CONFERENCE PROCEEDINGS

ARCEE

AFRICAN REGIONAL CONFERENCE ON ENGINEERING EDUCATION

AFRICAN REGIONAL CONFERENCE ON ENGINEERING EDUCATION AND SUB-REGIONAL WORKSHOP ON NEW ENGINEERING CURRICULUM

UNIVERSITY OF LAGOS

IN DEED AND IN TRUTH

in partnership with UNESCO

UNESCO

University of Lagos. Yaba, Lagos, Nigeria

23rd - 25th September, 2002

Edited by:

DR. FUNSO FALADE

COMPUTER-AIDED INSTRUCTION IN ELECTRICAL ENGINEERING EDUCATION

F. N. OKAFOR, T. O. AKINBULIRE and C. O. A. AWOSOPE
Electrical Engineering Department
University of Lagos
Akoka, Lagos
Email: cfrankok@yahoo.com

ABSTRACT:

This paper discusses the experiences of the authors in the application of computer aided instruction (CAI) to Electical Engineering Education. Examples of some CAI tools developed by the authors are presented. Also discussed are problems associated with development and/or acquisition of the necessary tools for CAI in a developing country like Nigeria.

INTRODUCTION:

Contemporary electrical engineering practice has become highly dependent on the digital computer; from the production of design drawings to cost analysis and from design optimization to performance simulation. It there follows that the modern engineer must of necessity be computer literate. It is equally clear however, that the engineer need not be a good programmer, but requires enough computer literacy to cost-effectively use existing software tools. Such tools, which exist in the form of computer aided design (CAD) packages are currently spanning the entire spectrum of engineering. Any attempt to use these packages via intermediaries (programmers) may lead to confusion and mistakes. Thus, one attributes of modern engineering practice is that some complex engineering designs can now be done interactively on digital computers. This is often followed by several simulation runs to determine the performance of the system under various working conditions. Simulation is experimentation with models and is faster and more cost-effective than using physical components.

Given this framework of modern engineering practice, an extra duty is imposed on engineering educators to prepare their studdents for the type of practice awaiting them. It was probably due to the realization of this fact, that most engineering faculties in Nigerian universities introduced a course on computer programming at the early stage of the enginnering programme. However, the other courses which follow make little use of the already acquired computer skill, and the teaching method is still adapted to the traditional pencil and paper technique. Therefore, real life engineering problems are rarely considered for classroom examples because the solution time required is deemed unrealistic.

Against this background, the authors initiated the development of interactive software computer aided design (CAD) modules as tools for computer aided instruction (CAI) in various core areas of electrical engineering curriculum. This paper discusses the experiences of the authors in the development and use of these (CAI) tools for teaching various subjects within the Electrical Engineering curruculum. Selected applications of some of the CAI tools are demonstrated. Also evaluated are problems associated with development and /or acquisition of necessary tools for CAI in a developing country like Nigeria. The success of the CAI project so far and some problems yet unsolved will be presented at the conference.

The paper is organised as follows. A brief overview of the projects is discussed in section 2. Some examples of the developed tools are discussed in section 3. Experiences of the use of the CAI tools are presented in section 4 while section 5 highlights some of the problems associated with the development/acquisition of CAI tools in a developing economy such as ours.

2. THE PROJECTS

The projects were initiated over a decade ago amidst several financial and manpower constraints. Available computer hardware in the Department then was limited to two micro-computers – an apple IIE and an IBM J x Pc. The university-owned IBM 370 main frame has no terminals and thus not suitable for interactive computing. The projects were therefore, started with the departmental microcomputers.

At the moment, the computing facility in the Department has greatly improved and so also is the student population. However, the CAI project has reached a stage where some of the developed modules are now being integrated into commercial engineering application packages like MATLAB.

2.1 Objectives:

The overall goal was to develop interactive software CAD packages as tools for computer aided instruction (CAI) in various core areas of electrical engineering. The basic idea was to combine a students perception and intuition with digital computing power. Therefore, in developing the packages the objectives had been to

- aid the teacher in the effective teaching of the subject matter by optimizing instruction time and reducing the tedium of correcting homework.
- improve the learning ability and scope of knowledge of the student by exposing him to industry oriented problems.
- Harness the manipulative power of the computer to minimise the level of details with which the studdent has to contend.

2.2 Design principles and specifications

The general design principles for interactive programs for education and research have been well discussed by Lemmens et al [1]. However such specifications as portability, interactive capability, core algorithm selection, graphics requirement and model description do affect the choice of programming language as highlighted by Wieslander [2], Martins [3] and Denham [4]. In developing countries, hardware constraints constitute another factor which generates other problems like limited wordlenght, limited working memory and poor graphics support capabilities. How good the final design turns out to be therefore, is dependent on the effective management of these factors.

The design principles for all the software tools in our CAI program can be summarised as

- ease of use (interactiveness)
- application of graphics
- flexibility, modularity and protability
- usefulness in education

2.3 Methodology

The approach involved the development of new algorithms and coding existing ones in such a way as to conserve computation time. Great emphasis was placed on the design of man-machine interface which must accommodate both the novice and the expert users.

2.4 Manpower:

The only available manpower were students at all levels. Hence, research projects aimed at developing software CAD packages were fashioned out for final year undergraduate and postgraduate students specialising in various core areas of electrical engineering. The pedagogical use of these tools is prominent in deciding the specific nature which a particular package assumes, based on the general principles discussed above. Since students are transitional, each initial output is subjected to stepwise refinements by subssequent workers. Also feedback from users provided a base for such refinements.

2.5 Structure of the packages:

Each package has a modulaor structure, i.e consists of subsystem whch can act as 'stand-alone' systems. The subsystems are called modules and contain other subroutines arranged in hierarchical manner. This structure allows for the use of the link overlay technique (see Rosenbrock [5]) which conserves the working core memory requirement. Figure 1 represents the structure of one of the packages which consists of five modules each containing other subroutines.

2.6 Implementation:

All the packages are implemented on micro-computer and can run on Pentium II processor with VGA graphic adaptor. Some modules can run onlower specified computers. The programs are coded in standard Fortran for portability, though Basic is sometimes used for some scetions for improved graphics. The very new ones are coded in C^{++}. The flexibility is such that user owned subroutines can be added (by expert users) to solve specific problems not necessarily treated by the package.

Each developed CAI tool incorporates a turnkey facility which enables it to boot the system as soon as the diskette containing the tool is secured in the disk drive. The entire package can also be installed in the hard disk and called into core by typing the appropriate command.

2.7 Interactive principles:

The man-machine interactive design is fundamentally command oriented. The user types in the desired command which the computer executes. The command consist of names and symbols which are electrical engineering and not computer oriented – as shown in appendix A. However some question and answer modes (see Rosenbrock [5]) do exist; usually during execution of commands. For instance, the command 'simu' calls for the execution of the time simulation module in LUCAD. Ordinarily, the result will be a display of time curves without a list of the data points unless the user answers 'YES' to the question "LIST DATA POINTS?". This mode has the added advantage of keeping the user abreast of the goings – on during the execution of a command. All the error messages are expressed in terms of what has gone wrong and what might be done next.

3. EXAMPLES OF SOME OF THE PACKAGES

The example introduced here are drawn from Electrical Engineering, but the perspective presented can be used to develop similar tools in any engineering discipline. Five CAI tools are described covering areas such as control systems engineering, power systems analysis and control as well as reliability engineering. The descriptions are anything but exhaustive.

3.1 Lucad-1

LUCAD-1 is a package for the modelling, identification, analysis, design and simulation of linear, time invariant, single – input single- output (SISO) feedback control systems. Specifically, the identification scheme employs complex curve fitting methods, based on "the minimization of the weighted squared error criterion to "obtain the transfer function of the system (as a ratio of two complex polynomials), from experimental frequency response data. The analysis procedure first uses the algebraic techniques of Routh and Hurwitz to ascertain the stability or otherwise of the control system n the absolute sense. Then it investigates relative stability using any of the graphical techniques of classical control theory (Bode, Nyquist and/or root locus diagrams) and computes the desired performance indices (gain margin, phase margin, steady state error etc.). The design strategy also follows from the classical SISO approach and leads to the design of controllers of the proportional, integral plus derivative (PID) type. Simulation is carried out in the time domain for control systems described either in the transfer function or state space model. In the former case, the system's time response/is obtained via the inverse Laplace transform of the output function while a solution of the state equations yields the time response for the latter.

In order to enhance its role as an educational and research tool, LUCAD-1 has a module with facilities for linear parameter estimation by polynomial least squares, solution of large ac and dc networks and matrix algebra. A rather detailed structure of LUCAD-1 is shown in Fig.1 while appendix A contains some of its commands.

3.2 Lucad-2

This package performs control systems analysis, design and simulaiton for both SISO and multi-input, multi-output systems using modern control theory based on the state-space methods. For SISO design, LUCAD-2 uses eigenvalue assignment by state feedback for linear systems either in the continuous or discrete domain. However, Shaa et al [6] had shown that for an nth order, mth input system, "entire eigenstructure assignment" is required in order to determine a unique mxn matrix K that places the system poles at the desired locations. Hence, LUCAD-2 adopts the latter approach in the design of MIMO systems. The Achermann's [7] design procedure is used in the discrete domain.

Work is in progress to include techniques based on linear quadratic optimal control theory as well as model reference adaptive schemes, model following control and self-tunning procedures.

3.3 Ronip

This is a graphics package that performs linear SISO control system design using Nichol's chart and the root locus. It is originally coded in basic due to its emphasis on graphic displays. RONIP easily shows the root locus plot of a given transfer function. It can also draw the

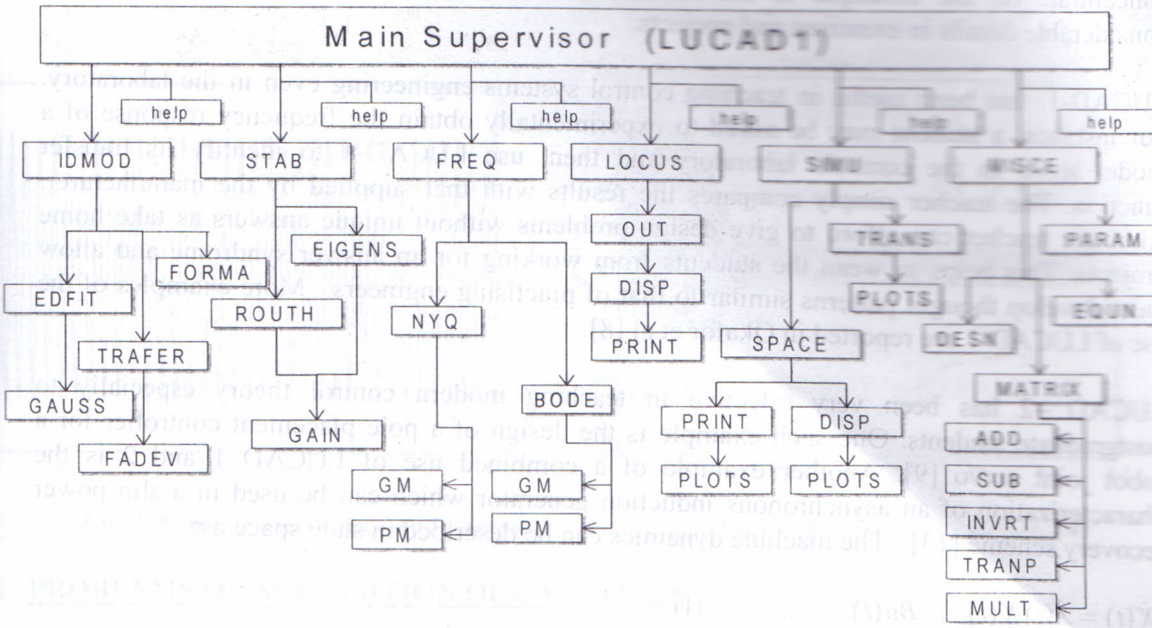


Fig 1. Detailed Structure of LUCAD 1

Nichol's chart with the constant M curves, the constant N curves and the log magnitude curves. At the users request, it computes any of the frequency domain figures of merit (gain) margin, phase margin, bandwidth etc. Similarly, it computes the time domain performance indices from the root locus plots- damping ratio, natural frequency of oscillation, overshoot etc.

3.4 Relab

This is a CAI tool that evaluates the reliability data of a power system using the minimal cut-set theory. It is capable of automatically generating the minimal paths for a desired load point from the structure of the power system. For each load point, RELAB computes the failure rate and its associated relaibility cost. It further constructs reliability cost models by applying regression and correlation analysis to the two sets of data. Then, the conforming models permit the prediction of load point failure rates from the knowledge of the corresponding reliability costs.

3.5 Flow-1

Data for load flow analysis is noted for the dominance of complex quantities. Initially this posed a problem as available compilers could not handle complex numbers on the microcomputer. The only option was to use special function subroutines which converts complex quantities into the real mode without distorting the logical sequence. Thus Flow-1 was developed on the Apple IIE for the solution of load flow equations using either the Gauss-Siedel method with accelerated convergence or the Newton-Raphson procedure. However as more modern personal computers were acquired with the F77 complier, Flow-1 had to be modified – for the new systems.

4. EXPERIENCE OF USING THE CAI TOOLS

The tools are being used in the department by both the staff and students. The teachers who are part of the CAI program use the tools in their routine teaching job, in private research and in the preparation of lecture materials. By using the packages, teachers have been able to concentrate on the concepts in the lectures and to work with realistic examples with considerable details in exercises and projects.

LUCAD-1 has been useful in teaching control systems engineering even in the laboratory. For instance, a student may be asked to experimentally obtain the frequency response of a model servo in the controls laboratory and then, use LUCAD-1 to identify its transfer function. The teacher simply compares the results with that supplied by the manufacturer. Also, the teacher can afford to give design problems without unique answers as take home projects. This helps to wean the students from working for an answer syndrome and allow them develop thought patterns similar to that of practising engineers. More examples of the use of LUCAD-1 are reported in Okafor et al [8].

LUCAD -2 has been very effective in teaching modern control theory especially to postgraduate students. One such example is the design of a pole placement controller for a robot joint servo [9]. Another example of a combined use of LUCAD 1 and 2 is the characterization of an asynchronous induction generator which can be used in a slip power recovery scheme [13]. The machine dynamics can be described in state space as:

$$\dot{X}(t) = A(t)X(t) + Bu(t) \quad \text{.......... (1)}$$

$$Y(t) = CX(t) \quad \text{.......... (2)}$$

where

$$A(t) = \begin{pmatrix} -\left(\dfrac{1}{aT_s} + j\omega_s\right) & \dfrac{L_m}{\sigma L_r T_r} \\ \dfrac{L_m}{aL_s T_r} & -\left(\dfrac{1}{\sigma T_r} + j\omega\right) \end{pmatrix} \quad \text{....... (3)}$$

$B = I_z$;

$$C = \begin{pmatrix} \dfrac{1}{\sigma L_s} & -\dfrac{L_m}{\sigma L_s L_r} \\ -\dfrac{L_m}{\sigma L_s L_r} & \dfrac{1}{\sigma L_r} \end{pmatrix} \quad \text{.......... (4)}$$

L_s, L_r and L_m are the stator, rotor and mutual inductances respectively, T_s and T_r are the corresponding time constants while σ is the leakage factor. If voltage control is assumed such that:

$u(t) = [v_s \,.\, v_r]^T$, $X(t) = [\lambda_s \,.\, \lambda_r]^T$ while $Y = [\, i_s, i_r]^T$ .... (5)

Where λ is the linkage flux and other terms have their usual definitions, the voltages and currents which characterise the machine are shown in figures 2, and 3.

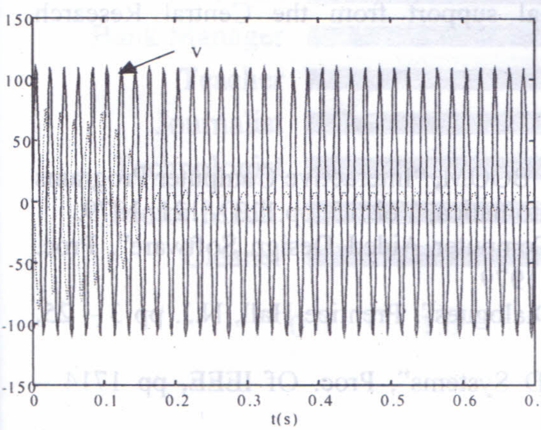


Fig.2 Rotor phase voltage and current

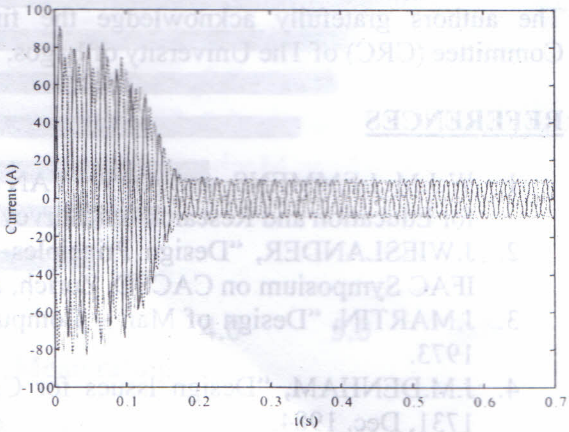


Fig.3 Statorcurrent i_a, i_b, i_c (A)

5. PROBLEMS OF ACQUISITION OF CAI TOOLS

The problem of acquisition of CAI tools in developing countries is definitely more than funds. A major obstacle is lack of will by educators themselves to introduce CAI in the educational process. This is informed by the fact that there has been no study group or committee set up by any engineering faclty in Nigeria to examine how CAI can be be integrated in our present curriculum- i.e, what tools are needed, what is the cost, how adequate is available manpower etc. There may be a need for a reorientation of the curriculum in favour of individualised instruction which CAI supports. Suppes [12] has recognised the principal obstacle to CAI as how to find ways of individualising instruction and of designing a curriculum that is suited to individuals instead of groups. It is only after this crucial decision stage that the cost factor comes in. From our experience, it has become clear that software tools should be developed locally to serve specific objectives. Available funds my be channeled towards hardware acquisition while basic research in local hardware development should be encouraged. Funds may be obtained from central research committees of individual universities, the national science and technology fund (NSTF), agencies like UNICEF, UNESCO, UNIDO, and organisations like the European Union (EU). An inter-university CAI committee, in our humble opinion, can attract a special fund allocation from governmnet. Endowment funds for CAI should be launched by engineering faculties, at least, to encourage private sector participation.

6. RECOMMENDATIONS AND CONCLUSION

This paper has summarised experiences from the use of locally developed software CAI tools in electrical engineering education. From the discussion; it has become imperative that CAI must be taken seriously by every Engineering Faculty.

Given this background, the authors wish to recommend that each Faculty of Engineering sets up an interdisplinary committee to work out modalities for the introduction of CAI to various engineering departments. Such committees shall also exist at departmental level where the needs of each subject can easily be ascertained.

Acknowledgements:

The authors gratefully acknowledge the financial support from the Central Research Committee (CRC) of The University of Lagos.

REFERENCES

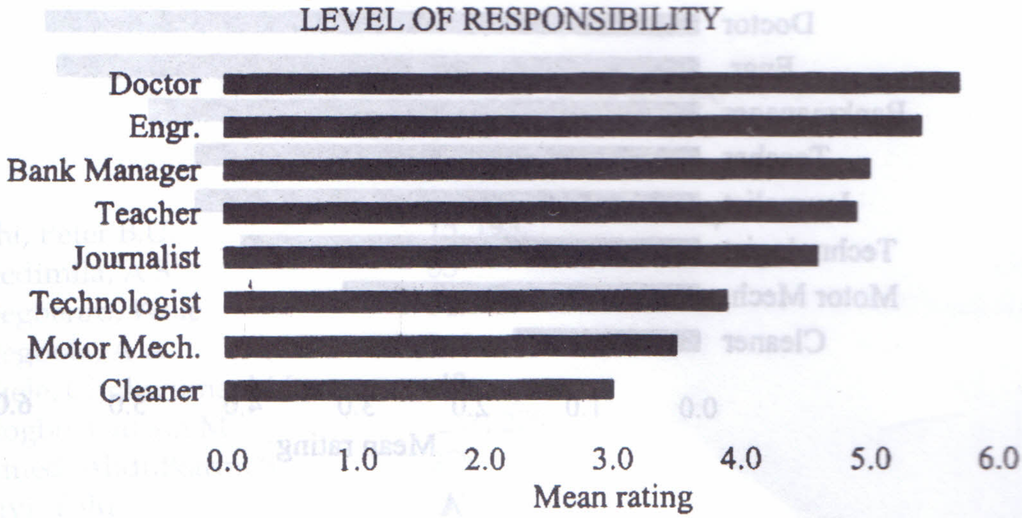
1. W.J.M. LEMMENS, and A.J.W. VAN DEN BOOM, "Interactive Computer Programs for Education and Research – A Survey", Automatica, Vol. 15, pp 113 – 121, 1979.
2. J.WIESLANDER, "Design Principles for Computer Aided Design Software", Proc. IFAC Symposium on CACSD, Zurich, Aug. 1979
3. J.MARTIN, "Design of Man – Computer Dialogues", Prentice Hall, N.J. pp 3 – 25, 1973.
4. J.M.DENHAM, "Design Issues for CACSD Systems", Proc. Of IEEE, pp 1714 – 1731, Dec. 1984.
5. H.H.ROSENBROCK, "Computer Aided Control System Design", London, Academic Press, 1974.
6. S.L. SHAH et al, "Enginvalue/Eigenvector Assignment for Multivariable Systems and Further Results for Output Feedback", Electronics Letters, Vol. 11, No. 16, pp 388 – 389, August, 1975.
7. J.E. ACKERMANN, "On the Synthesis of Linear Control Systems with Specified Characteristics", Automatica Vol. 13, pp 89 – 94, 1977.
8. F.N. OKAFOR, C.O.A. AWOSOPE and J. KATENDE, " A Computer Aided Modelling, Analysis and Design Package for Control Systems", Proc. Of National Seminar on Computer Applications in Engineering Design and Manufacturing, Lagos, pp 1 – 10, April, 1988.
9. J. KATENDE and O.G. OLUGBEKAN, "A Novel Microprocessor STR for a Robot Joint Servo" for presentation at the IFAC Symp. On LOW COST AUTOMATION (LUA '98), Milan, Italy, Nov. 1989.
10. J. KATENDE, "RONIP – A Root Locus and Nichol's Charts PC Software Package", To be published.
11. C.O.A. AWOSOPE et al, "A Fixed Minimal Path Array Method of Evaluating Reliability Indices of Power Systems." Electric Power Systems Research, vol 19 No. 4 , pp 167 – 176, 1990.
12. P. SUPPES, "The Computer and Excellence", Saturday Review, January 14, 1967.
13. OKAFOR; F. N, HOFMANN, W. and RABELO, B. „ Modelling of a Doubly-fed Wind Powered Induction Generator Feeding a DC-load." European Power Electronics Conference proceedings, CD-Rom. www.epe/01/0619. Graz, Austria, August 2001.

APPENDIX A

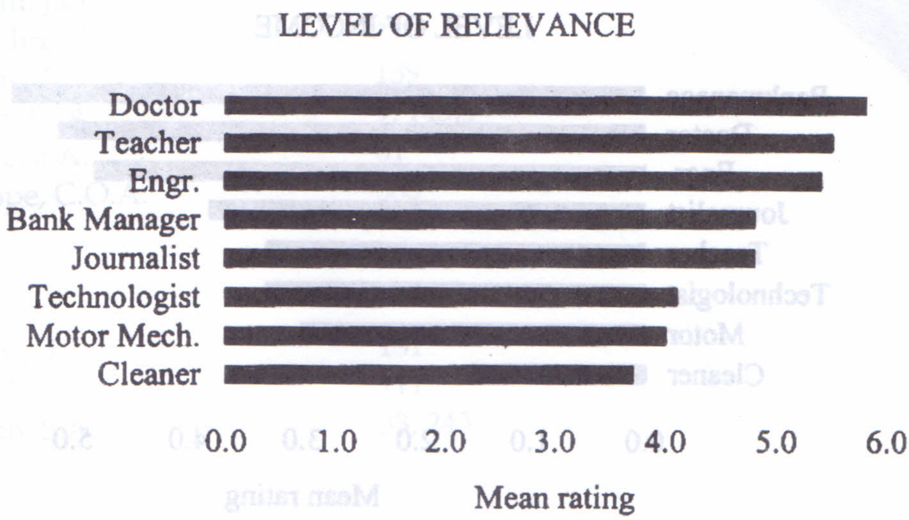
Parameters of the machine

Power rating (P) – 4kw	No. of poles (Z) – 2
Stator resistance (R_s) – 1.5Ω	Rotor resistance (R_r) – 0.9Ω
Stator inductance (L_s) – 9mH	Rotor inductance (L_r) –3mH
Mutual inductance (L_m) –139mH	Moment of inertia (J) – 0.045Kgm^2

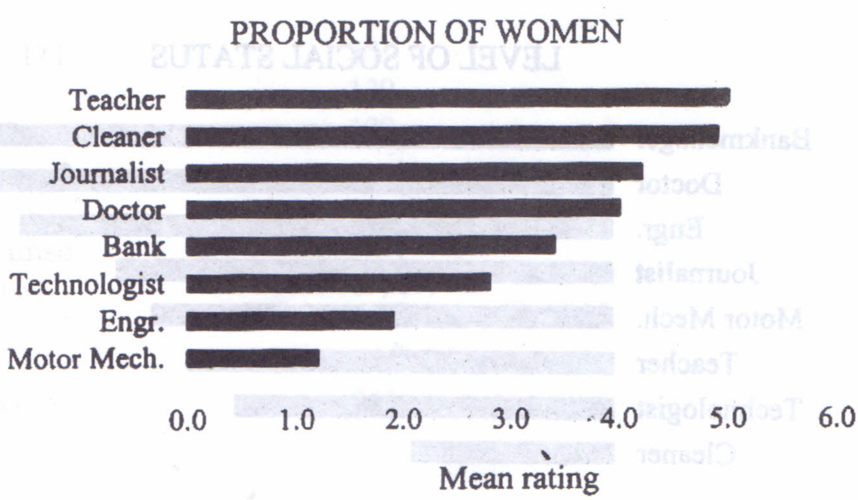
Viscous friction coefficient B – 0.00727Nm/s



D

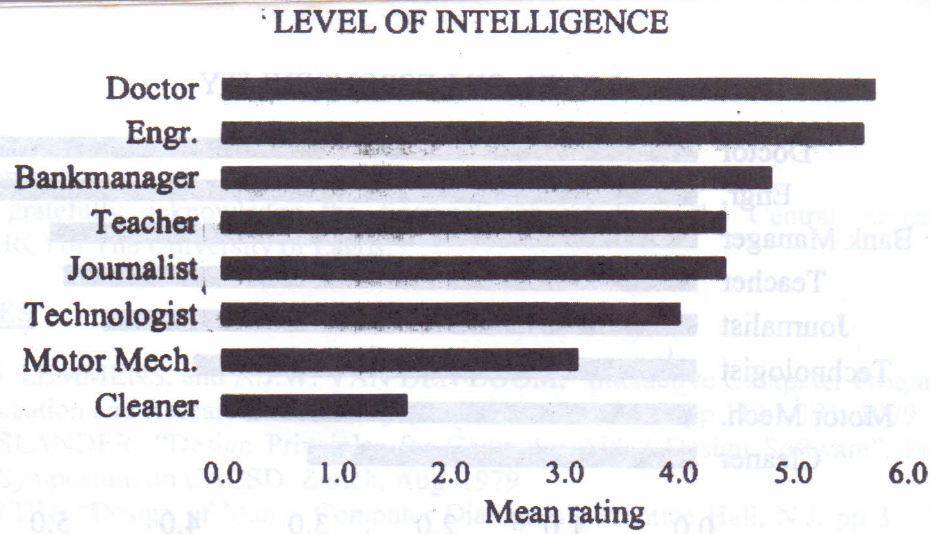


E

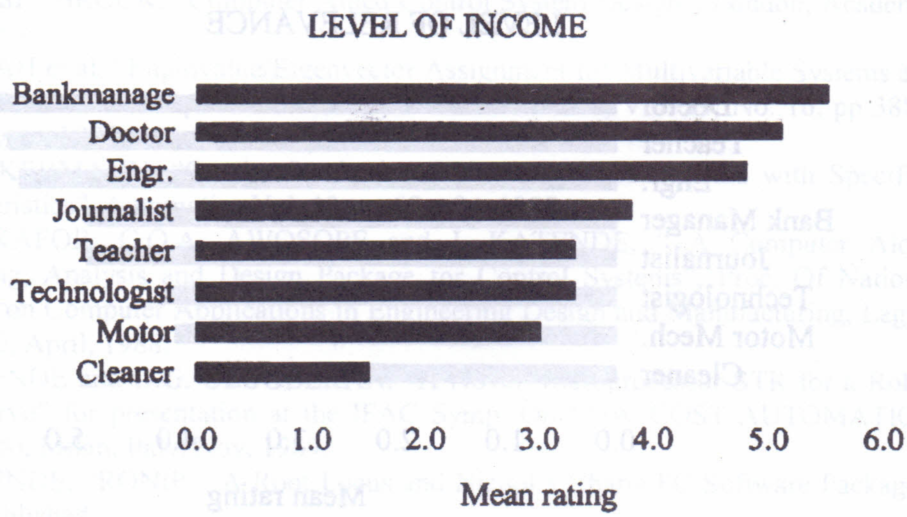


F

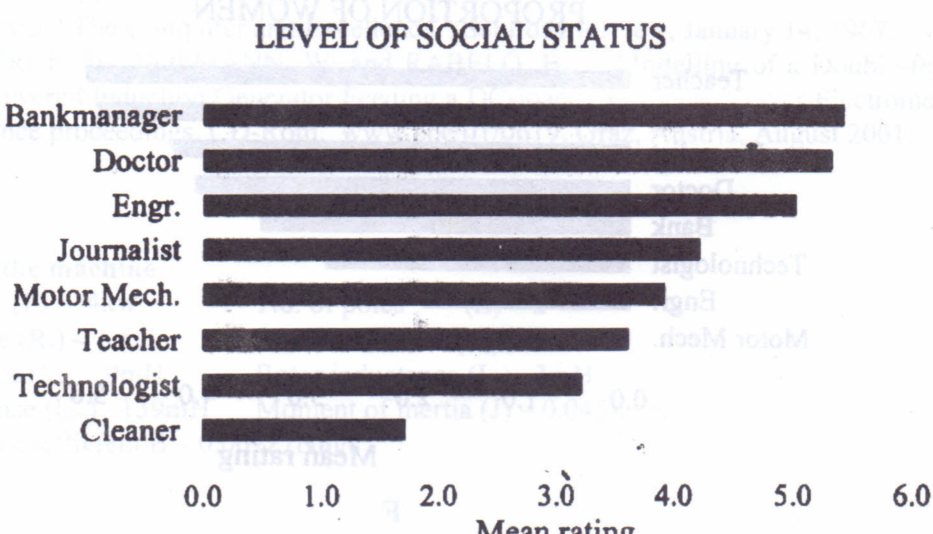
Figure 1: Mean ratings of occupational prestige on six dimensions.


LEVEL OF INTELLIGENCE
Doctor
Engr.
Bankmanager
Teacher
Journalist
Technologist
Motor Mech.
Cleaner
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Mean rating

A


LEVEL OF INCOME
Bankmanage
Doctor
Engr.
Journalist
Teacher
Technologist
Motor
Cleaner
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Mean rating

B


LEVEL OF SOCIAL STATUS
Bankmanager
Doctor
Engr.
Journalist
Motor Mech.
Teacher
Technologist
Cleaner
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Mean rating

C