for the Application System**

### 5.4 Sequence Diagram

A sequence diagram is an interaction of messages between typical instances of classes, components, subsystems or actors. The sequence diagram in Figure 6 demonstrates how the classes collaborate, and reflects the message flow initiated by the events described in the use cases.

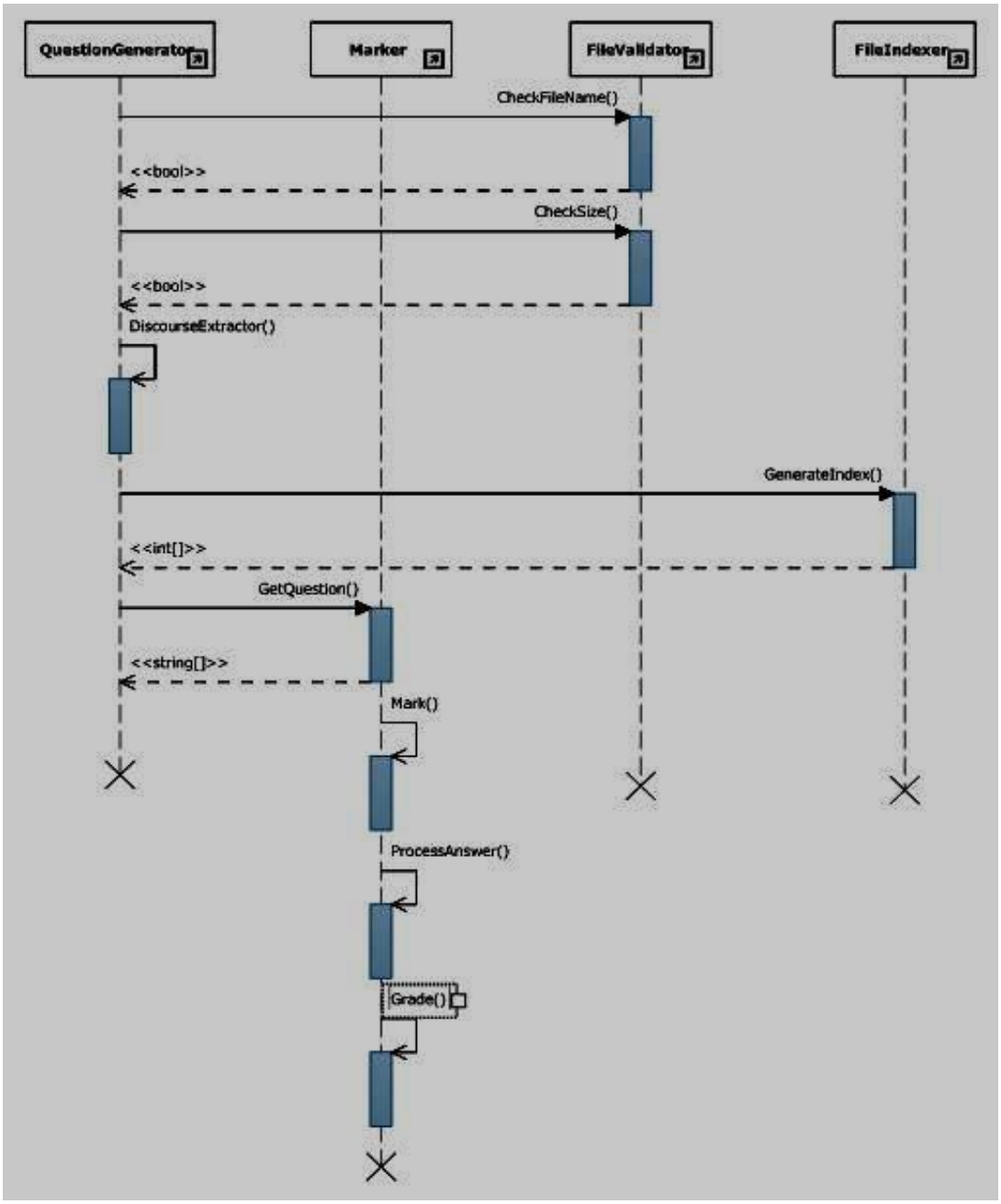


**Figure 6: Sequence Diagram for the Application System**

## 6.0 RESULTS AND DISCUSSION

Having developed the Automatic Test Generation System using Object Oriented Programming (OOP) approach, the implementation was done with the C#.Net programming language. C#.net is a multi-paradigm programming language encompassing strong-typing, imperative, declarative, functional, procedural, generic, object-oriented (class-based) and component oriented programming disciplines. Upon the launch of the application, the user selects a material or lecture note from the local disk. The system supports selection of .pdf, .txt, .doc and .docx formats. The question generator scans through the material and extracts the text from it. It then identifies sentences in the text and indexes each sentence into a string array. Other processes include:

- **Tokenizing each sentence:** Breaking the sentences down into words/tokens)
- **POS tagging (Parts-of-speech tagging):** Attaching a part of speech to each token in the sentence
- **Entity recognition:** Entities such as names of individuals, organizations, dates, times etc are identified in a sentence.

Each sentence in the array of sentences is then checked whether it contains a discourse connective. Containing a discourse connective qualifies the sentence to be generated in questions from. If a particular sentence contains a discourse connective, the sentence is split into two, using the pre-defined split() method in C# and using the discourse connective contained in such sentence as the de-limiter for the split method. The sentence is then split into two parts/arguments, and depending on the discourse connective and the sense of the discourse connective, the target argument is selected. For instance, "because" as a discourse connective has a causal (i.e expressing cause) sense and the target argument is usually argument1. Therefore the question will be generated from argument1 and the argument2 will be the answer. For example, the sentence "I am here today because I enjoy God's mercy" will be broken down into

Argument1 = I am here today

Argument2 = I enjoy God's mercy

Therefore the question will be generated by appending "why" to argument1 and switching the auxiliary verb in the sentence (in this case, the verb is "am") to the first position in the sentence. Also, a question mark is appended at the end of the sentence (this is necessary since a question is being asked). Therefore, the question generated will be: "Why am I here today?". The answer will be the argument2 which is: "I enjoy God's mercy".

Figure 7 is a screen-shot of the generated questions from a selected material:

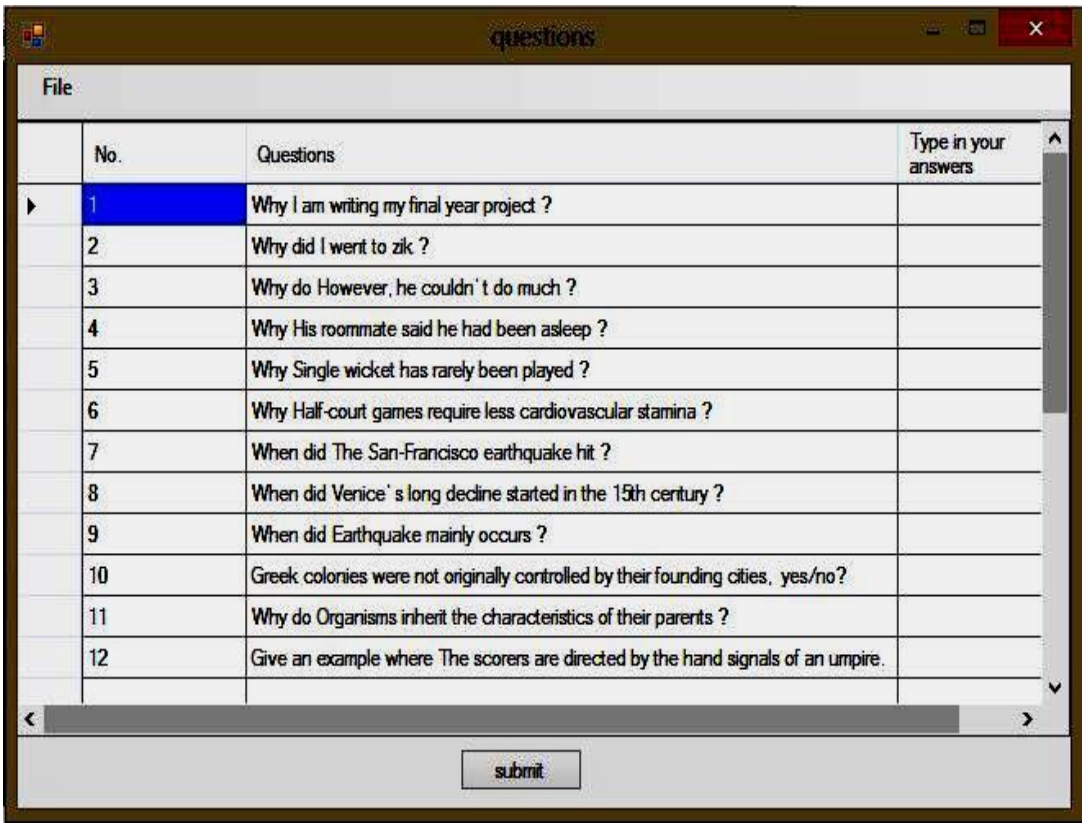


**Figure 7: Test Screen**

Figure 7 shows the generated questions from a selected pdf document. The questions are displayed using a DataGridView control. The column with the header: "Type in your answers" enables the user to type in the answer to a question against the question. After typing in the answers in the "Type in your answers" column as displayed in Figure 7, the user can decide to submit the answers by clicking on the submit button as shown in Figure 8.

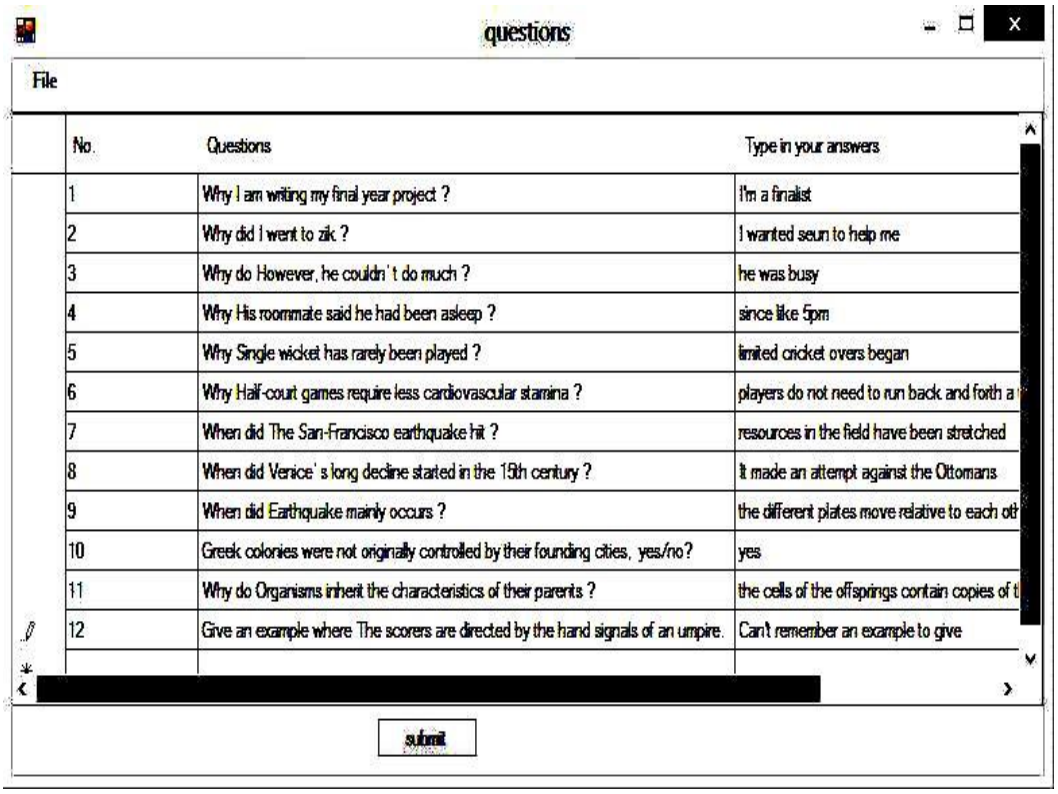


**Figure 8: User answers questions**

On click of the submit button, the application takes the answers supplied by the users and stores them in a list data structure. It then compares the answers supplied by the users with the original answer gotten from the questions. It is worth noting that English language is a very dynamic language and as such, there is usually more than one pathway to answering a question. i.e a user can supply an answer which does not necessarily tally word for word with the answer being expected by the system. Therefore, the system has been developed in a way such that the answer expected from the user must be at least 50% correct as compared with the expected answer. After marking, the application displays the users score on a dialog box. It also gives the user the option of taking another test or exiting the application after the score has been displayed.

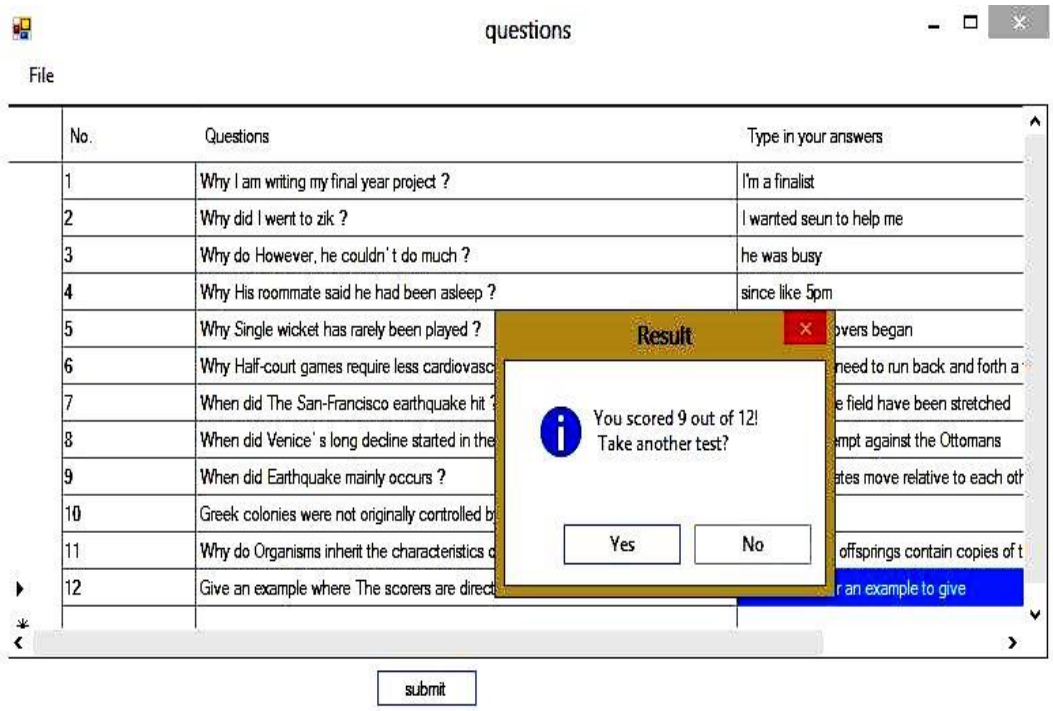


**Figure 9: Result Dialog**

The result dialog in Figure 9 displays the user scores and the total number of questions attempted by the user. The user can decide to take another test or to exit the application all together by clicking on the "No" button.

## 7.0 EVALUATION RESULTS

Our ATG system generates questions using discourse connectives by taking a pdf, plain text or MS Word document as input and outputs all the test questions based on the selected discourse connectives. The system was evaluated for syntactic and semantic correctness in order to evaluate our algorithm for guaranteed reliable extraction of questions and marking of answers. We used a set of approximately 1000 sentences from five literature books containing the 7 discourse connectives being utilized by our algorithm. By evaluating with two human experts in linguistics, the results show that the generated questions achieved average accuracies of 87.5% and 88.1% by each of the two evaluators. However, this does not rely on extensive manual analysis or annotation, and the accuracies are likely to improve with inclusion of more discourse connectives

## 8.0 CONCLUSION

This research has used Natural Language Processing techniques to deliver an automatic test generator system (ATG) that enables users to submit essay answers to questions automatically generated by the application. A unique feature of our ATG system is that it allows the user to submit essay questions, rather than the existing approach whereby question generators cater for multi-choice questions, fill-in - the-blank questions and yes/no questions.
In the near future, we plan to improve the system as regards sentence complexity and also include additional discourse connectives.

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# THE DESIGN OF A WEB – BASED INTEGRATED LIBRARY SYSTEM WITH INTERNET SECURITY SOLUTION

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**ABSTRACT**
Developing countries like Nigeria face series of defects in developing, managing and securing an Integrated Library System (ILS) in tertiary institutions and Secondary Schools where they are mostly needed. ILSs face issues such as non – interactive, speed, cost, unavailability of experienced users and programmers and also the negligence on security that makes most ILS vulnerable and unsafe for users.
As case study, this paper used a well-known tertiary Institution in the Western part of Nigeria, where their library system is about to be automated and Integrated. Authentication software, commonly known as Web Access Management (WAM) servers was used to govern the access given to the users and to licensed Electronic content. Due to the failure of protection for the system against infectious data been transmitted within the LIS, this study envisages these impediments and resolve for the design and implementation of a Web based Integrated Library System with internet security solution (Kaspersky Internet Network Security). In conclusion, the designed Web-based application implements a robust and extensible platform, capable to manage various functionalities needed by both the students and Librarians in a remote and safe manner.

**Keywords**: Integrated Library, Web, Internet Security, WAM

## 1.0 INTRODUCTION

Since the introduction of web-based services as a way of communicating and exchanging information over the internet, the position of ICT in communication and dissemination of information has increased enormously. In our society today and in the world at general, the advent and revolution of web-based computer software has been a great advancement in the world of systems management. [1] Emphasized, the importance of ICT in education and training therefore they advise that ICT should be embedded in the curriculum and ILS must be introduced. A review of studies of ICT impact on colleges shows that students learn better with the introduction of ILS on their websites [2]. According to [3] an Integrated Library system is one of the services users are expected to access through internet at their convenience. It is a multi-function web-

based multimedia content information management system, generally built on a standard relational database structure. Traditionally, the internet has been used for Information exchange, especially the World Wide Web is being used for this purpose. However, nowadays more and more rich content such as videos and other large data are shared using the internet. Example of web services is the library management system or integrated library system which has evolved over time from a library to what it is today. A library is a collection of sources, resources, services, and the structure in which it is housed. It is organized for use and can be maintained by a public body, an institution, or a private individual. In the more traditional sense, a library is a collection of books according to [4]. It can mean the collection, the building or room that houses such a collection, or both. Libraries are mainly entrusted with a host of predetermined tasks like acquiring, organizing, preserving, retrieving and disseminating information to the users. These have always been the primary objectives of the library right from ancient times to the present Internet era. However, the way this purpose has been achieved has drastically changed. Information technology has influenced the very nature of business and management libraries. They are undergoing significant changes today not only in outlook but also in function, services, methods and techniques for collection development, processing and dissemination of information. The conventional set up of brick and mortar libraries that store information within a constrained physical space have given way to data centers that integrate data sources around the globe by way of networking. Libraries have not yet explored their full potential maximally. With the advancement in technology and its direct application to libraries, business and management libraries are becoming lean and agile libraries that streamline information supply. The pervasive nature of the Internet, coupled with platform independent database connectivity is making library increasingly effective [5].

## 1.1 Statement of the Problem

Most universities in Nigeria at present use the manual library management system which is globally being replaced by web based computerized system or integrated library system. There are many problems associated with manual library management system which the integrated library system focused on solving. Since a web-based integrated library system depends on the internet to function, it is important to incorporate an anti-malware with the library portal for the safety of the user due to the virus threat on the internet in recent times. Against this backdrop, this study examined the design and implementation of an ILS and approach adopted to integrate the internet antivirus solution.

## 1.2 Research Objective

The main objective of this research is to reduce or eradicate the problems encountered in the existing manual system by designing and implementing an enhanced web based library integrated system with internet security. This will be achieved through the following:

(i) Design a web application framework using the model view controller architecture pattern.

(ii) Automate the library modules i.e. automating the cataloguing and

classification, acquisition, referencing, circulation, readers' services, administration, interlibrary lending and document delivering module and finally the OPAC system.

(iii) Integrate the automated modules and internet protection system into the framework with php script.

(iv) Test the web application developed for its functionality using a WAPT 6.0 software simulator.

## 2.0 LITERATURE REVIEW

Multiple terms have been used to define the Library depending on the technology available at a particular period. Liberians in the 1970s and 1980 referred to ILS as library automation systems or automated system. Libraries always used a card catalog to index their materials before the advent of the computer. Computers came into use to automate the card catalog [5]. Since the late 1980s, windowing systems and multi-tasking processors have allowed the integration of business functions. Instead of having to open up separate applications, library staff could now use a single application with multiple functional modules. This type of application is known as integrated library system [10]. Integrated Library System(ILS) otherwise known as library management system (LMS) is an enterprise resource planning system for a library, used to track items owned, orders made, bills paid, and patrons who have borrowed. An ILS usually comprises a relational database, software to interact with that database, and two graphical user interfaces (one for patrons, one for Librarians). Each patron and item has a unique ID in the database that allows the ILS to track its activity. Most ILSes separate software functions into discrete programs called modules, each of them integrated with a unified interface [6]. The following are modules in a library – acquisitions, cataloguing, classification, circulation, serials, referencing and information section, and the OPAC.

As the Internet grew, ILS vendors offered more functionality related to computer networks. As of 2009 major ILS systems offer web-based portals where library users can log in to view their account, renew their books, and authenticate themselves for access to online databases. Internet brought about the concept of web based integrated library system which is the hint thing in this recent time.

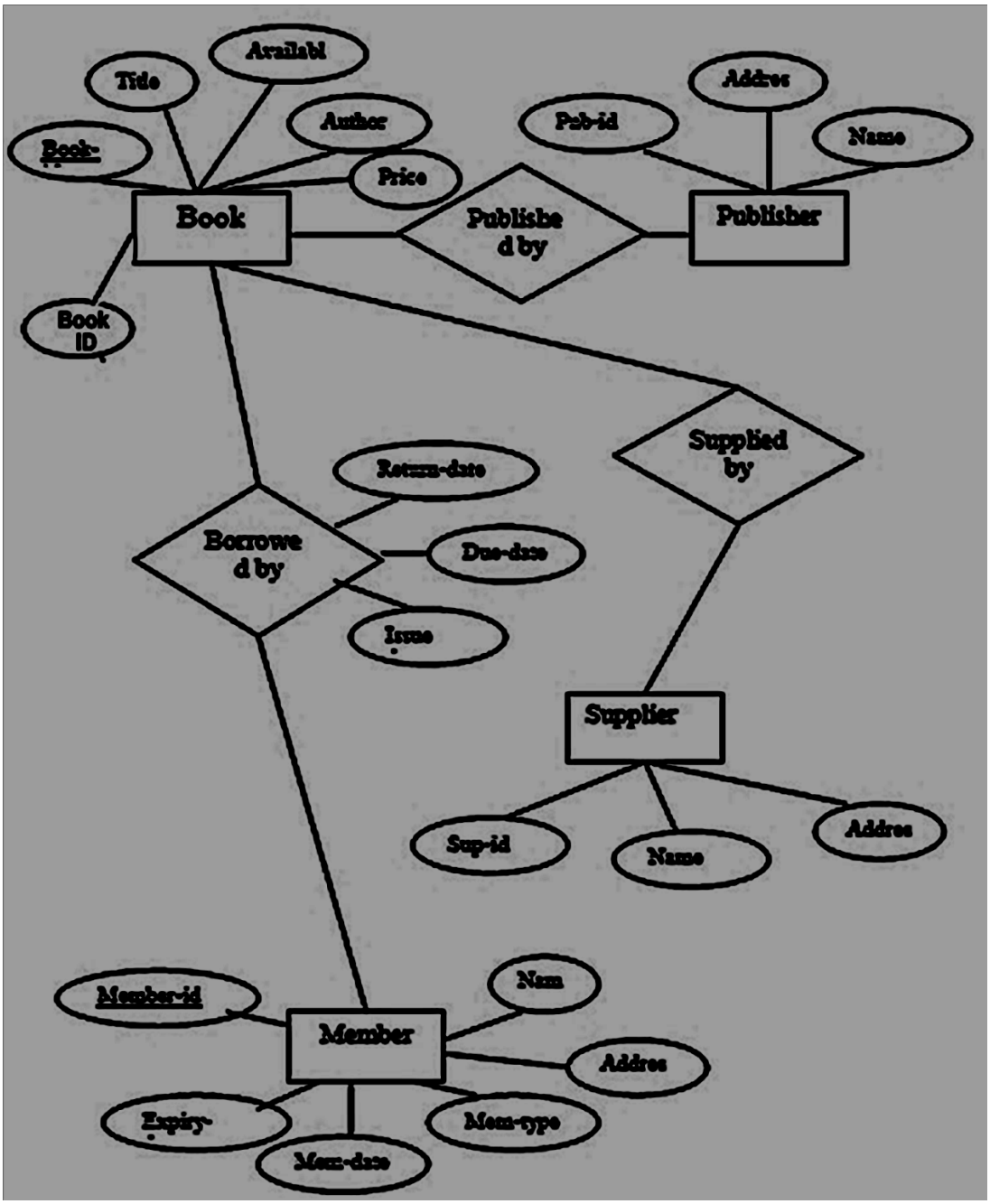


Figure 1: Descriptive Diagram of an Integrated Library system

## 2.1 WEB BASED INTEGRATED LIBRARY SYSTEM

Web based ILS according to [7] is a website for a specific audience that aggregates an array of library content and provides a set of library services. Web portal are the sites on the World Wide Web that typically provide personalized capabilities to their visitors. The web portal is designed to use distributed applications, different types of middleware, and hardware to provide services from a number of different sources. Authentication software, commonly known as Web Access Management (WAM) server is available to

govern the access to licensed electronic content. So, a web-based library portal or web-based library management system can simply be defined as a web site that offers access to a broad array of resources and services of libraries such as e-journals, online databases, Web OPAC, new additions and any other static information about library services. A web-based library management system is also known as web-based library portal.

## 2.2 Need for a web based integrated library system

[7] focuses on the availability of websites at management institutions and the extent of library information hosted on it. The study also examines the reasons why websites have failed to get the attention of majority of user and to identify the library services that should be provided online. In their research work they explained how the developments in information and communication technology (ICT) and the absorption in library and information science (LIS) have forced information professionals to change the way they function at present. Also they emphasized how academic world is increasingly becoming web-based thus institutions who wish to attract prospective students and university members must show significant improvement in their library infrastructures and resources online.

According to [8], libraries are also supposed to define and redefine their services and continuously keep their effects on value addition to the services rendered by them. So, this has led to proliferation of electronic resources which has posed several challenges like multiple logins, multiple interfaces and resource discovery. Web portals offer effective solutions to the challenges. Also, [4] emphasized that having a tech savvy library and information center with exhaustive information resources in all format has become unavoidable. Therefore, libraries are now procuring electronic sources, online databases along with locally digitized thesis and dissertations. All this effort of library in providing users with an integrated way of checking the availability of a source in all possible formats have necessitated a properly design web portal. The study also proved that more people visit an institution website when it contains a library portal. The following analyses were produced from their observations. That about 13.46% University staffs and 10.86% students visits their institutes' websites daily. 17.30% University staffs and 20.00% students prefer to visit weekly and about 34.62% University staffs and 34.28% students visit the website fortnightly. About 34.62% of University staffs and 34.8% of students visit the website on a monthly basis.

The poor number of visits that the institute website receives is because not all institutes give any dynamic and useful information on the website. These websites contain some static information about history of the institute, faculty profile and some description about resource units like library and computer lab. Further observation conducted shows that about 66.67% University staffs and 73.68% students indicated that they wish to search books' database. 58.33% University staffs and 61.05% students indicated they wish to know the availability of a particular document. About 78.33% University staff s and 83.16% students, highest number of

users, wish to do a refined search of books, using all possible approaches. Over 55% University staffs and 73.68% students indicated that they wish to reserve a book while 63.33% faculty members and 64.74% students indicated that they wish to access current awareness bulletins [4].

Since a web-based integrated library system depends on the internet to function it is important to incorporate an anti-malware with the library portal for the safety of the users due to the virus threat on the internet in recent times. Integrated library system operates on a server-to-client network which makes it possible for virus to spread easily. Once the server is infected the clients stand a chance of downloading virus infected files or documents. The number of reported incidents of virus and worm attacks has increased dramatically over the past years, so also is the cost of dealing with these attacks [9]. According to the study by [11], the average number of attacks per company increased by 79% from July 1, 2001 to December, 2001 .The cost of recovering from attacks is also skyrocketing. Following the much-publicized Nimda attacks, many major corporations cut off Internet connectivity for periods ranging from several days to several weeks. The combined costs related to damage and recovery from the Code Red worm approached $2.5 billion, and the related costs for Nimda were $3 billion; while worldwide damage from malicious attacks in 2001 has been estimated at $12-13 billion.

Malware such as spyware, viruses, worms and Trojan are rapidly becoming one of the major threats to the security of Internet users. A comprehensive analysis performed by [11] on internet security showed that a large portion of Internet-connected computers are infected with malware, and that, on average, each scanned host has 25 different spyware programs installed. The spyware is the most common and difficult to notice. Different from other types of malware, such as viruses and worms, the goal of spyware is generally not to cause damage or to spread to other systems. Instead, spyware programs monitor the behavior of users and steal private information, such as keystrokes and browsing patterns. This information is then sent back to the spyware distributors and used as a basis for targeted advertisement (e.g., pop-up ads) or marketing analysis. Spyware programs can also hijack a user's browser and direct the unsuspecting user to web sites of the spyware's choosing. Finally, in addition to the violation of users' privacy, spyware programs are also responsible for the degradation of system performance because they are often poorly coded. A number of anti-spyware products, whose goal is the identification and removal of unwanted spyware, have been developed. These tools are mostly based on the same technology used by anti-virus products. That is, they identify known spyware instances by comparing the binary image of these programs with a number of uniquely-characterizing signatures. These signatures are manually generated by analyzing existing samples of spyware. These anti-spyware tools suffer from the same drawbacks as signature-based anti-virus tools. This calls for continuous updating of their signature set. [12] Model the approach a focused attacker would take in order to breach an organization through web-based protocols and provides detection or prevention methods to counter that approach and it discusses the means an

attacker takes to collect information about the organization's web presence. It also describes several threat types, including configuration management issues, authorization problems, data validation issues, session management issues, and cross-site attacks.

This study presents the design and evaluation of a web–based integrated library system with an Anti-malware/spyware. According to [16], the drawback of the present system has instigated many organizations to introduce the ILS which exposes their users to online threat. As more users are connected to the Internet and conduct their daily activities electronically, computer users have become the target of an underground economy that infects hosts with malware or adware for financial gain. Unfortunately, even a single visit to an infected web site enables the attacker to detect vulnerabilities in the user's applications and force the download of multitude malware binaries. Frequently, this malware allows the adversary to gain full control of the compromised systems leading to the ex-filtration of sensitive information or installation of utilities that facilitate remote control of the host. We believe that such behavior is similar to our traditional understanding of virus. However, the main difference is that web-based malware infections are pull-based and that the resulting command feedback loop is looser. To characterize the nature of this rising thread, we identify the four prevalent mechanisms used to inject malicious contents on popular web sites: web server security, user contributed content, advertising and third-party widgets [13]. Their aim is to present the state of malware on the Web and emphasize the importance of this rising threat. The White Paper [14] condemned the predominant approach used by network organizations to provide protection against viruses and worms has been to install either host-based anti-virus or network-based antivirus as not foolproof; otherwise they must be combined to have reasonable level of protection.

## 3.0 METHODOLOGY

This section presents detail description of how data used in this research work was captured. This includes data required, source of data, and the model and database design. Data required for this dissertation were gotten from both primary and secondary sources. The data required for this research was voluminous so, the data was group according to the modules of the software for simplicity. The primary sources of data were the information derived from first hand source and these sources include direct interview, observation, presentations and tutorials from librarians. The secondary sources were information that was derived from existing information. Already used data in the library were collected and analyzed for the purpose of the study. Various modules in library perform different duties so; data collected were based on modules as analyzed later in the research.

### 3.1 Model for Web-based Application

The research work adopted the Model-View-Controller to implement the Web-based Integrated Library System with Internet security Solution. MVC was adopted because it organizes an interactive application into three separate modules: one for the application model with its data representation and business logic, the second for views that provide data

presentation and user input, and the third for a controller to dispatch requests and control flow. The diagram below represents Web-Tier Service Cycle. The Web tier does four basic things in a specific order:

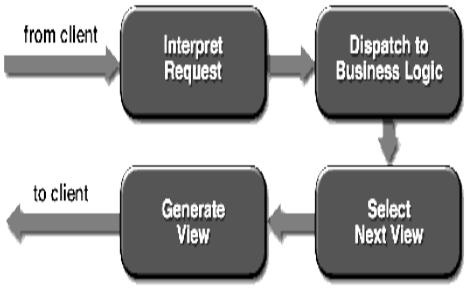


Figure 2: Web-Tier Service Cycle.

interprets client requests, dispatches those requests to business logic, selects the next view for display, and generates and delivers the next view. Figure 2 illustrates the duties.

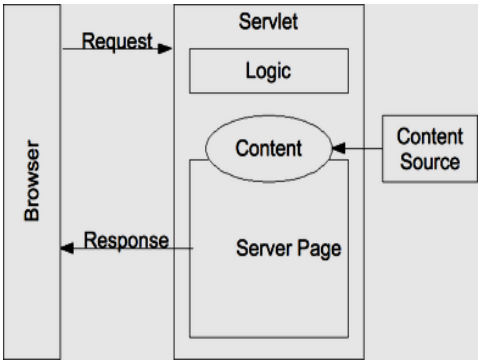


Figure 3: Model 2 Pattern

### 3.2 The Web-Tier

Web application frameworks is implemented using "Model 2" architecture, where a servlet manages client communication and business logic execution, and presentation resides mainly in JSP pages. The Model 2 architecture uses servlets for processing requests and selecting views. In this research the Front Controller is typically implemented as a servlet. The figure 3 below shows a simplified diagram of the model 2 pattern.

A Web-tier MVC controller maps incoming requests to operations on the application model, and selects views based on model and session state. Web-tier controllers have a lot of duties, so they require careful design to manage complexity. Web-Tier Controller Object Interactive Diagram illustrates the relationship and duties between the three tier computing involved in the web application.

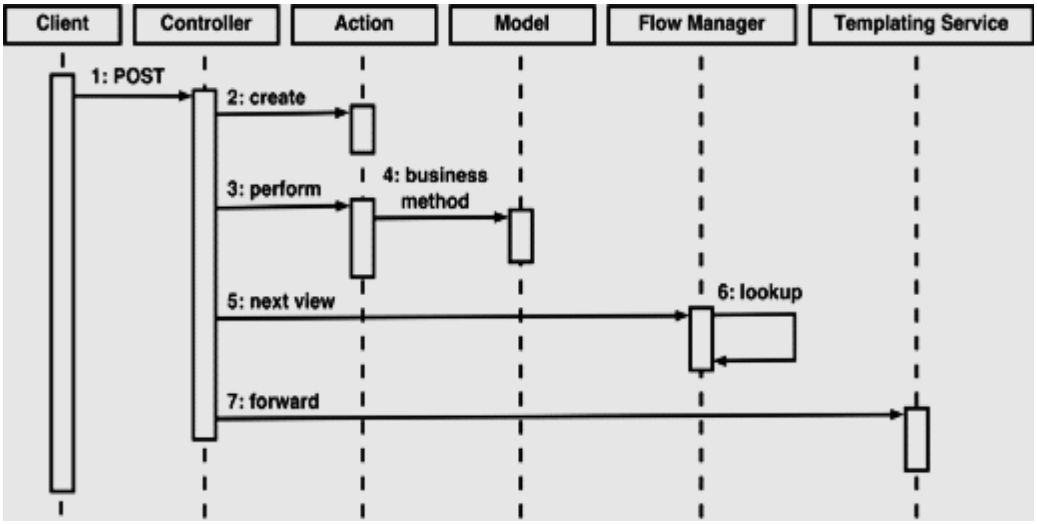


Figure 4: Web-Tier Controllers OID

### 3.3 Network architecture of the Proposed Web-based integrated library system with internet security solution.

Figure 5 demonstrates the network architecture of the ILS. The Kaspersky Internet Security Solution is installed on the server hosting the ILS; it protects all the downstream hosts that access the server.

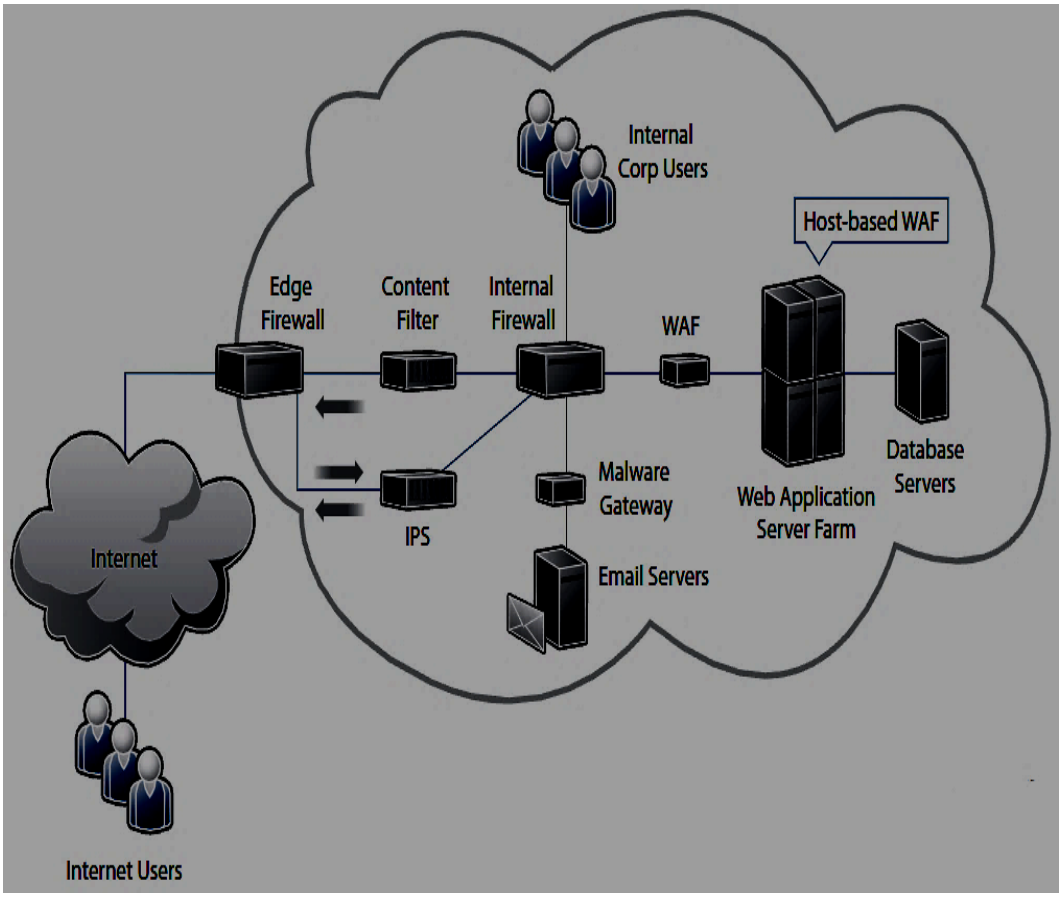


Figure 5: The network architecture of the proposed web-based integrated Library system with internet security solution

## 4.0 DESIGN

This section outline the design of the most common object, their basic identity and actions performed in the system by Using Unified Modelling Language comprehensive notations.

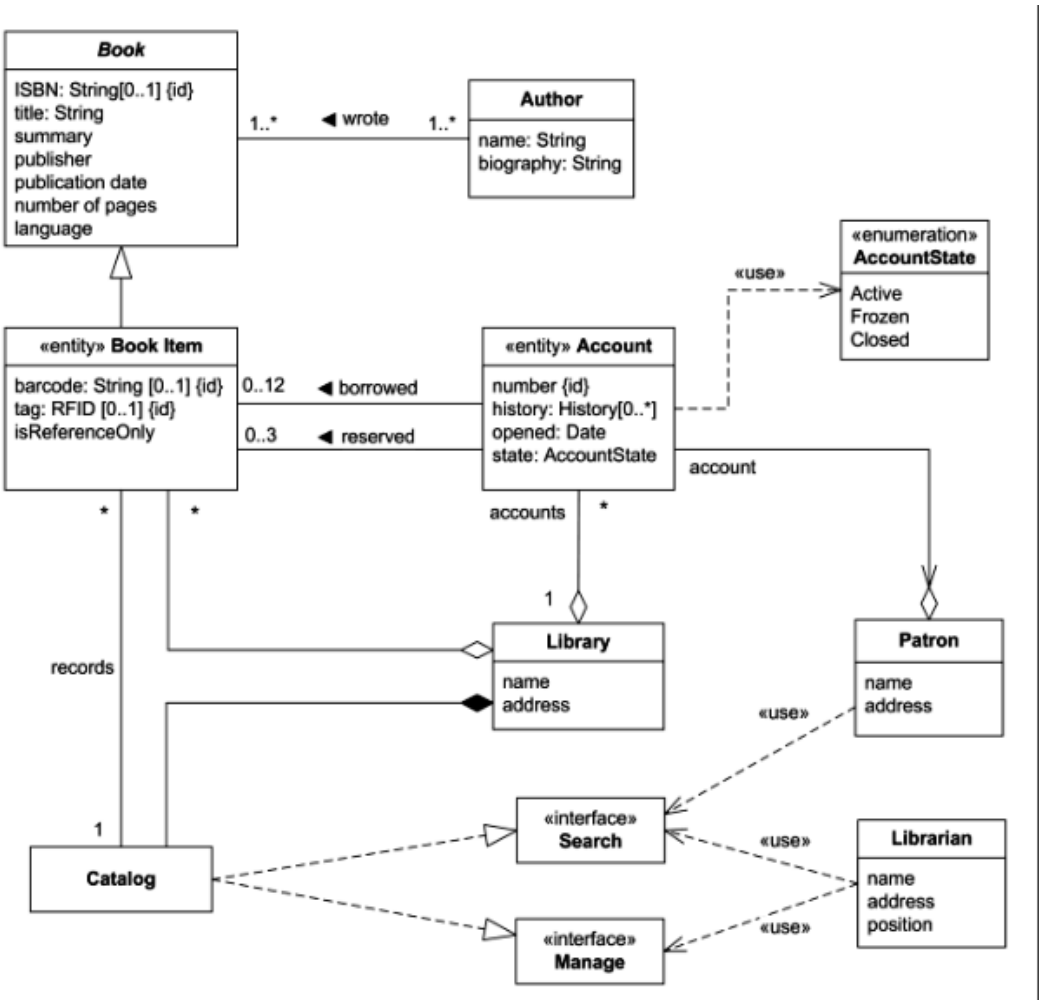


Figure 6: The Integrated Library System UML Diagram

### 4.1 Use Case Diagram

The use case diagram is used to identify the primary elements and processes that form the system. The primary elements are termed as "actors" and the processes are called "use cases". For the Library system the actors are: Students, Staffs, Librarian and reference librarian. The different roles the actor represents are the actual business roles of users in a system. An actor in a use case diagram interacts with a use case. A use case in the use case diagram is a visual representation of distinct business functionality in the system. Some of the use cases are individual for each actor and some are common. Use cases share different kinds of relationships. A relationship between two use cases is basically a dependency between the two use cases [15]. Figure 7 describes how book borrowing process is being handled by the application.

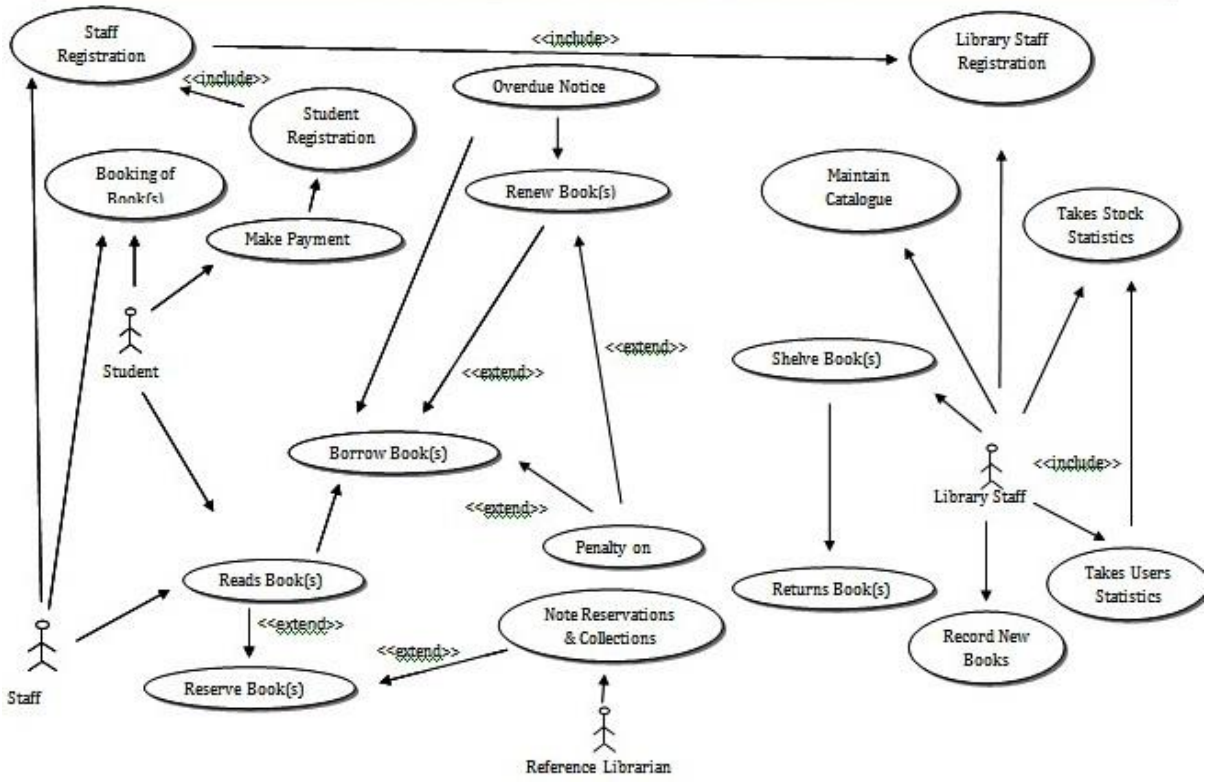


Figure 7: Use Case UML diagram: Online Library System

## 4.2 DESIGN OF MODULES AND PROCESSES OF THE ILS

The design of the modules and processes in the proposed ILS are described below using use case diagram.

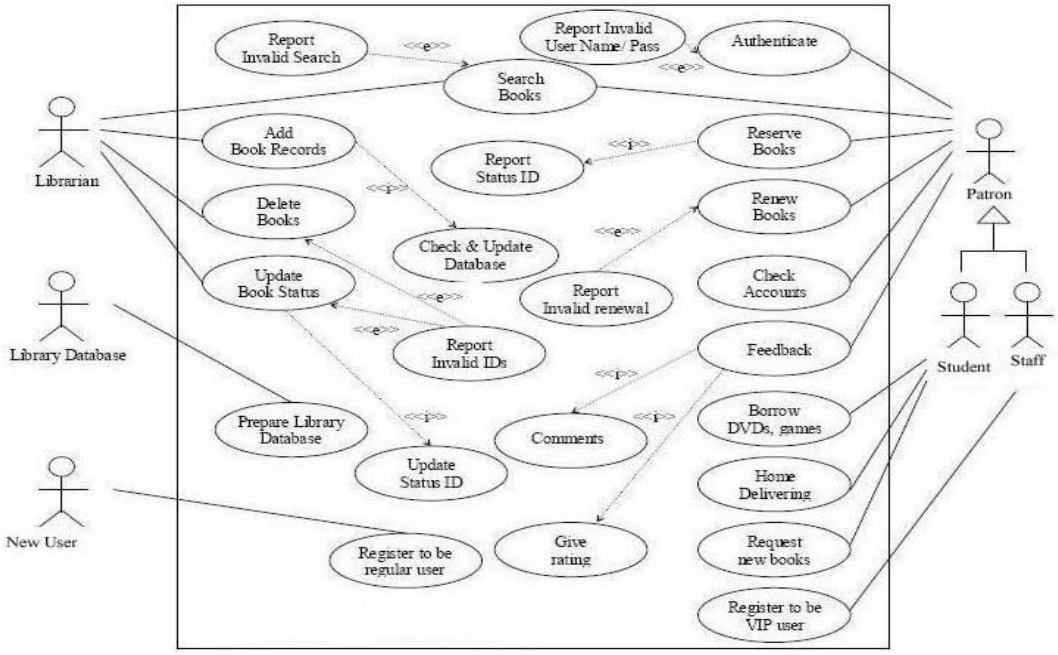


**Figure 8:** Modules and Processes in the ILS

## 4.3 User Activities

The most common activities carried out by user are illustrated bellow using activity diagrams.

### 4.3.1 Patron Registration

Figure 9 represent the flowchart that outlines how patron (student) registration is done.

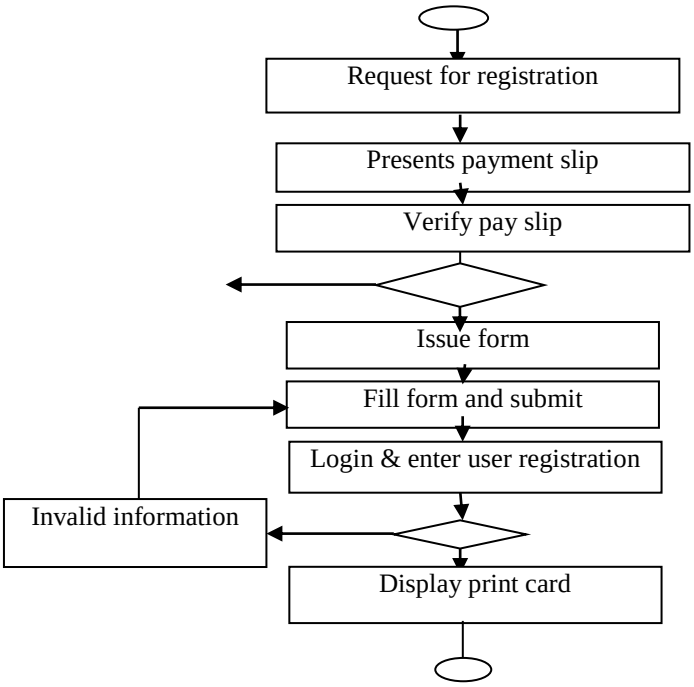


**Figure 9:** Flowchart outlining student Registration process

### 4.3.2 Borrowing

Borrowing of books in the library is illustrated below in figure 10.

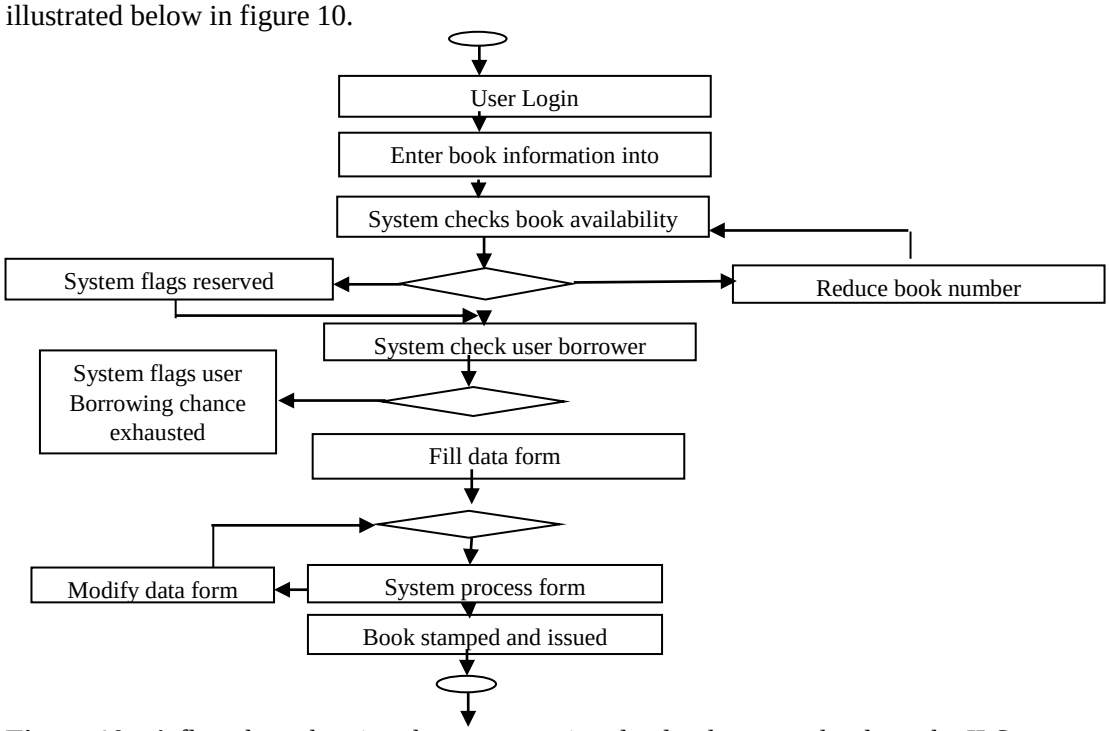


**Figure 10:** A flowchart showing the processes involved to borrow a book on the ILS

## 5.0 APPLICATION DEVELOPMENT WITH THE INTEGRATION OF INTERNET SECURITY SOLUTION

This design integrated kaspersky internet security 2013 with the web-based Integrated Library System. This particular model is adopted because it a Network based Anti-virus which means it is installed on a network gateway between two networks which also means it is server based. Also, it is a Host-based Antivirus solution which means it is installed on a server to protect downstream hosts that access the server. Other characteristics includes Signature based detection, Heuristic-based detection, File emulation, and Rootkit detection. Kaspersky Internet Security 2013 is installed on the server hosting the ILS, once the download of a file is initiated, the internet security scans the file to be downloaded as illustrated in figure 11 below:


Figure 11: GUI of the application with Internet security solution

After the scan for malware is completed, a dialog box display "scan complete; download file; threat found 0" or "scan complete; threat found (1….n**);** continue anyway; cancel download". To continue the download you click on resume or open as illustrated in figure12 below.


Figure 12: GUI of the application after the internet security scan

## 6.0 TESTING

Having developed web based Integrated Library System with Internet Security Solution; system testing is an implementation stage which is aimed at examining the performance, stress and endurance of the site design. To achieve this, the test was carried out manually and also with WAPT Pro 2.5. The web site was loaded on WAPT Pro 2.5 to test for performance, stress and endurance, some errors were detected and corrected. The test was carried out one more time to improve the integrity of the site. In addition, the site was manually tested to check what real users will experience when working with the web site under load. Figure 13 below shows the evaluation graph from the test carried out on WAPT Pro 2.5.

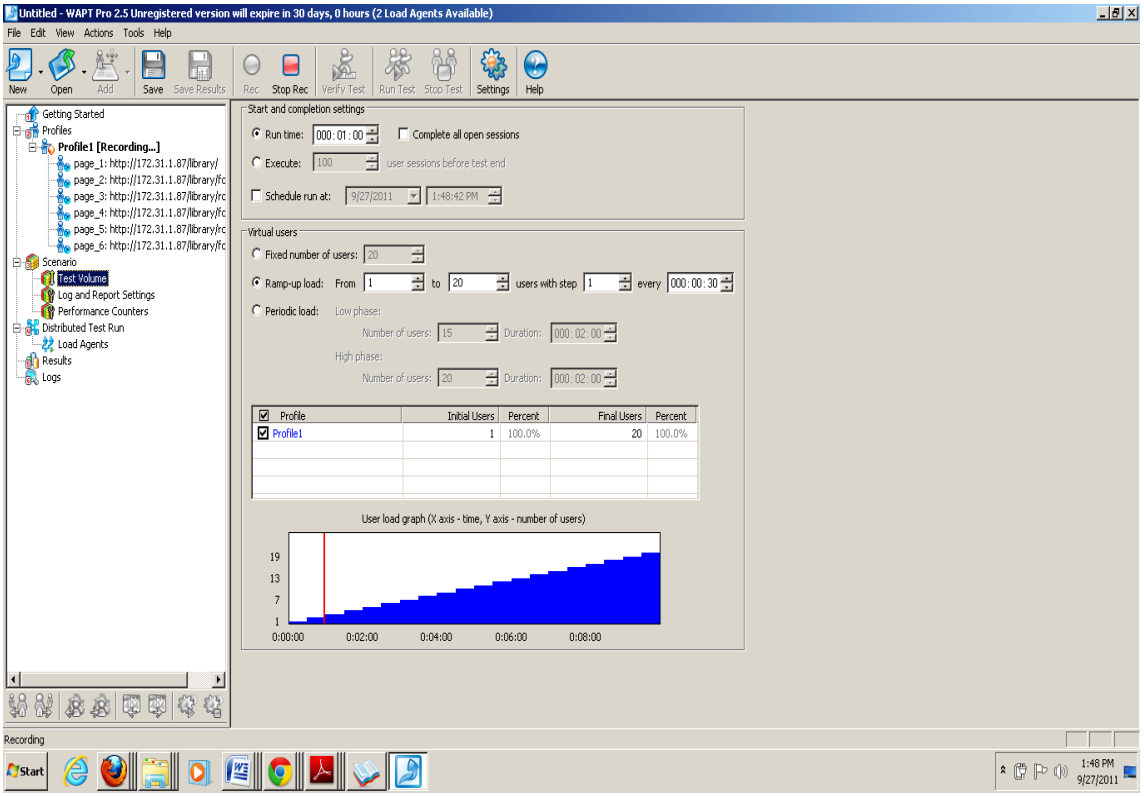


Figure 13: Evaluation graph showing test result of the application with WAPT Pro 2.5

## 7.0 CONCLUSION

The focus of earlier Integrated Library Systems is to ease data processing and the means of accessing the library which has reduce visit to many modern library because you can access the library remotely. Various methods have been used to design IlSs and different modules have been introduced in different designs across the world. But, this research work has designed and implemented a Web-based integrated library System with Internet Security Solution to protect the ILS and its users in a very low cost. The approach used is a zero cost approach because only Open Source programs and free software were used in this research work. Lastly, having integrated an Internet Security Solution it will sanitize and guaranty the users of a safe ILS.

## 8.0 RECOMMENDATION

The use of Model-View-Controller is strongly recommended as the architecture for this design because it can be implemented with PHP an Object Oriented and Open Source programming language. Secondly the Web base Integrated Library System should be hosted within University Library as a security measure. It is also strongly recommended that Orientation and training should be given to users most importantly librarians. Lastly, power supply and fast internet connection should be available at all times to prevent network timeout.

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# BLACK-BOX OPTIMIZATION BENCHMARKING OF PRCGA ON NOISY TESTBED

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**ABSTRACT**
Real-coded genetic algorithms (RCGAs) are a class of probabilistic optimization algorithms developed specifically for the continuous parameter optimization domain. Projection-based RCGA (PRCGA) is a hybrid RCGA that is benchmarked on a set of 30 noisy testbed functions. The recently introduced COmparison of Continuous Optimizers (COCO) methodology was used in carrying out the experiment reported in this paper. In the experiment, PRCGA was implemented as a generational RCGA with a multiple independent restart mechanism, tournament selection, $\alpha$-blend crossover, nonuniform mutation and a mechanism to prevent stagnation and premature convergence. The maximum number of function evaluations ($\#Fes$) for each test run is $10^5$ times the problem dimension. The results of this experiment show that PRCGA is able to solve more than half of the test functions with the dimension up to 40 with lower precision and can only solve about four test functions to the desired level of accuracy of $10^{-8}$.

**Keywords:** Benchmarking, Black-box optimization, Real-coded genetic algorithm, Projection

## 1.0 INTRODUCTION

Real-coded genetic algorithms (RCGAs) are a class of evolutionary algorithms (EAs) designed specifically for the continuous parameter optimization domain. RCGAs use real-valued vectors to represent individual solutions instead of the classical binary representation used in binary-coded genetic algorithms (BCGAs). RCGAs were introduced to address the drawbacks of BCGAs. A major drawback of BCGAs is the expensive computational cost of handling problems with large search space. Despite the advantages of RCGAs over BCGAs, RCGAs have the problem of falling into premature convergence. This is partly due to lack of population diversity and high selection pressure. Another drawback of RCGAs is that they do not exploit the local basins of solutions in the population [16].

To address this problems, hybridizing RCGAs with local optimization algorithms was proposed and have been used successfully by several researchers who have shown that the performance of RCGAs

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have been greatly improved. In this section, some recent examples of hybrid RCGAs are mentioned.

In 2003, Chelouah and Siarry [3] hybridized RCGA with Nelder-Mead algorithm, Ali and Törn [2] proposed another modification to RCGA using some ideas from the Controlled Random Algorithm in 2004 while Deep and Dipti [6] hybridized RCGA with self organising migrating algorithm. In 2008, Deep and Das [5] used quadractic approximation to hybridized RCGA and Sawyerr et al [16] used pattern search and projection to enhanced the performance of RCGA in 2011. By 2012, Chuang and Chen [4] introduced direction-based RCGA, as a novel RCGA during the Genetic and Evolutionary Computation Congress (GECCO 2012). The performance of this algorithm was quite impressive indicating that a good local search method can greatly improve the performance of RCGA. By 2013, Sawyerr et al [15] introduced an enhanced version of RCGA-P at GECCO 2013 [15] and benchmarked it on a set of BBOB-2013 noiseless testbed functions. The enhanced algorithm was equipped with two restart mechanism, a stagnation alleviation mechanism and was named PRCGA.

Over the last three decades, several test functions have been used to benchmark different algorithms by researchers in the mathematical optimization and Evolutionary Computation community. In 2005, two groups of researchers, Ali et al [1] and and Suganthan et al [18] independently proposed two sets of benchmark testbeds. Ali et al [1], proposed a set of test functions with varing degrees of difficulty and Suganthan et al [18] also proposed a set of testbed functions at the IEEE Congress of Evolutionary Computation (CEC 2005). These two testbeds have served as the basic testbeds for benchmarking optimization algorithms.

In 2009, Hansen et al [10, 11] proposed the COmparison of Continuous Optimizers (COCO) framework for the Black-Box Optimization Benchmarking (BBOB-2009) workshop at the 2009 GECCO conference. This framework consist of two sets of carefully chosen testbed functions. A set of noiseless testbeds and another set of testbeds with noise. The framework is a methodology for determining the potentials and weaknesses of one or more algorithms. It can also determine the differences between algorithms at every stage of the optimization search. The COCO methodology was chosen because it consist of carefully chosen scalable noiseless and noisy benchmark functions that represent real world problems with varing levels of difficulties.

PRCGA was benchmarked on the noiseless testbed in the BBOB 2003 workshop and its performance was not satisfactory overall but interestingly it was able outperform all its competitors in solving a highly multimodal and perhaps one of the most difficult problems in the workshop. This observation serves as a motivation for benchmarking PRCGA on the BBOB noisy testbed in this paper.

PRCGA is a hybrid RCGA that is equipped with a novel search operator called projection. Projection is an idea borrowed from the projection of vectors in linear algebra. The use of projection as a search operator in evolutionary computation was reported for the first time in [16, 17].

The remaining part of the paper is organized as follows: Section 2 presents the PRCGA algorithm. Section 3 presents the Experimental Procedure used in this work while Section 4 provides the CPU Timing Experiments, Section 5 presents results and discussion. Finally in Section 6, conclusion is given.

## 2.0 THE PRCGA ALGORITHM

The PRCGA algorithm, starts by creating an initial population $P_{t=0}$ from the solution search space $S$ randomly at generation $t = 0$. $P_{t=0}$ is evaluated and the genetic operators are applied to $P_{t=0}$ to create a new population of offspring solutions $O_{t=0}$. Using a replacement strategy, $O_{t=0}$ is used to replace $P_{t=0}$ to give $P_{t=1}$. The genetic operators are applied to the new population of solutions, $P_{t+1}$ and the evolutionary process continues until an optimal solution is found or the maximum number of generation is satisfied. The PRCGA algorithm in Algorithm 1, is a generational RCGA with four operators: Selection, Crossover, Mutation and Projection.

Selection, crossover and mutation are the *"genetic operators."*

### 2.0.1 Selection

Selection operators in GAs are used to guide the evolutionary search by selecting solutions with very good fitness values in the current population for mating, i.e. solutions with higher fitness in relation to other members of the same set are selected for mating. The reason is that the solutions with higher fitness value in a population possess good properties that, if paired and mated are passed on to the offspring produced. Examples of selection operators include fitness proportional selection (roulette wheel selection), ranked based selection, tournament selection, etc.

**Algorithm 1** *The PRCGA Algorithm*

**Input:** Fitness function $f$; Parameters
**Output:** Best solution $x_{best}$; $f(x_{best})$

1. Initialize $P_{t=0}, P_t = \{x_{1,t}, \dots, x_{N,t}\} \in$ S
2. $f(x_{i,t}) =$ evaluate($P_t$), $\{1 \leq i \leq N\}$
3. While not terminate, do steps 4 - 12
4. If $\sigma(f(P_t)) \leq \varepsilon$ do step 5 else step 6
5. $\hat{P}_t =$ perturb($P_t$)
6. $\hat{P}_t =$ tournamentSelection($P_t$)
7. $O_t =$ blend-$\alpha$Crossover($\hat{P}_t, p_c$)
8. $M_t =$ non-uniformMutation($O_t, p_m$)
9. $\Phi_t =$ projection($M_t$)
10. $f(x_{i,t}) =$ evaluate($\Phi_t$)
11. $P_{t+1} =$ replace($P_t$,$\Phi_t$)
12. $t = t + 1$
13. end while

In this work, tournament selection was used because it maintain a good selection pressure. A GA with good selection pressure will not easily fall into premature convergence. Tournament selection was used to select $\tau$ number of solutions uniformly at random from $P_t$ with replacement, where $\tau$ is the tournament size and $\tau$ is less than $N$, the size of the population $P_t$. Secondly, the selected solutions in $\tau$ are compared using their fitness values and the best solution is selected and assigned to $\hat{P}_t$, the mating pool. This procedure is repeated $m$ times to populate $\hat{P}_t = \{x_{1,t}, x_{2,t}, \dots, x_{m,t}\}$, where $m$ is the size of the mating pool and $m \leq N$.

### 2.0.2 Crossover

The crossover operator is the primary genetic operator that is used to pass on some of the parents' genes to their offspring

through mating. The offspring inherit traits from the participating parents. Several crossover operators have been proposed for RCGAs. Examples include, Arithmetic crossover, Blend-$\alpha$ crossover, Heuristic crossover, etc. In this work, the Blend-$\alpha$ crossover was used.

At every generation $t$, two parent solutions $(x_{i,t}, x_{j,t})$ are selected randomly and blend-$\alpha$ crossover is carried out on the pair, if a randomly generated number $\mu, (0 \leq \mu \leq 1)$ is greater than the specified crossover probability threshold, i.e., $\mu_i > p_c$. Blend-$\alpha$ crossover is used to uniformly generated the offsprings $(o_{1,t}, o_{2,t})$ from the interval $[\min(x_{i,t}^k, x_{j,t}^k) - \alpha * d^k, \quad \max(x_{i,t}^k, x_{j,t}^k) + \alpha * d^k]$ as follows:

$$o_{1,t}^k = \left(\min(x_{i,t}^k, x_{j,t}^k) - \alpha * d^k, \max(x_{i,t}^k, x_{j,t}^k) + \alpha * d^k\right)$$
$$o_{2,t}^k = \left(\min(x_{i,t}^k, x_{j,t}^k) - \alpha * d^k, \max(x_{i,t}^k, x_{j,t}^k) + \alpha * d^k\right), \quad (1)$$

where $k = 1,2, \ldots, n$ represents the index of a component of $o_{i,t}$, $(1 \leq j \leq N)$, $\alpha = 0.3 + 0.2 \times z$, $z$ is a uniform random number drawn from the interval $[0,1]$, $d^k = |x_{i,t}^k - x_{j,t}^k|$. The new pair $(o_{1,t}, o_{2,t})$ is then copied to the set $O_t$, otherwise the pair $(x_{i,t}, x_{j,t})$ is copied to $O_t$.

### 2.0.3 Mutation

The mutation operator is used for exploring the search space through some random jump within the search region. There are several mutation operators for RCGA but in this work the non-uniform mutation [14] was applied to the components of each member of $O_t$ with probability, $p_m$ as follows

$$m_{i,t}^k = \begin{cases} o_{i,t}^k + \Delta(t, u^k - o_{i,t}^k) & if \quad a \leq 0.5, \\ o_{i,t}^k - \Delta(t, o_{i,t}^k - l^k) & otherwise \end{cases} \quad (2)$$

The mutated individual $m_{i,t}$ is copied to the set $M_t$, otherwise $o_{i,t}$ is copied to $M_t$. $a$ is a uniformly distributed random number in the interval $[0,1]$. $u^k$ and $l^k$ are the upper and lower boundaries of $x \in S$, respectively. The function $\Delta(t, u^k - o_{i,t}^k)$ given below takes a value in the interval $[0, y]$

$$\Delta(t, y) = y(1 - r^{(1-\frac{t}{T})})^{\beta}, \quad (3)$$

where $r$ is a uniformly distributed random number in the interval $[0,1]$, $T$ is the maximum number of generations and $\beta$ is a parameter that determines the non-uniform strength of the mutation operator.

### 2.0.4 Projection

The projection-based operator works by projecting a vector, $y$ onto another vector, $x$ to give a displacement of the positions of the two points to create a third point, $\hat{y}$. This operation is similar to the way crossover operators work in genetic algorithms except that the projection operator produces only one offspring per operation. The projection operator is able to find good solutions through fitness guided search in the solution landscape. It performs exploration at the early stages of the genetic search and exploitation at the later stage. Figure 1 provides an illustration of projecting a vector $x$ on another vector $y$.

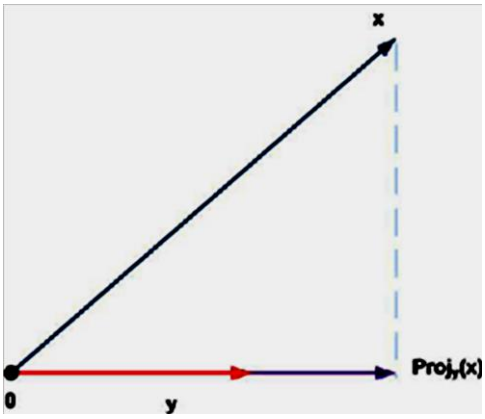


Figure1: Projection of vector x on vector y
Source: [15]

Projection operation is used to generate $\Phi_t$ from $M_t$ by randomly taking a pair of solutions, $(m_{i,t}, m_{j,t})$, for each $m_{i,t} \in M_t$. $(m_{i,t}, m_{j,t})$ are evaluated, if $f(m_{i,t})$ is better than $f(m_{j,t})$ then $m_{j,t}$ is projected on $m_{i,t}$ otherwise $m_{i,t}$ is projected on $m_{j,t}$ and a projected solution $\phi_{i,t} \in \Phi_t$ is created. This operation is defined by Eq. (4).

$$\phi_{i,t} = \frac{m_{j,t}^T m_{i,t}}{m_{i,t}^T m_{i,t}} m_{i,t} = \frac{m_{j,t}^T m_{i,t}}{\|m_{i,t}\|^2} m_{i,t} = \left( \frac{\|m_{j,t}\| \cos(\theta)}{\|m_{i,t}\|} m_{i,t} \right) \quad (4)$$

Note that the projected vector $\phi_{i,t}$ (the offspring) will be in the same direction as $x_{i,t}$ unless $\frac{\pi}{2} < \theta < \frac{3\pi}{2}$ in which case the angle $\theta$ between the two vectors is such that $\cos(\theta) < 0$, thereby projecting the vector in the opposite direction.

Sometimes the components $\phi_{i,t}^k$ of the trial point $\phi_{i,t}$ may fall outside the search space. In such cases, the corresponding component $\phi_{i,t}^k$ is regenerated. After the projected vector is generated, its fitness value $f(\phi_{i,t})$ is determined.

After the projected vector is generated, its fitness value $f(\phi_{i,t})$ is determined and a new population, $P_{t+1}$, is created with $x_{i,t}$, where,

$$x_{i,t} = \begin{cases} \phi_{i,t} & if\ f(\phi_{i,t}) < f(m_{i,t}), m_{i,t} \in M_t \\ m_{i,t} & otherwise \end{cases} \quad (5)$$

### 2.0.5 Replacement Strategy

There are two replacement strategies in genetic algorithms, namely generational and steady state models. The replacement strategy adopted in this work is the generational model [7]. The generational replacement strategy systematically replaces the whole parent population $P_t$ of size $N$ with the offspring population [20].

Finally, elitism is used to ensure that the best solution in the current population $P_t$ survives and is carried over to the next population $P_{t+1}$.

### 2.0.6 Stagnation prevention mechanism

A stagnation prevention mechanism was introduced to prevent premature convergence of the algorithm. The mechanism works by measuring the population diversity of $P_t$. This was done by calculating the standard deviation, $\sigma(f(P_t))$ of the fitness values $f(P_t)$ of all solutions $x_{i,t}, \in P_t$.

If $\sigma(f(P_t)) \leq \varepsilon = 10^{-12}$, a very small positive value and the global minimum $f(x_{min})$ is not yet found, then $x_{i,t}, \in P_t$ are sorted according to their fitness values and the top $10\%$ preserved. The remaining $90\%$ of $x_{i,t}, \in P_t$ are replaced with uniformly generated random values from the interval $[-5,5]^D$. The resultant population is the mating pool, $\hat{P}_t$. On the other hand, if $\sigma(f(P_t)) > \varepsilon$ then tournament selection is applied on $P_t$ to create the mating pool $\hat{P}_t$ [15].

## 3.0 EXPERIMENTAL PROCEDURE

The experimental setup was carried out using the COmparison of Continuous Optimizers (COCO) methodology [9] on the benchmark functions provided in [8, 13]. Two independent restart strategies were used for PRCGA. A restart strategy is used to restart the experiment whenever the population of solutions stagnates or when the maximum number of generations have been met and $f(x_{min})$ is not found. For

each restart strategy, the algorithm is restarted with an initial population $P_0$ uniformly sampled from the search space $[-5,5]^D$ according to [15].

There are two stopping conditions for the restart strategies. The first restart strategy checks if the best solution obtained so far and during the last $(50 + 25 \times D)$ generations did not vary by more than $10^{-12}$ as in [4] while the second restart condition is when the maximum number of generations is satisfied and $f(x_{min})$ is not found. Whenever the stopping conditions are met, the algorithm is reinitialized and restarted from the beginning without using any information from the previous run.

Table 1: Parameter Settings for the Experiment

| **Sno.** | **Parameter** | **Value** |
|---|---|---|
| 1 | Population size | $\min(100,10 \times D)$,$D$ = dimension |
| 2 | Maximum number of generation $(T)$ | 10,000 |
| 3 | Mutation probability $(p_\mu)$ | 0.15 |
| 4 | Crossover probability $(p_c)$ | 0.8 |
| 5 | Tournament size $\tau$ | 3 |
| 6 | Elitism $(E)$ | 1 |
| 7 | Maximum number of evaluation $\#FEs$ | $10^5 \times D$ |
| 8 | Non-uniformity factor for the mutation $\beta$ | 15 |
| 9 | Crafting effort $CrE$ [9] | 0 |

5-D

| $\Delta f$ | 1e+1 | 1e+0 | 1e-1 | 1e-2 | 1e-3 | 1e-5 | 1e-7 | #succ |
|---|---|---|---|---|---|---|---|---|
| $f_{101}$ | 11 | 37 | 44 | 49 | 62 | 69 | 75 | 15/15 |
| | 3.2(3) | 6.5(3) | 12(2) | 16(2) | 24(5) | 104(192) | 209(311) | 15/15 |
| $f_{102}$ | 11 | 35 | 50 | 66 | 72 | 86 | 99 | 15/15 |
| | 3.1(3) | 7.3(3) | 10(3) | 11(2) | 32(6) | 81(162) | 139(278) | 15/15 |
| $f_{103}$ | 11 | 28 | 30 | 30 | 31 | 35 | 115 | 15/15 |
| | 4.7(6) | 9.4(4) | 18(6) | 29(5) | 44(10) | 64(28) | 28(10) | 15/15 |
| $f_{104}$ | 173 | 773 | 1287 | 1574 | 1768 | 2040 | 2284 | 15/15 |
| | 3.3(2) | 204(249) | 1039(1324) | 1331(1516) | ∞ | ∞ | *∞3.0e5* | 0/15 |
| $f_{105}$ | 167 | 1436 | 5174 | 9998 | 10388 | 10824 | 11202 | 15/15 |
| | 3.5(1) | 64(92) | 57(79) | 119(146) | 193(204) | ∞ | *∞2.7e5* | 0/15 |
| $f_{106}$ | 92 | 529 | 1050 | 1770 | 2666 | 2887 | 3087 | 15/15 |
| | 7.4(3) | 186(285) | 260(294) | 2509(2613) | 1666(1740) | ∞ | *∞2.6e5* | 0/15 |
| $f_{107}$ | 40 | 228 | 453 | 692 | 940 | 1376 | 1850 | 15/15 |
| | 0.99(0.9) | 1.7(1.0) | 2.0(0.8) | 2.4(1) | 2.4(2) | 2.8(2) | 9.5(10) | 15/15 |
| $f_{108}$ | 87 | 5144 | 14469 | 24649 | 30935 | 58628 | 80667 | 15/15 |
| | 0.41(0.5) | 3.4(5) | 2.8(3) | 3.6(3) | 6.1(6) | 21(21) | *∞2.6e5* | 0/15 |
| $f_{109}$ | 11 | 57 | 216 | 375 | 572 | 873 | 946 | 15/15 |
| | 3.7(3) | 4.7(3) | 2.8(1) | 2.9(1) | 2.9(1) | 5.9(4) | 14(10) | 15/15 |
| $f_{110}$ | 949 | 33625 | 1.2e5 | 5.6e5 | 5.9e5 | 6.0e5 | 6.1e5 | 15/15 |
| | 0.84(0.3) | 6.1(8) | 4.5(6) | 2.4(3) | 7.5(8) | ∞ | *∞2.7e5* | 0/15 |
| $f_{111}$ | 6856 | 6.1e5 | 8.8e6 | 2.3e7 | 2.3e7 | 3.1e7 | 3.1e7 | 3/15 |
| | 1.5(1) | 0.85(1) | 0.44(0.5) | 0.17(0.2) | 0.17(0.2) | ∞ | *∞2.6e5* | 0/15 |
| $f_{112}$ | 107 | 1684 | 3421 | 4162 | 4502 | 5132 | 5596 | 15/15 |
| | 6.1(3) | 62(90) | 88(114) | 453(539) | 896(1039) | ∞ | *∞2.7e5* | 0/15 |
| $f_{113}$ | 133 | 1883 | 8081 | 24021 | 24128 | 24128 | 24402 | 15/15 |
| | 10(2) | 36(55) | 62(70) | 82(89) | 167(169) | 167(180) | 165(181) | 1/15 |
| $f_{114}$ | 767 | 14720 | 56311 | 78890 | 83272 | 83272 | 84949 | 15/15 |
| | 2.1(4) | 5.3(9) | 22(24) | 24(26) | 47(54) | 47(52) | 46(56) | 1/15 |
| $f_{115}$ | 64 | 485 | 1829 | 2274 | 2550 | 2550 | 2970 | 15/15 |
| | 3.2(2) | 63(49) | 154(228) | 557(658) | ∞ | ∞ | *∞2.6e5* | 0/15 |
| $f_{116}$ | 5730 | 14472 | 22311 | 26243 | 26868 | 30329 | 31661 | 15/15 |
| | 24(33) | 89(95) | ∞ | ∞ | ∞ | ∞ | *∞2.6e5* | 0/15 |
| $f_{117}$ | 26686 | 76052 | 1.1e5 | 1.3e5 | 1.4e5 | 1.7e5 | 1.9e5 | 15/15 |
| | 3.9(6) | 24(27) | ∞ | ∞ | ∞ | ∞ | *∞2.6e5* | 0/15 |
| $f_{118}$ | 429 | 1217 | 1555 | 1774 | 1998 | 2430 | 2913 | 15/15 |
| | 192(322) | 255(317) | 756(849) | ∞ | ∞ | ∞ | *∞2.7e5* | 0/15 |
| $f_{119}$ | 12 | 657 | 1136 | 2363 | 10372 | 35296 | 49747 | 15/15 |
| | 0.81(0.8) | 1.9(0.9) | 1.9(0.8) | 4.2(7) | 16(25) | ∞ | *∞2.7e5* | 0/15 |
| $f_{120}$ | 16 | 2900 | 18698 | 34491 | 72438 | 3.3e5 | 5.5e5 | 15/15 |
| | 0.72(0.9) | 4.6(8) | 7.2(9) | 14(14) | ∞ | ∞ | *∞2.6e5* | 0/15 |
| $f_{121}$ | 8.6 | 111 | 273 | 533 | 1583 | 3870 | 6195 | 15/15 |
| | 0.89(0.9) | 2.4(3) | 2.9(2) | 3.0(1) | 12(10) | ∞ | *∞2.7e5* | 0/15 |
| $f_{122}$ | 10 | 1727 | 9190 | 21579 | 30087 | 53743 | 1.1e5 | 15/15 |
| | 1.1(1) | 1.6(0.8) | 1.9(2) | 7.1(9) | 29(34) | 73(78) | 35(39) | 0/15 |
| $f_{123}$ | 11 | 16066 | 81505 | 2.3e5 | 3.4e5 | 6.7e5 | 2.2e6 | 15/15 |
| | 0.75(0.6) | 5.2(8) | ∞ | ∞ | ∞ | ∞ | *∞2.7e5* | 0/15 |
| $f_{124}$ | 10 | 202 | 1040 | 8974 | 20478 | 45337 | 95200 | 15/15 |
| | 1.1(1) | 2.6(1) | 34(19) | 18(27) | 17(20) | 46(54) | *∞2.6e5* | 0/15 |
| $f_{125}$ | 1 | 1 | 1 | 1.3e5 | 2.4e5 | 2.4e5 | 2.5e5 | 15/15 |
| | 1 | 19(21) | 694(412) | **0.07**(0.1)$^{\downarrow 3}$ | 18(19) | ∞ | *∞2.7e5* | 0/15 |
| $f_{126}$ | 1 | 1 | 1 | 8.8e5 | ∞ | ∞ | ∞ | 0 |
| | 1.1 | 19(18) | 1237(1570) | 0.30(0.4) | ∞ | ∞ | ∞ | 0/15 |
| $f_{127}$ | 1 | 1 | 1 | 1.3e5 | 3.4e5 | 3.9e5 | 4.0e5 | 15/15 |
| | 1 | 15(19) | 566(314) | 0.36(0.2) | 5.8(6) | 11(12) | *∞2.7e5* | 0/15 |
| $f_{128}$ | 111 | 4248 | 7808 | 10500 | 12447 | 17217 | 21162 | 15/15 |
| | 0.70(1) | 18(33) | 17(27) | 18(27) | 18(22) | 14(20) | 17(19) | 7/15 |
| $f_{129}$ | 64 | 10710 | 59443 | 2.3e5 | 2.8e5 | 5.1e5 | 5.8e5 | 15/15 |
| | 2.4(3) | 9.0(12) | 8.7(11) | 2.7(3) | 2.3(3) | 1.5(2) | 2.4(2) | 2/15 |
| $f_{130}$ | 55 | 812 | 3034 | 8198 | 32823 | 33889 | 34528 | 10/15 |
| | 1.4(1) | 72(160) | 40(52) | 15(21) | 3.7(5) | 3.7(5) | 5.2(7) | 10/15 |

20-D

| $\Delta f$ | 1e+1 | 1e+0 | 1e-1 | 1e-2 | 1e-3 | 1e-5 | 1e-7 | #succ |
|---|---|---|---|---|---|---|---|---|
| $f_{101}$ | 59 | 425 | 571 | 677 | 700 | 739 | 783 | 15/15 |
| | 24(5) | 6.8(1) | 8.0(1) | 10(1) | 14(2) | 24(7) | 45(31) | 15/15 |
| $f_{102}$ | 231 | 399 | 579 | 755 | 921 | 1157 | 1407 | 15/15 |
| | 6.0(1) | 7.1(2) | 7.7(1) | 8.4(1) | 10(3) | 15(9) | 26(30) | 15/15 |
| $f_{103}$ | 65 | 417 | 629 | 1043 | 1313 | 1893 | 2464 | 14/15 |
| | 20(5) | 6.5(1) | 7.1(1) | 6.4(1) | 7.2(1) | 10(3) | 13(5) | 15/15 |
| $f_{104}$ | 23690 | 85656 | 1.7e5 | 1.8e5 | 1.8e5 | 1.9e5 | 2.0e5 | 15/15 |
| | 83(90) | 75(84) | 59(66) | 116(132) | ∞ | ∞ | *∞1.3e6* | 0/15 |
| $f_{105}$ | 1.9e5 | 6.1e5 | 6.3e5 | 6.4e5 | 6.5e5 | 6.6e5 | 6.7e5 | 15/15 |
| | 6.0(9) | 3.7(5) | 8.9(10) | ∞ | ∞ | ∞ | *∞1.1e6* | 0/15 |
| $f_{106}$ | 11480 | 21668 | 23746 | 24788 | 25470 | 26492 | 27360 | 15/15 |
| | 45(49) | 54(66) | 229(248) | ∞ | ∞ | ∞ | *∞1.2e6* | 0/15 |
| $f_{107}$ | 8571 | 13582 | 16226 | 21100 | 27357 | 52486 | 65052 | 15/15 |
| | 1.6(1) | 1.7(0.7) | 2.1(0.8) | 2.3(0.6) | 2.8(1) | 4.8(3) | 11(10) | 10/15 |
| $f_{108}$ | 58063 | 97228 | 2.0e5 | 4.0e5 | 4.5e5 | 6.3e5 | 9.0e5 | 15/15 |
| | ∞ | ∞ | ∞ | ∞ | ∞ | ∞ | *∞1.1e6* | 0/15 |
| $f_{109}$ | 333 | 632 | 1138 | 1679 | 2287 | 3583 | 4952 | 15/15 |
| | 4.3(0.8) | 4.9(1.0) | 5.5(1) | 7.5(3) | 19(19) | 149(186) | 1109(1100) | 1/15 |
| $f_{110}$ | ∞ | ∞ | ∞ | ∞ | ∞ | ∞ | ∞ | 0 |
| | ∞ | ∞ | ∞ | ∞ | ∞ | ∞ | ∞ | 0/15 |
| $f_{111}$ | ∞ | ∞ | ∞ | ∞ | ∞ | ∞ | ∞ | 0 |
| | ∞ | ∞ | ∞ | ∞ | ∞ | ∞ | ∞ | 0/15 |
| $f_{112}$ | 25552 | 64124 | 69621 | 72175 | 73557 | 76137 | 78238 | 15/15 |
| | 30(24) | 37(38) | 296(342) | ∞ | ∞ | ∞ | *∞1.3e6* | 0/15 |
| $f_{113}$ | 50123 | 3.6e5 | 5.6e5 | 5.9e5 | 5.9e5 | 5.9e5 | 5.9e5 | 15/15 |
| | 2.5(3) | ∞ | ∞ | ∞ | ∞ | ∞ | *∞1.1e6* | 0/15 |
| $f_{114}$ | 2.1e5 | 1.1e6 | 1.4e6 | 1.6e6 | 1.6e6 | 1.6e6 | 1.6e6 | 15/15 |
| | ∞ | ∞ | ∞ | ∞ | ∞ | ∞ | *∞1.1e6* | 0/15 |
| $f_{115}$ | 2405 | 30268 | 91749 | 1.3e5 | 1.3e5 | 1.3e5 | 1.3e5 | 15/15 |
| | 615(837) | ∞ | ∞ | ∞ | ∞ | ∞ | *∞1.1e6* | 0/15 |
| $f_{116}$ | 5.0e5 | 6.9e5 | 8.9e5 | 1.0e6 | 1.0e6 | 1.1e6 | 1.1e6 | 15/15 |
| | ∞ | ∞ | ∞ | ∞ | ∞ | ∞ | *∞1.1e6* | 0/15 |
| $f_{117}$ | 1.8e6 | 2.5e6 | 2.6e6 | 2.8e6 | 2.9e6 | 3.2e6 | 3.6e6 | 15/15 |
| | ∞ | ∞ | ∞ | ∞ | ∞ | ∞ | *∞1.1e6* | 0/15 |
| $f_{118}$ | 6908 | 11786 | 17514 | 22206 | 26342 | 30062 | 32659 | 15/15 |
| | 441(404) | ∞ | ∞ | ∞ | ∞ | ∞ | *∞1.3e6* | 0/15 |
| $f_{119}$ | 2771 | 29365 | 35930 | 63288 | 4.1e5 | 1.4e6 | 1.9e6 | 15/15 |
| | 1.5(1) | 1.5(0.5) | 1.6(0.5) | 21(24) | ∞ | ∞ | *∞1.1e6* | 0/15 |
| $f_{120}$ | 36040 | 1.8e5 | 2.8e5 | 8.5e5 | 1.6e6 | 6.7e6 | 1.4e7 | 13/15 |
| | 6.0(14) | ∞ | ∞ | ∞ | ∞ | ∞ | *∞1.1e6* | 0/15 |
| $f_{121}$ | 249 | 769 | 1426 | 3433 | 9304 | 34434 | 57404 | 15/15 |
| | 3.4(1) | 4.8(1) | 5.5(2) | 15(9) | ∞ | ∞ | *∞1.1e6* | 0/15 |
| $f_{122}$ | 692 | 52008 | 1.4e5 | 3.8e5 | 7.9e5 | 2.0e6 | 5.8e6 | 15/15 |
| | 0.51(0.3) | 18(21) | ∞ | ∞ | ∞ | ∞ | *∞1.1e6* | 0/15 |
| $f_{123}$ | 1063 | 5.3e5 | 1.5e6 | 3.3e6 | 5.3e6 | 2.7e7 | 1.6e8 | 0 |
| | 0.81(2) | ∞ | ∞ | ∞ | ∞ | ∞ | *∞1.1e6* | 0/15 |
| $f_{124}$ | 192 | 1959 | 40840 | 64491 | 1.3e5 | 3.9e5 | 8.0e5 | 15/15 |
| | 1.1(0.8) | 3.4(2) | 14(25) | 92(103) | ∞ | ∞ | *∞1.1e6* | 0/15 |
| $f_{125}$ | 1 | 1 | 1 | 1.2e7 | 2.5e7 | 8.0e7 | 8.1e7 | 4/15 |
| | 1 | 201(6) | 1424(1138) | ∞ | ∞ | ∞ | *∞1.1e6* | 0/15 |
| $f_{126}$ | 1 | 1 | 1 | ∞ | ∞ | ∞ | ∞ | 0 |
| | 1 | 194(40) | 2298(1754) | ∞ | ∞ | ∞ | ∞ | 0/15 |
| $f_{127}$ | 1 | 1 | 1 | 1.6e6 | 4.4e6 | 7.3e6 | 7.4e6 | 15/15 |
| | 1 | 200(29) | 1048(915) | 5.9(5) | ∞ | ∞ | *∞1.1e6* | 0/15 |
| $f_{128}$ | 1.4e5 | 1.3e7 | 1.7e7 | 1.7e7 | 1.7e7 | 1.7e7 | 1.7e7 | 9/15 |
| | 30(32) | 0.31(0.3) | 0.24(0.2) | 0.24(0.3) | 0.25(0.2) | 0.26(0.2) | 0.53(0.6) | 2/15 |
| $f_{129}$ | 7.8e6 | 4.1e7 | 4.2e7 | 4.2e7 | 4.2e7 | 4.2e7 | 4.2e7 | 5/15 |
| | ∞ | ∞ | ∞ | ∞ | ∞ | ∞ | *∞1.1e6* | 0/15 |
| $f_{130}$ | 4904 | 93149 | 2.5e5 | 2.5e5 | 2.5e5 | 2.6e5 | 2.6e5 | 7/15 |
| | 54(103) | 22(28) | 8.2(10) | 10(12) | 10(11) | 10(13) | 14(14) | 4/15 |

Table 2: Expected running time (ERT in number of function evaluations) divided by the best ERT measured during BBOB-2009 (given in the respective first row) for different $\Delta f$ values for functions $f_1$–$f_{24}$. The median number of conducted function evaluations is additionally given in *italics*, if $\mathrm{ERT}(10^{-7}) = \infty$. #succ is the number of trials that reached the final target $f_{\mathrm{opt}} + 10^{-8}$.

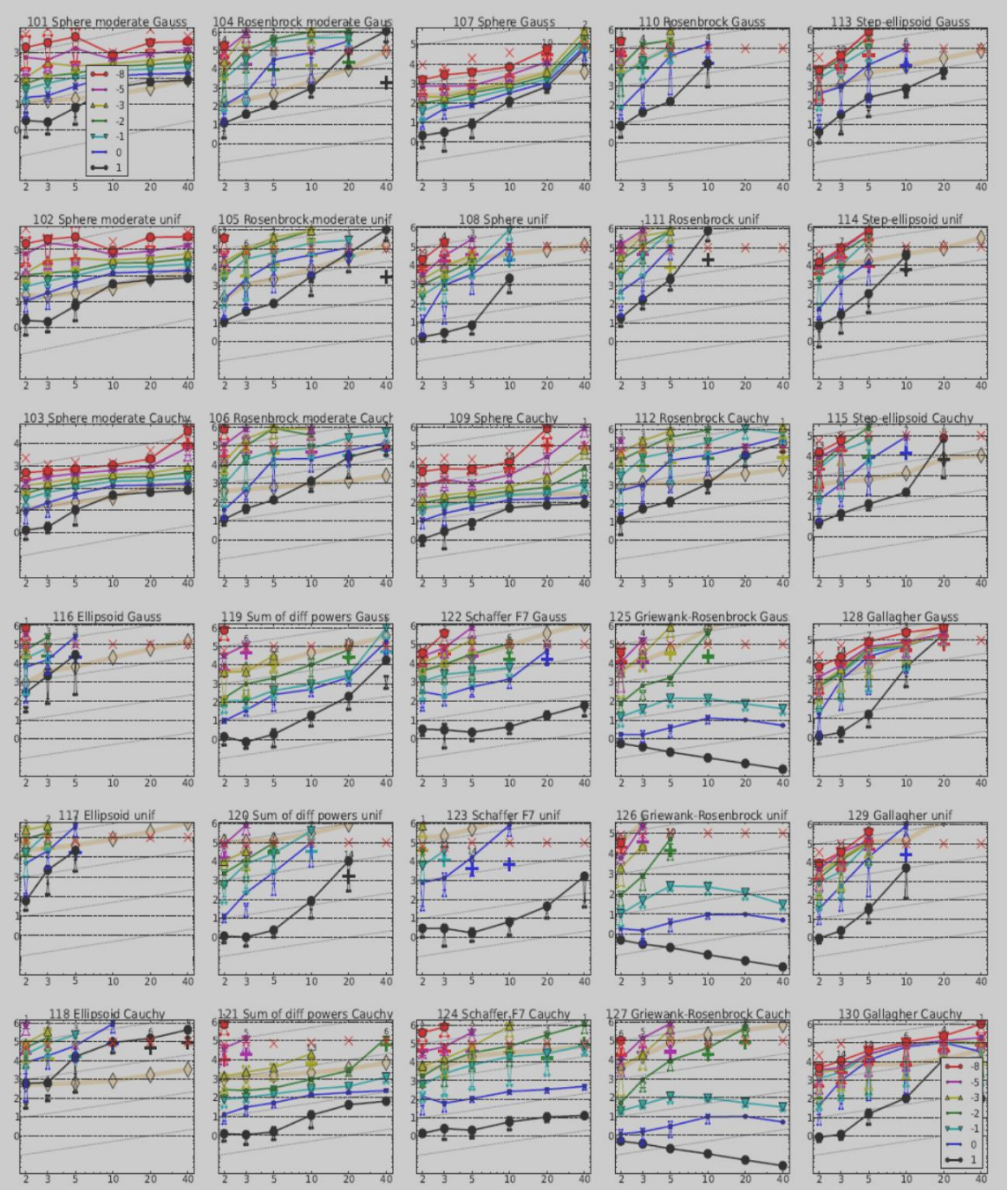


Figure 2: Expected number of the *f*-evaluations (EST, lines) to reach $f_{\mathrm{opt}} + \Delta f$; median number of *f*-evaluations (+) to reach the most difficult target that was reached not always but at least once; maximum number of *f*-evaluations in any trial (×); interquartile range with median (notched boxes) of simulated runlengths to reach $f_{\mathrm{opt}} + \Delta f$; all values are divided by dimension and plotted as $\log_{10}$ values verus dimension. Shown are $\Delta f = 10^{\{1,0,-1,-2,-3,-5,-8\}}$. Numbers above ERT-symbols (if appearing) indicate the number of trials reaching the respective target. The light thick line with diamonds indicates the rspective best result from BBOB-2009 for $\Delta f = 10^{-8}$. Horizontal lines mean linear scaling, slanted grid lines depict quadratic scaling.

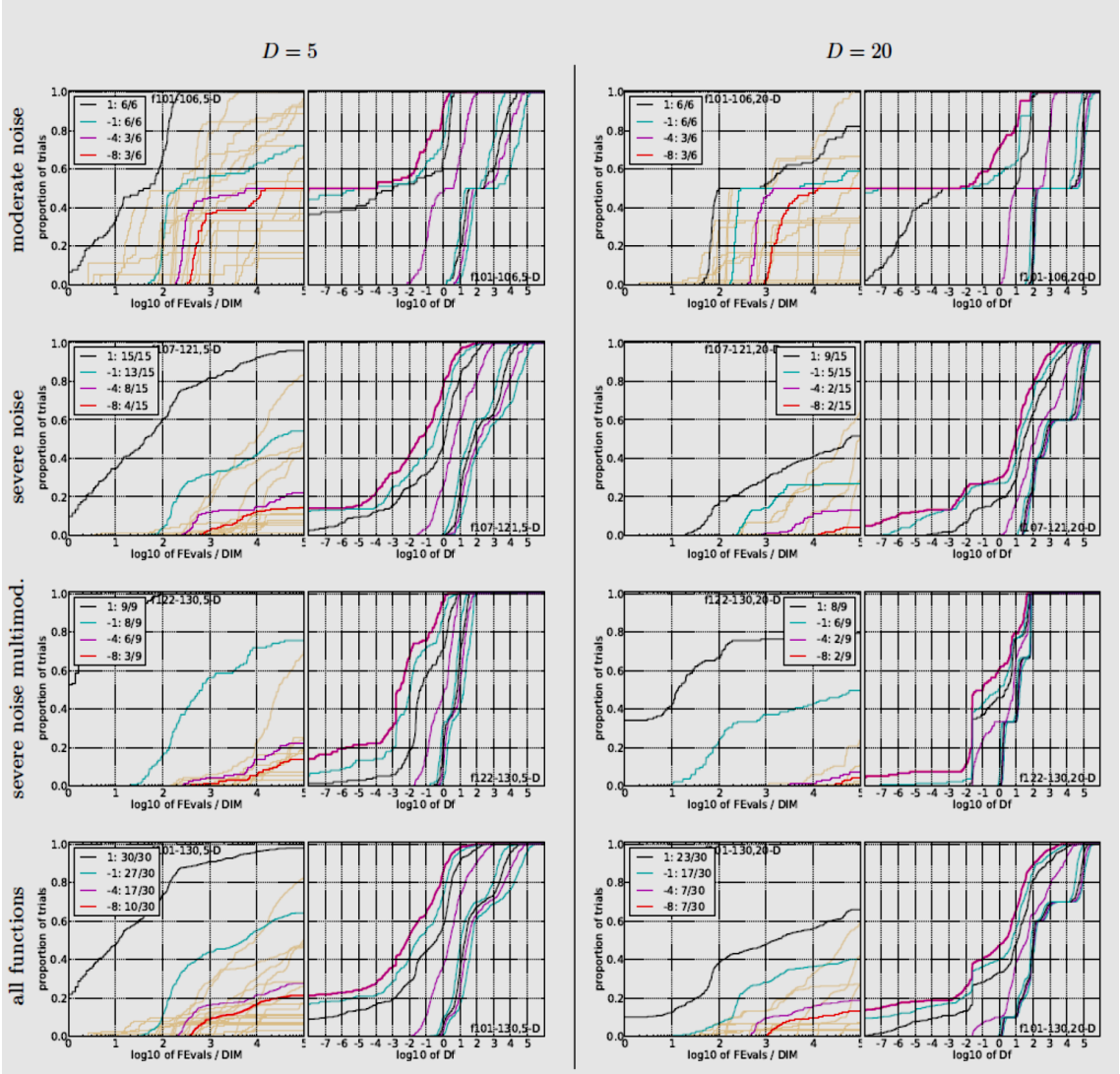


Figure 3: Empirical cumulative distribution functions (ECDFs), plotting the fraction of trials versus running time (left subplots) or versus $\Delta f$ (right subplots). The thick red line represents the best achieved results. Left subplots: ECDF of the running time (number of function evaluations), divided by search space dimension $D$, to fall below $f_{\text{opt}} + \Delta f$ with $\Delta f = 10^k$, where $k$ is the first value in the legend. Right subplots: ECDF of the best achieved $\Delta f$ divided by $10^k$ (upper left lines in continuation of the left subplot), and best achieved $\Delta f$ divided by $10^{-8}$ for running times of $D, 10\,D, 100\,D$ ... function evaluations (from right to left cycling black-cyan-magenta). The legends indicate the number of functions that were solved in at least one trial. FEvals denotes number of function evaluations, $D$ and DIM denote search space dimension, and $\Delta f$ and Df denote the difference to the optimal function value. Light brown lines in the background show ECDFs for target value $10^{-8}$ of all algorithms benchmarked during BBOB-2009.

### 3.1 The COCO Framework

Numerical experiment of PRCGA was carried out on a testbed consisting of 30 noisy test functions [8, 13]. These functions are carefully designed to reflect the difficulties inherent in real-world application problems. The functions are categorized as functions with moderate noise, function with severe noise and highly multimodal functions with severe noise. All the functions are scalable with the dimension $D$ ranging from 2 to 40 and their search domain is $[-5,5]^D$.

A successful run for an algorithm is achieved if the best solution found satisfy $f_t = f_{opt} + \Delta f_t$ , where $f_{opt}$ is the optimal function value, $\Delta f_t$ is the precision to reach and $\Delta f_t \in [10^{-8}, 10^2]$. If an algorithm solves a function to the desired precision value of $10^{-8}$, then it has found the optimum and it has also solved the different optimization problems on the way to the optimum. If on the other hand it cannot reach the optimum, it would have solved the function partially.

### 3.2 Parameter Settings

The parameters used for PRCGA are shown in Table 1.

## 4.0 CPU TIMING EXPERIMENTS

The CPU timing experiment conducted for PRCGA used the same independent restart strategies on the function $f_8$ for a duration of 30 seconds on an Intel(R) Core(TM) $i7-2600$ CPU processor, running at 3.40 GHz under a 64 -bit Microsoft Windows 7 Enterprise N with 4.00GB RAM and Matlab $7.10(R2010a)$.

The time per function evaluation was $5.2, 5.4, 5.3, 6.0, 8.3 \text{times} 10^{-5} \text{and} 1.3 \text{times} 10^{-4}$seconds for PRCGA in dimensions $2, 3, 5, 10, 20$ and 40 respectively.

## 5.0 RESULTS

The results of PRCGA from experiments carried out according to [9] on the benchmark functions given in [8,12] are presented in Figures 2, 3 and 4 and in Tables 2, and 3.

Figures 2 shows the performance of PRCGA on all the noisy benchmark functions with dimensions $2, 3, 5, 10, 20 \text{and} 40$. The performance of PRCGA on the noisy benchmarks is not too impressive.

PRCGA was able to solve problems $f_{101}, f_{102}, f_{103}$ and $f_{130}$ up to dimension 40 with the desired accuracy of $10^{-8}$. In dimension 20 it was able to solve problems $f_{107}, f_{109}$ and $f_{128}$ while it solved problems $f_{113}, f_{114}$ and $f_{129}$ in dimension 5.

PRCGA succeeded in solving more than half of the test problems with the precision of $10^{-2}$. It also performed better than the RCGA in [19] in test problems $f_{108}, f_{114}, f_{122}$ and $f_{124}$ but generally the RCGA in [19] solved more test problems at the required level of accuracy than PRCGA.

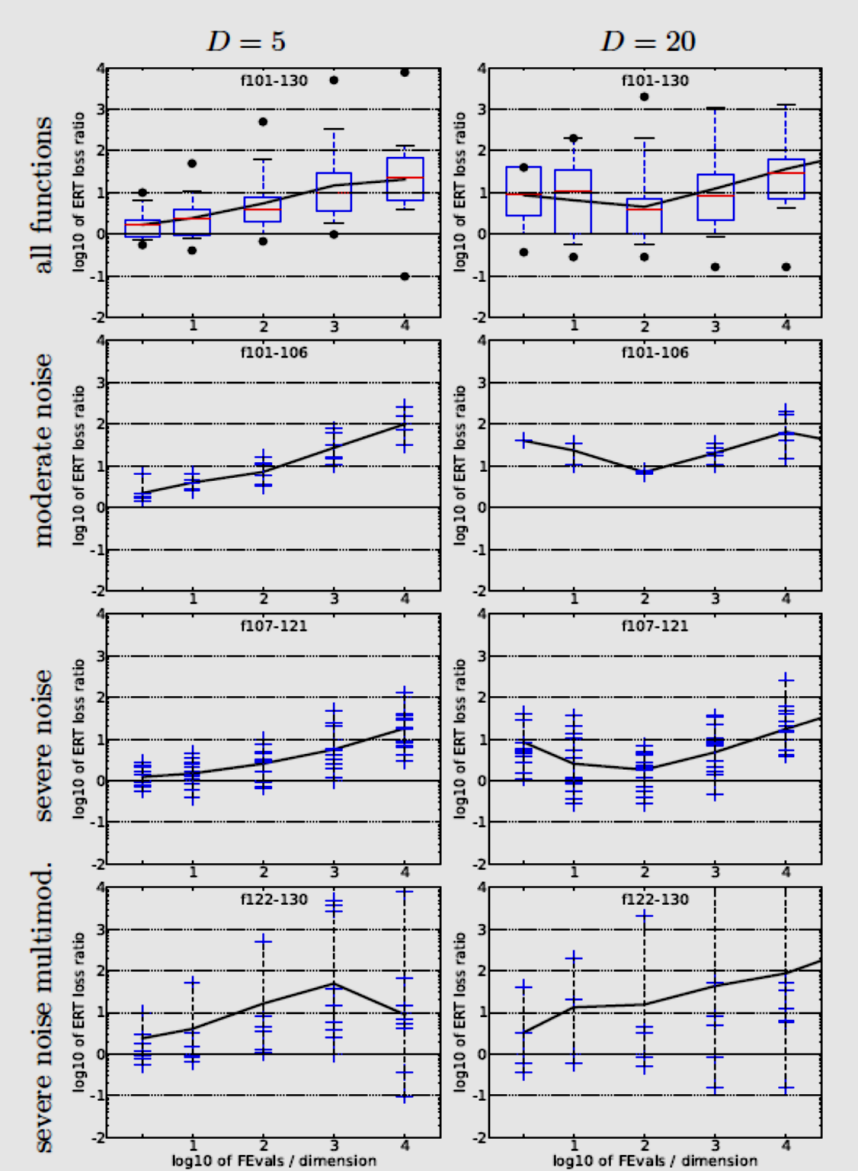


Figure 4: ERT loss ratio vs. a given budget FEvals.

Each cross (+) represents a single function. The target value $f_t$ used for a given FEvals is the smallest (best) recorded function value such that ERT($f_t$) ≤ FEvals for the presented algorithm. Shown is FEvals divided by the respective best ERT($f_t$) from BBOB- -2009 for functions $f_{101}-f_{130}$ in 5-D and 20-D. Line: geometric mean. Box-Whisker error bar: 25-75%-ile with median (box), 10-90%-ile (caps), and minimum and maximum ERT loss ratio (points). The vertical line gives the maximal number of function evaluations in a single trial in this function subset.

**Table 3: ERT loss ratio compared to the respective best result from BBOB-2009 for budgets given in the first column (see also Figure 3).**

| | $f101$–$f130$ in 5-D, maxFE/D=100012 | | | | | |
|---|---|---|---|---|---|---|
| #FEs/D | best | 10% | 25% | med | 75% | 90% |
| 2 | 0.55 | 0.73 | 0.89 | 1.6 | 2.3 | 8.1 |
| 10 | 0.41 | 0.73 | 0.96 | 2.3 | 3.8 | 28 |
| 100 | 0.68 | 0.97 | 1.7 | 4.1 | 7.8 | 2.6e2 |
| 1e3 | 0.99 | 1.6 | 3.3 | 9.6 | 32 | 1.4e3 |
| 1e4 | 0.10 | 3.6 | 6.6 | 24 | 72 | 1.4e2 |
| 1e5 | 0.30 | 1.9 | 12 | 21 | 1.5e2 | 3.3e2 |
| $RL_{US}/D$ | 5e4 | 5e4 | 5e4 | 5e4 | 6e4 | 7e4 |
| | $f101$–$f130$ in 20-D, maxFE/D=100007 | | | | | |
| #FEs/D | best | 10% | 25% | med | 75% | 90% |
| 2 | 0.37 | 1.0 | 2.7 | 9.1 | 40 | 40 |
| 10 | 0.28 | 0.58 | 1.0 | 10 | 34 | 2.0e2 |
| 100 | 0.28 | 0.54 | 1.0 | 3.8 | 6.8 | 1.0e3 |
| 1e3 | 0.16 | 0.83 | 2.1 | 8.5 | 27 | 5.1e3 |
| 1e4 | 0.16 | 4.1 | 6.1 | 30 | 60 | 5.2e3 |
| 1e5 | 3.3 | 14 | 23 | 43 | 90 | 6.9e3 |
| 1e6 | 0.53 | 14 | 31 | 1.6e2 | 5.9e2 | 3.2e3 |
| $RL_{US}/D$ | 5e4 | 5e4 | 5e4 | 5e4 | 8e4 | 1e5 |

The last row $RL_{US}/D$ gives the number of function evaluations in unsuccessful runs divided by dimension. Shown are the smallest, 10%-ile, 25%-ile, 50%-ile, 75%-ile and 90%-ile value (smaller values are better). The ERT Loss ratio equals to one for the respective best algorithm from BBOB-2009. Typical median values are between ten and hundred.

## 6.0 CONCLUSION

The performances of RCGAs on noisy black-box optimization testbed have been average, despite the fact that RCGAs are robust solvers and have been used to solve a wide variety of real-world application problems. The benchmarking of RCGAs on noisy BBOB testbed shows that RCGAs are weak in solving a range of noisy problems and that there are potentials for improving the performances of RCGAs through hybridization.

Currently, the authors are examining ways of improving RCGAs by using different hybridization schemes to hybridize RCGAs with efficient local optimizers .

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