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A Rule-Based System for Determining Intelligence Quotient of Children

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Abstract: **Intelligence Quotient (IQ) has been the principal predictor of academic achievement in schooling. IQ is usually determined by using questions. Humans employed to administer questions sometimes tend to be bias. This paper presents a novel way of determining the IQ of a child through the administration of questions by employing rule-based systems complemented with multiple regression technique. Questions are divided into four sections, namely, word comprehension, logical reasoning, mathematics skills and picture analysis. The timing of each question is based on child's age and the number of characters in the question through multiple regression analysis whilst the determination of the IQ is done by the expert system. The system is robust and free of bias. It ensures that self-motivation and persistent qualities are achieved.**

Keywords: **Children, Expert System, Fuzzy logic, IQ, Intelligence Quotient, Rule-based, Regression Model.**

I. INTRODUCTION

Intelligence Quotient (IQ) has been the predominant method for determining the level of intelligence of a person. It is a measure of a relative intelligence determined by a standardized test developed to measure a person cognitive ability [1], [2]. It helps parent to know the type of program their child should take in school. It also helps parent to know what their children are capable of becoming in future and what the child can do. It also helps to determine whether children are sufficiently intelligent to benefit from schooling. The results also help to identify strengths and weaknesses in children's learning styles. IQ covers logical reasoning, word comprehension and math skills and it is obtained as the numeric expression of intellectual capacity by multiplying the metal age of the subject, ascertained by testing and dividing the result by the chronological age [3], [4]. People with higher IQ can think in abstracts and make connections by making generalizations easier [5]. IQ testing helps to introduced into applications of assessing potential employees at job interviews.

Many attempts have been employed to determine the IQ of a child in modern times. The first scientist to test mental ability was Alfred Binet, a French psychologist who devised an intelligence test for children in 1905, based on the idea that intelligence could be expressed in terms of age [4] Binet created the concept of "mental age," according to which the test performance of a child of average intelligence would match his or her age, while a gifted child's performance would be on par with that of an older child, and slow learner ability would be equal to those of a younger child. Binet's test was introduced to the United States in a modified form in 1916 by Lewis Terman [6]. The scoring system of the new test, devised by German psychologist William Stern, consisted of dividing a child's mental age by his or her chronological age and multiplying the quotient by 100 to arrive at an "intelligence quotient" [7]. The Wechsler Intelligence Scales, developed in 1949 by David Wechsler, addressed an issue that still provokes criticism of IQ tests today: the fact that there are different types of intelligence. The Wechsler scales replaced the single mental-age score with a verbal scale and a performance scale for nonverbal skills to address each test taker's individual combination of strengths and weaknesses. The Stanford-Binet and Wechsler tests (in updated versions) remain the most widely administered IQ tests. Average performance at each age level is still assigned a score of 100, but today's scores are calculated solely by comparison with the performance of others in the same age group rather than test takers of various ages [8], [9].

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Since humans are employed to administer the questions favouritism usually occurs. This paper presents a novel way of determining the IQ of a child through the administration of questions by employing rule-based expert systems. Expert system is a term that describes a computer program or applications that uses artificial intelligent techniques to solve problems that ordinary requires a knowledgeable human or that simulates the judgment and behaviour of a human or an organization that has expert knowledge and experience in a particular field to reduce erratic human influence which makes or evaluates decisions based on established rules within the software which provide effective support to users. Expert systems are built on knowledge gathered from human experts, analogous to a database but containing rules that may be applied to solving a specific problem. [10], [11]. The expert system consists of two major components: knowledge base and inference engine. The knowledge base contains the domain knowledge which is used by the inference engine to draw conclusions. The inference engine is the generic control mechanism that applies the axiomatic knowledge to the task-specific data to arrive at some conclusion [12]. A typical type of an expert system is the classical rule-based system. In the rule-based systems, knowledge is represented in the form of production rules. A rule describes the action that should be taken if a symptom is observed. The empirical association between premises and conclusions in the knowledge base is their main characteristic. These associations describe cause-effect relationships to determine logical event chains that were used to represent the propagation of complex phenomena. The figure below shows the architecture of an expert system

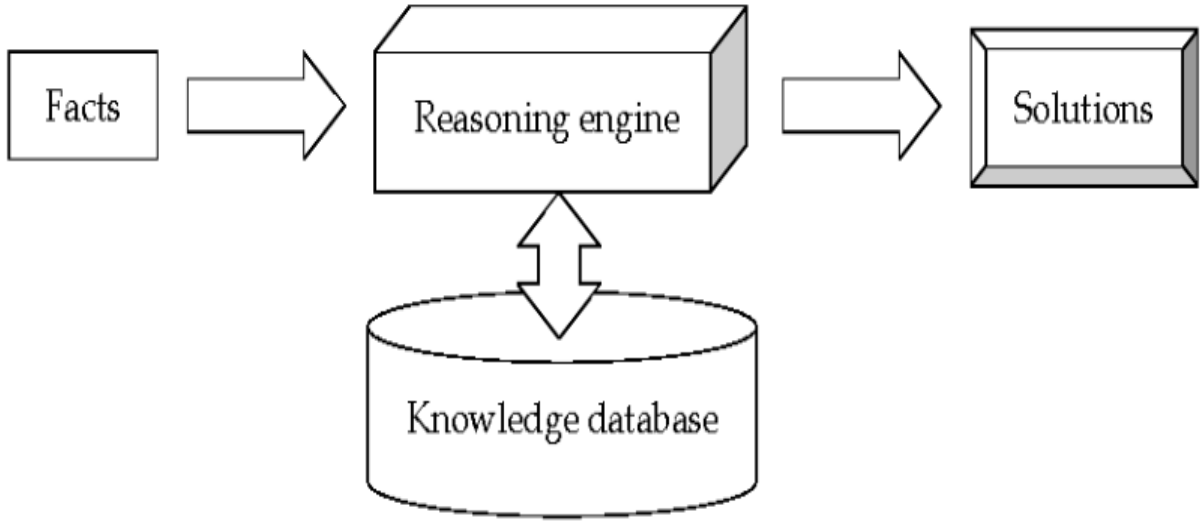

Fig 1: Architecture of an Expert System

II. SYSTEM ARCHITECTURE AND DESIGN

The system is developed to instil persistent attribute in children. Questions used in the IQ determination are grouped into four categories: Logical, mathematics, verbal and picture. Logical questions are employed to determine the abstract thinking capabilities of children. Mathematic questions are employed to determine the analytical skills of children. Verbal questions are employed to determine the interpersonal skills of children. Picture questions are employed in which children are made to identify unique features or identify certain objects in images. These questions measure persistent level of children. Images are made dynamic when displayed. With the constant changing and shifting or objects, children's self-motivation to persist in searching for objects is tested.

The system is divided into three components, namely, interface, rule-based and repository.

- **Interface Component**: Is responsible for presentation and liaise between the user and the system.
- **Rule-based Component**: It consists of formatting manager, inference engine and shuffle manager. Formatting manager acts as an interface between the interface component and the rule-based system. Shuffle manager handles connections between the user and the database making sure that the same questions are not issued at the same time.
- **Repository Component**: It handles the data used by the system which is periodically updated by the administrator. Fig. 2 below shows the architecture of the system.

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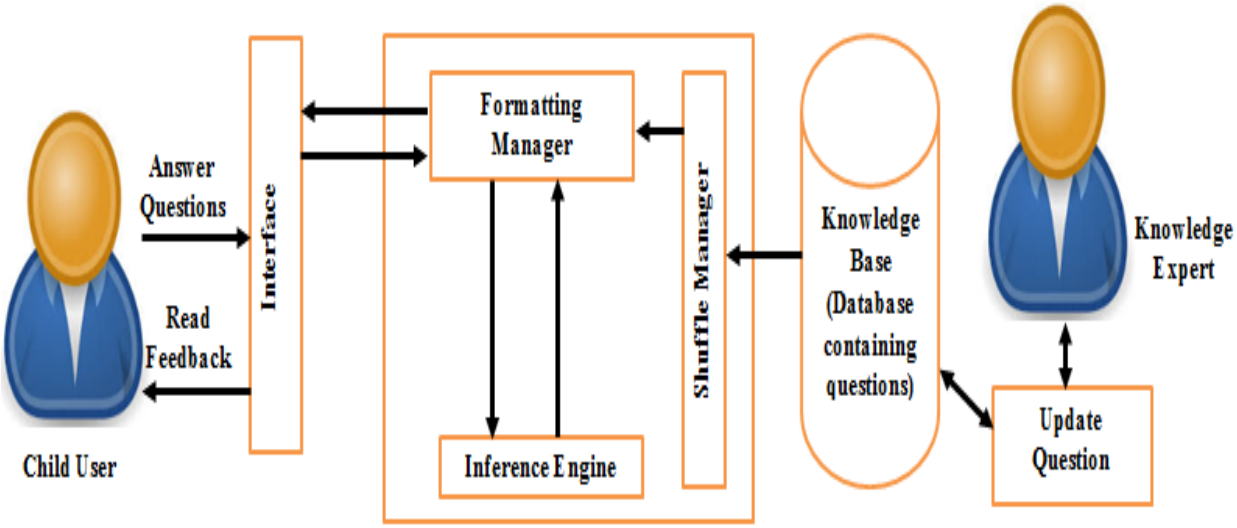

Fig 2: Architecture of the System

III. INTELLIGENCE QUOTIENT DETERMINATION

To determine the intelligence quotient of a child, the child has to pass through certain processes. These processes ensure that the child takes the appropriate set of questions and also the formula used in this work is apply to the score obtained to determine the IQ

A. IQ Determination Process:

The child logs into the system and he is presented with the set of questions. All questions are answered at the time of participation so that his IQ can be determined. However, in the occurrence of any unbearable circumstances, the questions answered whether correct or wrong are being tracked so that next time the child logs into the system, those questions are not used in his reassessment. Children using the system at the same time have different set of question. Given that each section has N questions and children are to answer five questions in each section. The number of children that the system can accommodate at any time is N/5. The questions are all multiple choice. Each child solves twenty questions. The time in seconds used to solve each question is recorded and the total number of questions answered correctly is also recorded. The logic behind the implementation is illustrated below:

Begin

1.0 If child is a new user, then register otherwise child logs in by providing credentials

2.0 If login is successful

- 2.1 Retrieve child's age
- 2.2 Retrieve questions from database based on age group
  - 2.2.1 Take Logical questions first
  - 2.2.2 When completed, take Maths questions
  - 2.2.3 When completed, take Verbal questions
  - 2.2.4 When completed, take Picture questions
- 2.3 Compute results and interpret them
- 2.4 Display results

3.0 Otherwise go to step 1.0

End

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B. IQ Determination Formula:

Unlike the usual formula for calculating the intelligence quotient of a child which is the mental age divided by the child chronological age multiplied by 100, where mental age is the total number of test score and chronological age is the age of the person measured in years, month or days, this work uses different approach. This work uses the questions and the time spent in answering the questions to determine the IQ. The questions are based on the age of the child and thus the age factor is implicitly taken care off.

Each question is timed. Let the time for each question in seconds be t_i. The average time for the total number of questions, N is

$$T = \frac{\sum_{i=1}^{N} t_i}{N}$$

The child spends some time answering each question. The time spent on each question is recorded. Let the time spent by the child on each question be t_{ci}, then the average time used by the child in answering the N questions is

$$T_c = \frac{\sum_{i=1}^{N} t_{ci}}{N}.$$

Also, let S be the total number of questions answered correctly by the child.

Thus the IQ is computed as

$$IQ = \frac{S}{N} * \frac{T}{T_c} * 100\%$$

By substitution,

$$IQ = \frac{S}{N} * \frac{\sum_{i=1}^{N} t_i}{\sum_{i=1}^{N} t_{ci}} * 100\%$$

To ensure that IQ score is not more than 100%, Let $D = \frac{\sum_{i=1}^{N} t_i}{\sum_{i=1}^{N} t_{ci}}$ where D is the deviation of the time spent by the child.

The final IQ formula is

$$IQ = \frac{S * D}{N} * 100\% \quad such\ that \quad \forall D, \quad D \leq 1$$

Otherwise

$$IQ = \frac{S}{N} * 100\% \quad such\ that\ \forall D, \ D > 1$$

Base on the value of IQ computed above, the child intelligence quotient can be grouped into

- Above 90-100 – Genius or near Genius
- 80 – 90 Very superior
- 60 – 79 Superior
- 50 – 59 Normal
- Below 50 Deficiency

C. Timing the Questions:

In order to determine the time for each question, five hundred children between the ages of 5 and 10 inclusive were randomly selected. A regression analysis was used to determine the relationship between the number of characters and the age in years of a child.

Let x_1 represent the number of characters

x_2 represents age of the pupils

y represents the time of reading.

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The linear multiple regression required to determine the dependent variable, y, from the two independent variables, x_1 and x_2 is given as

$Y = a + b_1x_1 + b_2x_2$ ---------- (1)

Where a is the intercept, the b's are the slopes or coefficients of the variables. a is computed by using $\bar{Y} - b_1\bar{x}_1 - b_2\bar{x}_2$ given that $\bar{Y}$, $\bar{x}_1$and $\bar{x}_2$ are the mean values of Y, x_1 and x_2 respectively.

b_1 is computed by using $\left(\frac{r_{x_1x_2} - r_{x_2,y} * r_{x_1x_2}}{1-(r_{x_1x_2})^2}\right) * \left(\frac{SD_y}{SD_{x_1}}\right)$ such that $r_{p,q}$ is the correlation of p on q where p and q are the observations or variables under study and SD_K is the standard deviation of the variable k. The correlation $r_{p,q}$ is calculated by the formula $r_{p,q} = \frac{n\sum p*q - (\sum p)*(\sum q)}{\sqrt{n(\sum p^2)-(\sum p)^2} * \sqrt{n(\sum q^2)-(\sum q)^2}}$ whereas the SD_K is calculated by the formula $SD_K = \sqrt{\frac{(k_i-\bar{k})^2}{n-1}}$ such that $\bar{k}$ is the mean of the data described the variable k_i

Similarly, b_2 is computed by using $\left(\frac{r_{x_2,y} - r_{x_2,y} * r_{x_1x_2}}{1-(r_{x_1x_2})^2}\right) * \left(\frac{SD_y}{SD_{x_2}}\right)$

Table 1 below shows the summary of the data measured

TABLE 1: SUMMARY OF DATA COLLECTION

	Mean	**Standard Deviation**
Total number of characters (x_1)	29.188	14.840
Age of respondents (x_2)	7.750	1.918
Time users use to read a sentence (y)	4.281	2.727

Employing the above formulas found in Microsoft Excel, the relationship between the reading time (y), the age (x_2) and the total number of characters (x_1) is determined as $Y = 6.143 + 0.132X_1 - 0.737X_2$. Allowing 5 seconds to think about the question, the final equation is given by

$Y = 11.143 + 0.132X_1 - 0.737X_2$ ..... (2)

Thus consider as an example, if the total number of characters in question is 110 and a child of 8 years is to answer the question, the estimated time obtained from $Y = 11.143 + 0.132(110) - 0.737(8)$ is 19.767 seconds.

IV. SYSTEM TESTING AND CONCLUSION

A desktop system using Java Platform, Standard Edition (Java SE) was implemented to test the system. Below is a typical interface for question administration.

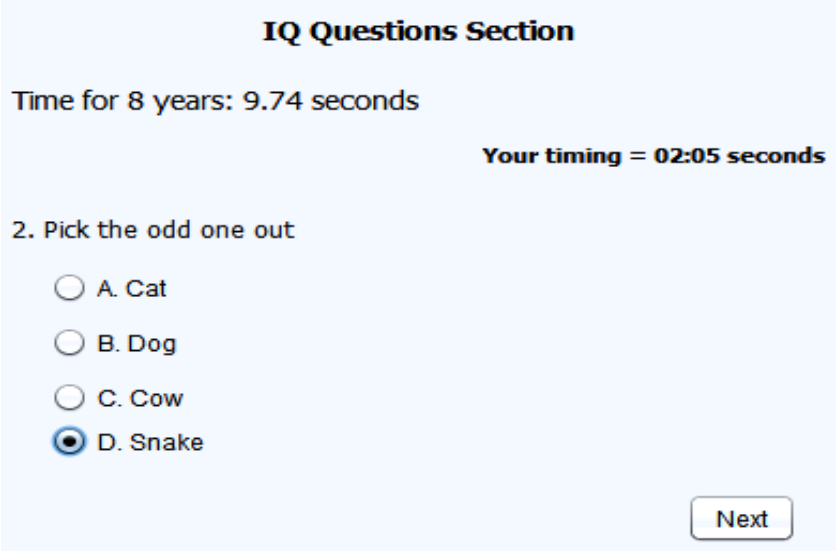

Fig 3: Sample IQ Question for 8-year old Child

From Fig 3 above, there is no back button. Users are not allowed to come back to already answered questions. Each category consists of five questions and they are mingled to avoid given clues to children. On completion of the 20th question, a different interface is displayed which contains the results and the interpretation. A typical result interface is displayed in Fig 4 below.

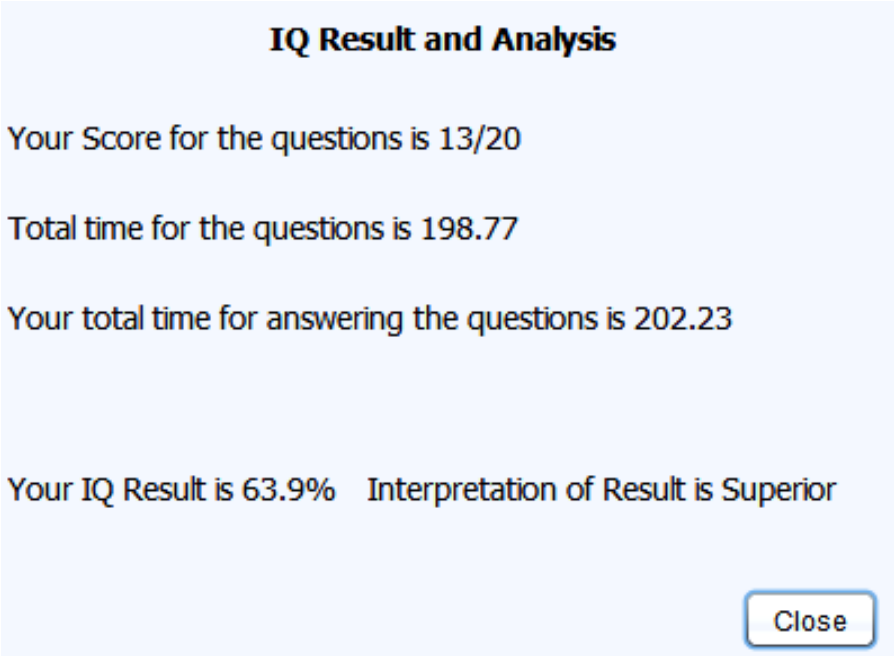

Fig 4: Sample IQ Determination and Analysis

In conclusion, a robust system for determining the IQ of children has been implemented using rule-based technique complemented with multiple linear regression method. The major strength of the system is the uniform timing of questions across the same age. However, the system can only serve a limited number of children at the same time. The major limitation of all IQ test is that it does not measure many of the qualities necessary for achievement in the world of work, such as persistence, creativity, self-confidence, motivation and interpersonal skills, or the ability to set priorities and to allocate one's time and effort efficiently. In addition, the creativity and intuition responsible for great achievements in both science and arts are not reflected by IQ tests.

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