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**Three AI Approaches for Improving Classification Decisions
Concerning Cytology Personnel according to U.S. Federal Law
(CLIA'88): An Integrative Study.**

by

Mohamed EL Etribi

**A Dissertation submitted to the Graduate Faculty in Business
in Partial Fulfillment of the Requirements For the Degree of
Doctor of Philosophy, The City University of New York**

1998

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Abstract

Three AI Approaches for Improving Classification Decisions concerning Cytology Personnel according to U.S. Federal Law (CLIA'88): An Integrative study.

by

Mohamed EL Etribi

Advisor: Professor George Schneller IV

The use of Expert Systems (ES), Neural Networks (NN) and connectionist expert systems (ES&NN) in the delivery of health care are receiving greater attention, due to factors such as constrained budgets, staff turnover, increased malpractice suits, and increasing dependence in cytotechnologists to carry out tasks formerly performed by pathologists. This study concentrates on clinical and organizational ramifications that these intelligent systems may have on health care. This Dissertation uses specific ES, NN, and ES&NN systems in determining how such systems might be used effectively to solve a problem, and efficiently to solve fast, in the face of cost, legal and other constraints mentioned.

Clinical Laboratory testing is an important part of patient care. The Clinical Laboratory Improvement Amendment (CLIA'88) was enacted to assure that

Americans receive high quality, and reliable testing in Laboratories of all types and sizes throughout the nation. CLIA'88 personnel standards require specific skills, and knowledge for Laboratory workers which vary due to the complexity of tests performed.

The study will examine the use of Expert Systems (ES) and Neural Networks (NN) technology for cytology personnel evaluations according to CLIA'88 Regulations. Specific ES, NN, and a hybrid ES&NN were developed by the author, using commercially available packages. After a sequence of preliminary tests of the three systems, the final versions were deemed valid. A questionnaire of fifteen different cases, which covered the twenty possible CLIA'88 codes (four technical supervisors, two general cytosupervisors, eight cytotechnologists, and six unqualified codes) was developed. This questionnaire was sent to three hundred evaluators in the field of medical technology. Eighty-six valid responses were received and analyzed.

The results showed that ES, NN, and ES&NN all made more accurate evaluations (the ability to correctly classify subjects into relevant codes) than Human Experts (Credentials Agency Evaluators) and Users (Clinical Laboratory Evaluators). Also, these systems are more consistent (the artificial intelligent systems are able to replicate their results) than humans. ES&NN was more accurate and consistent than ES in solving this multiple-criteria decision making problem.

The personnel evaluations of the three classes (unapproved personnel, cytotechnologists, and cytosupervisors) were obtained and analyzed for the

Users and Experts. There are no significant differences for the Users and Experts in evaluating unqualified personnel and cytosupervisors. The Human Experts' evaluations of the cytotechnologists are significantly superior to Users.

The experimental results support the incorporation of ES, NN, and ES&NN systems into the present health care delivery. These preliminary studies, strongly support the efficacy of such AI systems applications in Cytology personnel evaluations. It suggests that they may have wider applications in health care.

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1. Introduction

The Clinical Laboratory Improvement Amendment of 1988 (CLIA'88) which was enacted in February 1992. Congress has greatly expanded federal regulatory authority from the 13,000 Clinical laboratories then regulated to an estimated 200,000 lab sites.

Clinical laboratory testing is an important part of patient care. Some six billion laboratory tests are done each year (Department of Health and Human Services {HHS} fact sheet-1992). This represents annual expenditures of an estimated thirty billion dollars.

CLIA'88 personnel standards require specific skill, knowledge and supervision levels for lab workers, according to the complexity of the tests that can be expected to perform.

The complexity model used by HHS depends on a scoring system based on seven criteria (HHS-1992). A weight ranging from one to three was assigned by an HHS committee to each of the seven criteria: knowledge, training, experience, reagent preparation, operational steps, quality control, and equipment maintenance. A weight of one indicates that the procedure is easy for that criterion, while a weight of three indicates that the procedure is difficult, and needs extensive independent judgment. A total score of thirteen or more placed a procedure in the high complexity category. A score from eight to twelve placed the procedure in the moderate complexity category. A third category called a

waived test corresponds to the minimum score, seven points.

Simple manual tests or home tests were placed by the Center of Disease Control (CDC) as waived tests. Urinalysis and Pregnancy tests are examples of waived tests. Besides posing no reasonable risk of harm to patients if performed incorrectly, waived tests require a minimal degree of independent judgment and interpretation, patient sample preparation, no extensive quality control or environmental control, and minimal training and experience.

A review group inside the Department of Health and Human Services determines if a test meets the criteria for a waived, moderate or high complexity categories. HHS grouped laboratory tests according to these complexity categories. HHS update this lists periodically according to feedbacks from providers and test kit's manufactures.

The key distinctions between the categories of moderate and high complexity tests are as follows,

1. Specialized instructions are required for a high complexity test, while, on-the-job instructions are deemed sufficient for a moderate complexity test.
2. If troubleshooting is automatic or self-correcting, or if there is clearly described procedure requiring minimal judgment, then the HHS review group will put the test in the moderate complexity category. Automated Chemistry and Hematology tests are examples of a moderate complexity category.
3. If troubleshooting is not automatic, and decision-making is required, or the test requires direct intervention to resolve most problems, and maintenance

requires special knowledge, then HHS puts the test in a high complexity category. Cytology and Histology tests are examples of tests with high complexity.

The personnel requirements for high complexity testing are naturally more stringent than moderate complexity testing. Those conducting waived tests do not have to meet any personnel requirements. Appendix A shows the different personnel categories under CLIA'88 requirements. Laboratories doing moderate complexity testing must have employees who together cover four areas of responsibility: Laboratory Director, Technical Consultant, Clinical Consultant, and Testing Personnel. Each of the high complexity testing laboratories has a Director, Technical Supervisor, Clinical Consultant, General Supervisor, and Testing Personnel.

“Refer to Appendix A ”

Cytology screening for the presence of abnormality is widely recognized as one of the greatest successes in oncologic prevention. For example, the introduction of the Pap smear in the early 1940 by George Papanicolaou, has helped in reducing cervical cancer mortality by more than 70% in the U.S.A. (American Cancer Society-1993). The number of cases of invasive cervical cancer has decreased from 14.2 per 100,000 in 1973 to 8.2 per 100,000 in 1993. This decline is attributed to cytology screening (American Cancer Society-1997). There were 48% fewer deaths in 1993 than twenty years earlier.

Nonetheless, the Pap smear has serious limitations as evidenced by its

high false-negative rate. In fact, some studies have reported incorrect results for cervical cytology smears as high as 50% (Koss-1987). The Koss study showed also that many false diagnoses are attributed to human screening errors, mostly from unqualified screeners or excessive work loads. About sixty million gynecologic cytology smears were done in 1995, 700,000 of these cases were positive (Garner-1995). If no treatment or medical intervention were offered, probably 20,000 patients would have developed invasive cancer.

The quality of Pap smear screening in the United States has come under intense criticism in both public and professional sectors over the past few years. Morbidity and mortality from misread Pap smears have also caused swiftly mounting malpractice and liability exposure (Rosenthal-1993). The past five years have brought an increase in the number of lawsuits filed against laboratories for illegally misreading Pap smears.

According to The Doctors' Company, the nation's largest physician-owned professional liability insurance company, the number of claims filed for cases involving the Pap smear more than tripled between 1992 and 1995 (Pelehach-1997). A federal investigation revealed poor practices on the part of the laboratories and what some termed "flagrant misses." Seven women who had their Pap smears screened later died of cervical cancer (Frale-1997).

Reports in the media during the late 1980s of these errors prompted the United States Congress to enact CLIA'88 in February 1992. This amendment enacts a three-part approach ensuring reliability of testing:

1. Quality assurance to ensure accuracy

2. Proficiency tests to measure the performance of personnel
3. Personnel standards to ensure appropriate education, training and experience for technical laboratory workers

Despite these regulations, the errors rate of cytology screening remains unacceptably high. False positives may result in unnecessary surgery, and patients may have their healthy organs removed because of a wrong diagnosis. In the other hand, false negatives can result in death, as cancer will spread if it is not detected early. The yearly manual personnel evaluations of the approximately 27,000 candidates are time-consuming and prone to error (Snyder-1995). Laboratory personnel screening outcomes depend largely on human judgment. Such personnel evaluation errors can contribute to death or injury. The malpractice insurance premium has increased in the last decade due at least in part to wrong diagnosis by incorrectly evaluated screened personnel.

An attractive solution would be to automate as much of the personnel evaluation process as possible. The possibility of less drudgery combined with more consistent objective judgment by evaluation automation will increase the process accuracy, and free up valuable human experts' time in carrying out other CLIA'88 requirements.

The use of Expert Systems and/or Neural Networks technology (with human experts) might be beneficial in the remedy of the above problem. Expert Systems (ES) have been in use since 1970 and have wide applications (Reddy-1988). Neural Networks were developed for recognition of ill-defined objects

such as handwritten characters (Koster-1991), finger prints (Leung-1990), and prediction of bank failures (Tam-1992 & Salchenberger-1992).

The human brain is made up of billions of cells called neurons. Each of these cells is a tiny information processor with extremely limited capabilities; however, connected together, these cells form the most intelligent system known. Neural Networks are a new class of computing systems formed from hundreds or thousands of simulated neurons connected to each other in much the same way that the brain's neurons are connected.

A Neural Network (NN) is a program that is in some sense able to learn, and can be trained. NN extracts a pattern of information from a structured set of data. NN gleans information from patterns in a way that is purportedly similar to the human brain. Unlike ES, NN uses non linear processes. NN belongs to the class of data-driven approaches that is to say NN stimulates inductive reasoning. ES, by contrast employs deductive reasoning by using production rules. NN contains many layers of simple non linear computing units or nodes interconnected by links.

Both ES and NN technologies aspire to imitate human intelligence. Both use qualitative information as their basic input and output streams. Neither is appropriate for intensive concrete processing of quantitative data that is better suited for conventional procedural computing. ES and NN have a common origin and a common goal, but they apply two distinctly different approaches.

Both ES and NN have great potential for solving classification problems, and it is reasonable to explore the possibility of their integration into a single tool.

This could provide a powerful tool in solving complex problems (Deng-1992, Gallant-1988, Hillman-1990 & Knight-1990). Although expert systems function well within limited areas of competency, they perform quite poorly outside these boundaries. NN models rely on classification and association between data to reach solutions. They are able to “learn” from a set of sample decisions and classify new cases according to the similarities associated with the “memorized” patterns. The method, by which these patterns arise from the samples are called parallel distributed processing (Baker-1990). It is termed “parallel” because multiple aspects of a pattern are considered simultaneously.

However, Neural Networks suffer from several limitations of their own. They lack the capacity to explain their conclusions and, perhaps more important, they are unable to reason in a sequential or step-wise manner that results in precise conclusions.

The previous discussion suggests that the symbolic or sequential processing of ES, and the parallel distributed processing of NN are not competing AI strategies, but rather they are complementary. By uniting them we may avoid many of the weaknesses inherent in each method while capitalizing on their unique strengths. This research will provide insight into the use of Expert Systems and Neural Networks technology in personnel evaluations. This research will present an operational basis for future research in the automation of personnel evaluations.

1.1. Goals of this Research

This research will focus on how Expert Systems and Neural Networks technologies perform, separately and combined in Cytology personnel evaluations.

The study is conducted as follows:

- a. Search the literature for articles addressed the use of Expert Systems, Neural Network, and ES&NN systems in pattern recognition and classification problems.
- b. Examine the various kinds of computer technology, especially ES and NN softwares currently used in the health care sector.
- c. Choose from the available ES and NN shells, the ones which are suitable for the personnel evaluation problem.
- d. Build specific ES, NN and ES&NN programs for the CLIA'88 cytology personnel problem.
- e. Verify, validate, and test the above programs by the author and in the field.
- f. Conduct experiments for evaluating the effectiveness of these artificial systems as opposed to the manual cytology personnel evaluation currently in use.
- g. Suggest expanding the results obtained from above to cover any other personnel evaluation and similar situations.

1.2. The Contribution of this Research

Appendix B shows the cytology personnel requirements under CLIA'88 regulations. The specific factors involved in deciding the cytology technical personnel classification according to CLIA' 88 regulations are identified.

There are three classes or categories: technical supervisor, general cytosupervisor, and cytotechnologist. There are four subclasses or codes under the technical supervisors category, two subclasses for the cytosupervisor category, and eight subclasses for the cytotechnologist category.

A candidate may satisfy the requirements for more than one class, and may have more than one subclass, because the requirements of CLIA'88 are not mutually exclusive. Please see Figure 1. For example a candidate, who satisfies these requirements:

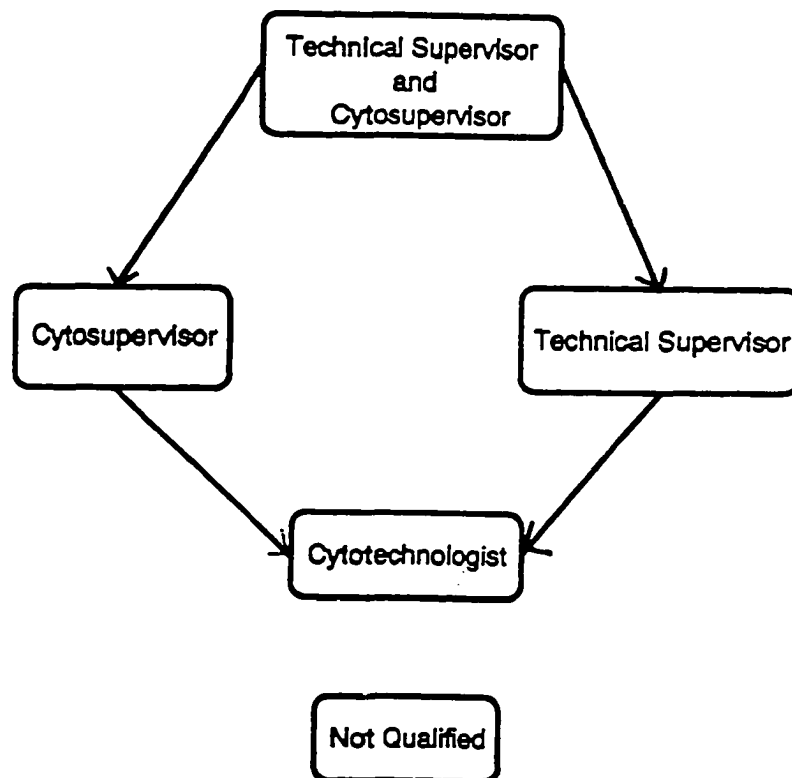
- a. Certified in Anatomic and Clinical Pathology by ABP. or AOBP,
- b. Certified in Cytopathology by the American Society of Cytology (ASC),
- c. The applicant has a general cytosupervisor license.

According to Appendix B, this candidate is classified under three subclasses of technical cytosupervisor (CYT1, CYT2, and CYT3). Also, this individual is classified under general Cytosupervisor (CYG1), and cytotechnologist (CYO1.)

Figure 1 shows the relationship hierarchy for the three categories. If a candidate is in any box, that a candidate has satisfied requirements for not only the title of this box but also the title of any connected categories below the box it connected to. For example, if a candidate is qualified as a cytosupervisor, he or she is also qualified as a cytotechnologist as shown in Figure 1.

Figure 1

THE RELATIONSHIP LATTICE FOR
CYTOLOGY PERSONNEL CLASSIFICATIONS



If a candidate is in any of the classification boxes, he has not only that qualification but any connected category below it.

ES, NN, and ES&NN tools were developed by the author using commercially available software packages, and tested. In order for the reader to understand the contribution of this work, we begin by describing the personnel evaluation classes, and the factors involved in the classification. A preliminary

Experimental evaluation of these systems for pattern classification was undertaken by the author. Approximately, 27,000 cytology personnel are evaluated manually every year. It is believed that we can expand these systems to cover all CLIA'88 technical personnel. This will cover about 300,000 technical personnel annually (Snyder-1995). In this paper, the following questions were examined:

- a. Can ES, NN, and ES&NN systems be used in this specific personnel classification problem "How to evaluate Cytology personnel?"
- b. Can ES, NN, and ES&NN systems compete successfully with experienced human evaluators in evaluating cytology personnel?
- c. Which of the three systems is best in cost, accuracy, and consistency in evaluating cytology personnel?
- d. Can we generalize this specific use of cytology personnel evaluation to include other classification problems?
- e. What other problem fields may be suitable for each of the three systems?

1.3. Review of Relevant Research and Theory

1.3.1. Information Technology in Health Care.

Computers have far more potential in the health care field than simply streamlining clerical work. There are tremendous pressures infringing on health care organizations from many directions-changing regulations, distinct reimbursement requirements, and increased competition.

Cassidy (1992) suggested that information technology has significant inputs in these domains: patient care, performance, payments, protection, regulations, and planning.

Sharkey (1990) found that the average hospital devotes 2% of revenues to data processing expenses. This gives them control on their financial status, but not on their clinical status.

1.3.2. Information Systems Applications in Health Care

There are many applications of information systems in health care. The following are some examples of these applications:

- a. Electronic Data System's corp., developed a centralized and integrated Health Care claims processing for General Motors company. This system has saved three hundred million dollars in three years (Margles, 1992).
- b. Allied-Signal company saved about two hundred millions dollars in two years when they started using information systems to monitor Health Care costs.

c. Elliot (1992) found that one hundred Veteran Administrations hospitals saved millions of dollars in resource management and total quality by using Decision Supports Systems (DSS).

d. Simmons and Ying (1991) developed an Expert System to help untrained personnel with medical appointment scheduling. The findings implied that Expert Systems can provide results similar to those of an experienced appointment secretary.

h. The 3M company developed the HELP system as a product that they marketed to hospitals nation wide. HELP system combined the DSS and Expert Systems functions. The HELP system collected data and acted as an intelligent consultant in a client hospital's decision making (Colliste, 1992).

1.3.3. Expert System

An Expert System (ES) is a computer program that contains extensive knowledge about a specific narrow, real world domain. ES is sometime called a Knowledge-Based System (KBS). ES sometimes emulates the Human Experts in solving problems. An Expert System attempts to solve domain-specific problems using strategies or heuristics to produce a logical sequence from data and expert derived facts. According to Jacobstein (1994), Expert Systems are essential weapons in the global effort for faster product development, service delivery, higher quality, and decreased costs. Many Expert Systems were developed in an incremental fashion because the knowledge was not fully

understood. Many researchers believe that ES must be designed to adapt to revisions easily (Lyons-1992).

There are three major contributions of Expert Systems to business: Improving the efficiency of services, simplifying and enhancing the business, and supports decision-making under circumstances of uncertainty and risk taking (Lyons-1992).

The area where ES or KBS have the greatest potential impact on business is in support of decision making. Psychological studies show that managers rely on a limited number of heuristics, which reduce the complex tasks of assessing probabilities and predicting values (Luger-1989).

Expert systems have often been used for classification problems such as:

1. A knowledge-Based System (KBS) for determining government relocation allowance (Rouch et al-1991). Through a consultation with the system, the government employee can determine which kinds of expenses are identified in the government regulations as reimbursable relocation expenses.
2. Another KBS that helps Social Security Administration managers plan short-term workloads for Benefit Authorizer specialists (Mockler et al-1995). The KBS recommends which workload priorities should be processed during the upcoming week or which should be deferred for future periods.
3. Reddy (1988) mentioned that several Fortune 500 companies are using Expert Systems in their operations such as:
 - a. American Express uses a credit authorization KBS in order to authorize and screen credits.

b. Federal Express uses an inventory control KBS to decide whether or not to store spare parts.

c. IBM uses a scheduling KBS to plan the factory operations in semiconductor manufacturing.

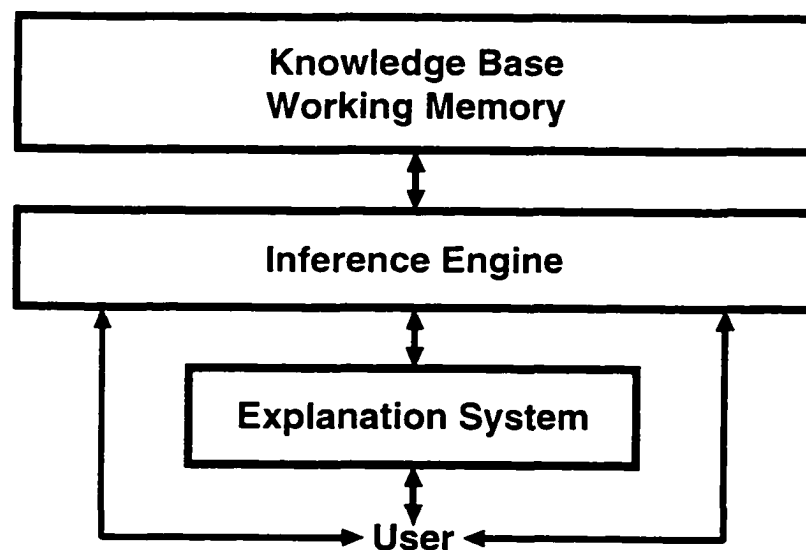
An expert system shell is an ES with its knowledge Data-Base removed leaving only the inference engine components. The basic structure of an ES is:

- a. Knowledge Base, which contains the production rules,
- b. Working memory, which includes a user interface,
- c. An inference engine, which guides the consultation to its conclusion,
- d. Explanation system, which explains how ES arrived to decisions.

The following figure 2 shows the structure of an Expert System.

Figure 2

The Basic Structure of An Expert System



ES is used in the fields of medicine, engineering, business, geology, tax analysis, and law (Hicks & Lee-1988). Such systems are being successfully utilized to diagnose illness, analyze structures, train personnel, and recommend strategies.

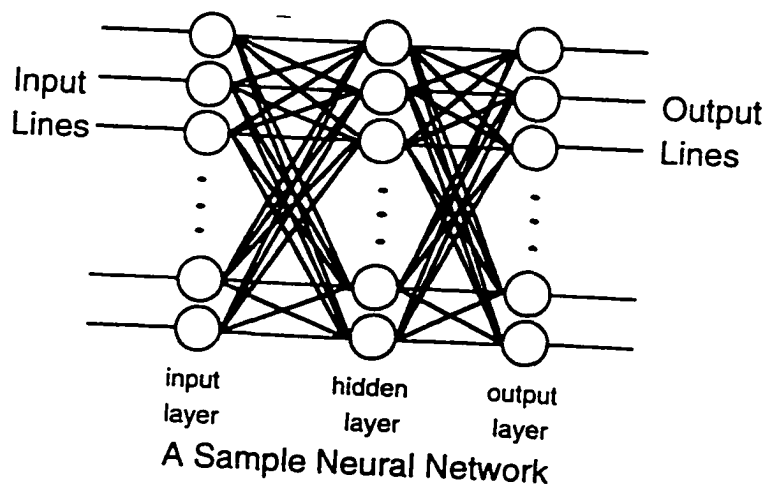
Several articles list and describe major available shells and their distinguishing characteristics (Brody, 1989). Mockler & Dologite (1992) gave a summary chart of expert system shells, their capabilities, and costs. Enrado (1991) describes the capabilities of expert system shells in the expert system resource guide.

Using these resources, the author chose VP-Expert shell 3.0 (Professional Version) for the cytology personnel classification problem. VP-Expert shell is available commercially, and is also easy to use. It is an Expert Systems development tool. This means VP-Expert provides the inference engine, the user interface, and the commands. It is compatible with spreadsheets, and databases. It solves problems using both backward and forward chaining. VP-Expert contains commands that allow it to explain its actions during a consultation. VP-Expert shell is one of the higher rated and least expensive shells (Brody-1989). It enables developing systems in a language very close to plain English and so it is useful in working with nontechnical people.

1.3.4. Neural Networks

The NN model is non parametric, uses examples for which NN is able to perform learning, and adaptively adjust connections between neuron layers to fit the data by the learning process. The usual way to describe such Networks is to visualize a three-layer network as shown in the following figure (California Scientific Software-1993).

Figure 3



The Neural Networks consists of many neurons, grouped into layers. The first layer is the input neuron. The hidden neurons learn how the input combines to produce the desired results. The output neurons translate the results to users. The neurons in one layer are connected to the neurons in the next layer.

Neurons in one layer listen to the neurons in the previous layer and send results to neurons in the next layer. The connections, represented by lines between layers, are what gets corrected during training.

The input pattern is stored in the weights connected one(or more) neuron(s) in the first layer to a second layer, and the desired output pattern is stored on the weights connecting the second-layer neurons to the output layer. The input and output patterns may not be the same. After the weights are learned, the output pattern will be produced. This is similar to remembering a pattern when events remind one of it, rather than seeing it again.

In NN, learning takes place within the system. It is the NN system's task to learn by adjusting these weights as exposed by a given data. So, learning is an integral part of NN.

A Neural Networks is a computing system which consists of a number of simple, highly interconnected processing elements. Neural Networks process information by determining the value of an output signal based on the values of several input signals (Wilson & Sharda-1990). For example Wilson & Sharda describes a small NN which has a neuron with input values of three and six, and with corresponding weights of 0.2 and 0.1, will have the output value of 1.2. They reported also, that Angel & Cran modified the weighted sum of the neuron inputs by a mathematical transfer function. The transfer function modifies the weighted sum of the input values to a reasonable value before passing the signal onto the next layer. If the input sum were not modified, the output could become very large, especially with many input connections.

The following formula will transform any real number into a number between zero and one.

$$f(X) \equiv (1 + e^{-X})^{-1} \text{ where } e = 2.71828$$

In the example above, $f(1.2)$ becomes 0.76852.

There are a large number of Neural Networks shells available (Dologite-1993). Three well-known systems are:

- a. BrainMaker, which was developed by California Scientific Software, has two versions. Its lowest priced version cost is around \$200, and its professional version cost \$800.
- b. NeuroShell, which was developed by Ward Systems Group, is one of the least expensive shells. Its only version costs around \$220.
- c. NeuralWorks NN shell, which was developed by NeuralWare, is a more powerful and expensive Neural Networks tool. It sold for around \$2000.

The author chose BrainMaker V3.1 for Windows "Neural Network Simulator" by California Scientific Software for the cytology personnel classification problem because it is available commercially, and it is easy to use. It imports data from Lotus, Excel, and dBASE. BrainMaker shell processes 750,000 connections per second. Also, BrainMaker checks Network error rates during training, and checks files for errors and inconsistencies.

Since Neural Networks learn by examples, they have been used as an alternative to or with Expert Systems (Zahedi-1991). NN's are useful in applications that have imprecise answers, and are more effective when the level of fuzziness and uncertainty are high in the problem to which we apply them.

NN's have been used in classification and pattern recognition problems such as in:

- a. Signature validation (Francett-1989), the NN identified, forged signatures more accurately than human experts.
- b. Breast Cancer Cell Analysis (California Scientific Software-1993), the BrainMaker shell was used to analyze images, and ultimately ignored healthy cells and classified malignant cells as cancer cells.
- c. Hospital Expenses Reduction (California Scientific Software-1993), the Anderson Memorial Hospital improved the quality of care, reduced death rate, and saved \$500,000 in the first 15 months using BrainMaker shell in pattern recognition.
- d. Cervical cancer screening (Mango-1994).
- e. Survival Time Prognosis (California Scientific Software-1993), the Hvidovre Hospital, Denmark used BrainMaker shell in developing a program which predicted the survival longevity of patients diagnosed with cirrhosis of the liver.
- f. Cancer screening (Remnic-1990 & Shandler-1993).

Perhaps the most important advantage of NN is its adaptivity. NN adjusts its connection weights to optimize behavior as pattern recognizer, decision makers, system controllers, predictors, and so forth. Self-optimization allows the NN to design itself (Widrow et al-1994). The system designer first defines the NN architecture (input, hidden layers, and output) and chooses the number of layers. According to the pattern presentation, the training methodology for the

network will be chosen. The NN then adapts to the application. Adaptivity allows the NN to do well even when the environment varies over time.

NN is not programmed with rules, like an Expert System. It learns by example and repetition. It is trained by presenting a set of facts over and over again to the network until the network gets them correct. Each time a fact is presented, the network produces an output. The training pattern portion of the fact is used to determine if the network was right or wrong. The error size is the difference between what the network actually output and what the training pattern says is correct.

NN's learn by example, but unlike ES's, they cannot give explanations about how decisions were arrived at. Integrating NN with ES may overcome this drawback. Many researchers believe that, the future lies in developing integrated systems, which combine conventional computer systems, ES and NN (Lee-1992). A comparison between ES and NN technology is shown in the following table (Gallant-1988, Herrmann-1995, Hillman-1990, Knight-1990 & Yoon-1993 and 1994).

Table 1

A Comparison between Expert system and Neural Network

| Characteristics | ES | NN |
|--------------------------|---|--|
| Knowledge | Knowledge is stored explicitly as production rules or frames. Excel at cognitive tasks | Knowledge (examples or history) is stored implicitly as interconnection weights. Excel at perceptual tasks. |
| Reasoning | It relies on deductive reasoning to arrive at conclusion. Can explain its reasoning | It uses inductive approach in recognizing patterns. Has difficulty explaining its reasoning. |
| Problem Solving | the inference engine guides the rules serially, to arrive at decisions | Connections' weights identify in parallel the patterns |
| Training | Rules are changed externally by the knowledge engineer | Training is done internally, using patterns data provided by the designer |
| Search | Most expert systems use backward chaining, forward chaining, reduction, unification, hypothetical reasoning, incremental reasoning and constraint propagation methods in traversing the knowledge base and arriving at new facts | Most NN's use the nearest match approach for recalling what it has been learned |
| Data presentation | The input data are introduced step-by-step during the consultation | The input data are presented in the beginning of the consultation |

1.3.5. Connectionist Expert System

Expert systems process knowledge sequentially, represent it explicitly, and mostly use deductive reasoning (Zahedi-1991). By contrast, NN uses the parallel approach to stimulate human intelligence. ES and NN have each displayed some specific advantages and disadvantages. As shown in Table 1, the ES do not recognize all the patterns as NN does because they arrived at the decision serially. So most of the ES errors are underassessment, which are less serious than overassessment encountered by NN.

Neural Networks and Expert Systems have their niches. NNs are better at problem diagnosis, decision making, and other classifying problems where fuzzy logic is important. Expert Systems excel where there are hard and fast rules.

ES&NN is used in classification and pattern recognition problems such as:

a. Analyzing the financial health of small businesses (Baker-1990). The ES&NN performs two main tasks: (1) Interpreting the financial ratios of a company and (2) estimating the likelihood that a firm can raise additional capital through borrowing.

b. Hecht-Nielson Neurocomputer Corporation is working on a large project combining Neural Networks and Expert Systems for pattern recognition. One of the company's tools is using ES&NN for the development of a medical diagnostic system (Sherald-1989).

c. Duke University developed an Artificial Intelligence (AI) product called DUCALL or Duke University Computer Assisted Language Learning Project.

DUCALL has 200 systems installed and in use in the Netherlands and U.S. Military Academy at West Point, N.Y. (Sherald-1994).

1.3.6. CLIA`88 Regulations

The implementation of CLIA`88 began February 1, 1992, four years after the law was passed. The complexity model includes three regulatory levels, which were named: "waived, moderate complexity, and high complexity levels."

The most stringent personnel qualifications are applied to the high complexity approved laboratory. The director of the high complexity laboratory must have a doctorate level. In the mean time, the moderate complexity laboratory does not require a doctorate level directorship.

Boone (1992) showed that the more experience and training of the technical staff, the better performance of these laboratories that do manual tests or require independent judgment, such as cytology screening. Crawley et al (1986) found that laboratories with supervisors who had formal training and experience had better performance than other laboratories.

A recent study in the Laboratory Medicine Journal by Pelehach (1997), supports what certified laboratory professionals long have believed: lack of continuing education of testing personnel hurt laboratory performance. The study conducted in the state of California, demonstrated that Physicians' Office Laboratories (POL's) which do not employ licensed medical technologists failed proficiency testing at more than four times the rate of non POL's which employ licensed medical technologists (Pelehach-1997). Physician Office Laboratories

that employ licensed medical technologists in some capacity fared better than POL's without licensed staff, but failed proficiency tests twice as often as licensed clinical laboratories, which employ licensed testing personnel.

The preliminary findings of this objective study show that education and training are key to quality performance of clinical laboratory tests (Laboratory Medicine-1997). The above studies support the rationale of the implementation of CLIA'88 regulations.

1.4. Theoretical Framework

The author developed the ES, NN, and ES&NN for the Cytology Personnel Problem, upon reviewing the role of AI in classifications and pattern recognition. Assumptions will be discussed in this section, and hypotheses will be discussed in the next section.

The following are assumptions and opinions of many papers (Gallant-1988, Lee-1992, Sherald-1989, & Weigend-1990):

a. ES&NN is preferable to either ES or to NN because it combines the advantages of the explanation facility from ES and those of the pattern recognition ability of NN.

b. ES&NN identifies any evaluation discrepancy between the ES and NN. This leads to further investigation by Human Experts, which will ultimately increase the confidence in the resulting classification validity.

c. ES, NN, and ES&NN are each more economical in doing cytology

personnel evaluations than Human Experts as they are more flexible, convenient, and can be administered by clerks who are paid less than experts. These tools do the personnel classification at least as accurately as real experts, who do such classification in their daily work.

d. ES is more accurate than NN in personnel evaluations. Most of the ES errors are of the underassessment, which are less serious than the overassessment encountered by NN. ES explains its decision, which NN does not.

In this study, three experiments were performed, to prove or disprove these opinions or assumptions.

1.5. HYPOTHESES

These general propositions lead to the following hypotheses, which were tested in this research:

1. ES&NN is more accurate in the cytology personnel evaluations (how well the cytology personnel evaluations performed in comparison to a correct evaluation of CLIA'88 regulations?) than:

Hypothesis 1a. ES.

Hypothesis 1b. NN.

2. ES is more accurate than NN in cytology personnel evaluations.

3. Human Experts are less accurate in cytology personnel evaluations than:

Hypothesis 3a. ES.

Hypothesis 3b. NN.

Hypothesis 3c. ES&NN.

4. Human Experts are less consistent (is the system able to replicate its results?) in cytology personnel evaluations than:

Hypothesis 4a. ES.

Hypothesis 4b. NN.

Hypothesis 4c. ES&NN.

A three level scoring system of the values evaluation entities are used in this study:

- a. Correct assessment is given the score of three
- b. Underassessment is given the score of two
- c. Overassessment is given the score of one

A correct evaluation of an applicant's qualification is one which conforms precisely to CLIA'88 requirements. An underassessment evaluation is one which the applicant has been classified lower than his or her correct classification by CLIA'88 requirements. For example, suppose the applicant is qualified as cytosupervisor, but the system under evaluates him or her as a cytotechnologist only or worse, as unqualified for cytology work. Another example, suppose that the applicant qualified as a cytotechnologist per CLIA'88 regulations, but the system identified him or her as unqualified. As noted, the grade for underassessment is two.

An overassessment is one in which an applicant has been classified

higher than his or her rank according to CLIA'88 regulations. For example supposes the system evaluated the applicant as a cytosupervisor, but the applicant is only qualified as a cytotechnologist according to CLIA' 88 regulations.

Another example, the system evaluates the applicant as a cytotechnologist, but he or she is not qualified as a technical personnel in cytology. The grade for overassessment is only one.

The reason that the score of overassessment is lower than underassessment is the greater danger of entering unqualified personnel in the cytology field because of overassessment. In the other hand, underassessment of cytology personnel will not cause any harm to patients.

The percentage of errors in screening cancer cells is more when unqualified personnel work. These errors can cause death or injury to patients, which will increase law suits. It also increases the health care costs due to the increase of malpractice insurance. The only disadvantage of underassessment evaluation is the decreasing of the number of qualified personnel. This will reduce the pool of qualified cytology personnel. Under evaluated individuals will have the right to appeal.

2. METHODOLOGY:

The success of the classification of personnel according to known cases is the dependent variable. Every system will have a rating score depending on its performance. The score is varied from one for overassessment, to two for underassessment, to three for correct assessment. The averages of the different cases determine the rating score for each system. The applicant personnel qualifications are the independent variables. Every applicant has different qualifications according to eight criteria. These criteria are education, experience, training, degrees, boards, delegation, licenses, and dates of employment.

The evaluation of each applicant was done by using these Artificial Intelligent (AI) systems (ES, NN, ES&NN). Also, Human Experts (Certifying Agency Evaluators) and Users (Clinical Laboratory Evaluators) did the personnel evaluations for the previous cases.

The research framework for this study combines elements from the Health Care, Information Systems, and Personnel Evaluations fields. In figure 4 the author presents a system overview diagram of the Experimental Framework (input/output model). Please see Figure 4.

2.1. Research Framework

The cytology personnel evaluation model is presented in Figure 4. The figure shows input, process and output phases. There are eight inputs into the CLIA'88 cytology personnel qualifications: education, experience, training, degrees, boards, technical supervisor's delegation, licenses, and dates of employment. The outputs are: four technical supervisor codes, two general cytosupervisor codes, eight cytotechnologist codes, and six unqualified codes. The personnel evaluations were carried out independently by the Artificial Intelligence systems (ES, NN, and ES&NN), by the Human Experts (Credentials Agency Evaluators), and by the Users (Clinical Laboratory Evaluators). An explanation of the model variables follows:

a. Input

The input consists of the applicant's qualifications. It contains eight different categories according to CLIA'88 Regulations.

Education - There are different education requirements. The education requirements range from high school diplomas, Associate degrees, Bachelors, Masters, Doctorates, and Medical Degrees. Only high school diplomas will be considered for qualifying the applicant as a cytotechnologist before January 1969. Only the Medical Degrees will qualify the applicant as a technical supervisor.

Experience - This includes pre-experience and post-experience. Experience ranges from six months to twenty-four months for pre-technologist

qualifications. For post experience qualifications, the applicant must have more than thirty-six months in order to be qualified as a general cytosupervisor.

Training - This includes less than six months, from six months to less than twelve months, and twelve months or more. Training must be done in approved clinical laboratories to be accepted toward personnel evaluations.

Degrees - These include passing CAHEA-accredited school of cytotechnology examination, or certifying in cytotechnology by certifying agency approved by the Health and Human Services(HHS), or the applicant must achieve a satisfactory grade in a proficiency examination administered by the HHS.

Board Certification - The success in the board certification is required in order for the applicant to be qualified as a technical supervisor.

There are three board certifications:

- a. American Board of Anatomic Pathology,
- b. American Board of Clinical and Anatomic Pathology
- c. American Board of Cytology.

Delegations - An individual, in the final year of a training program leading to the American Board of Pathology certification in Anatomic and Clinical Pathology or Anatomic Pathology or the American Board of Cytology, must obtain delegation from a technical supervisor in order to be approved as a technical supervisor. The technical supervisor's delegation must be obtained from a qualified technical supervisor.

Licenses - Some states issue licenses for cytotechnologists and/or cytosupervisors. The applicant must obtain such licenses to be considered for approval as a technical cytology personnel.

Dates of Employment - Applicants who held a job before January 1, 1969, have different requirements than those who held jobs after December 31, 1968.

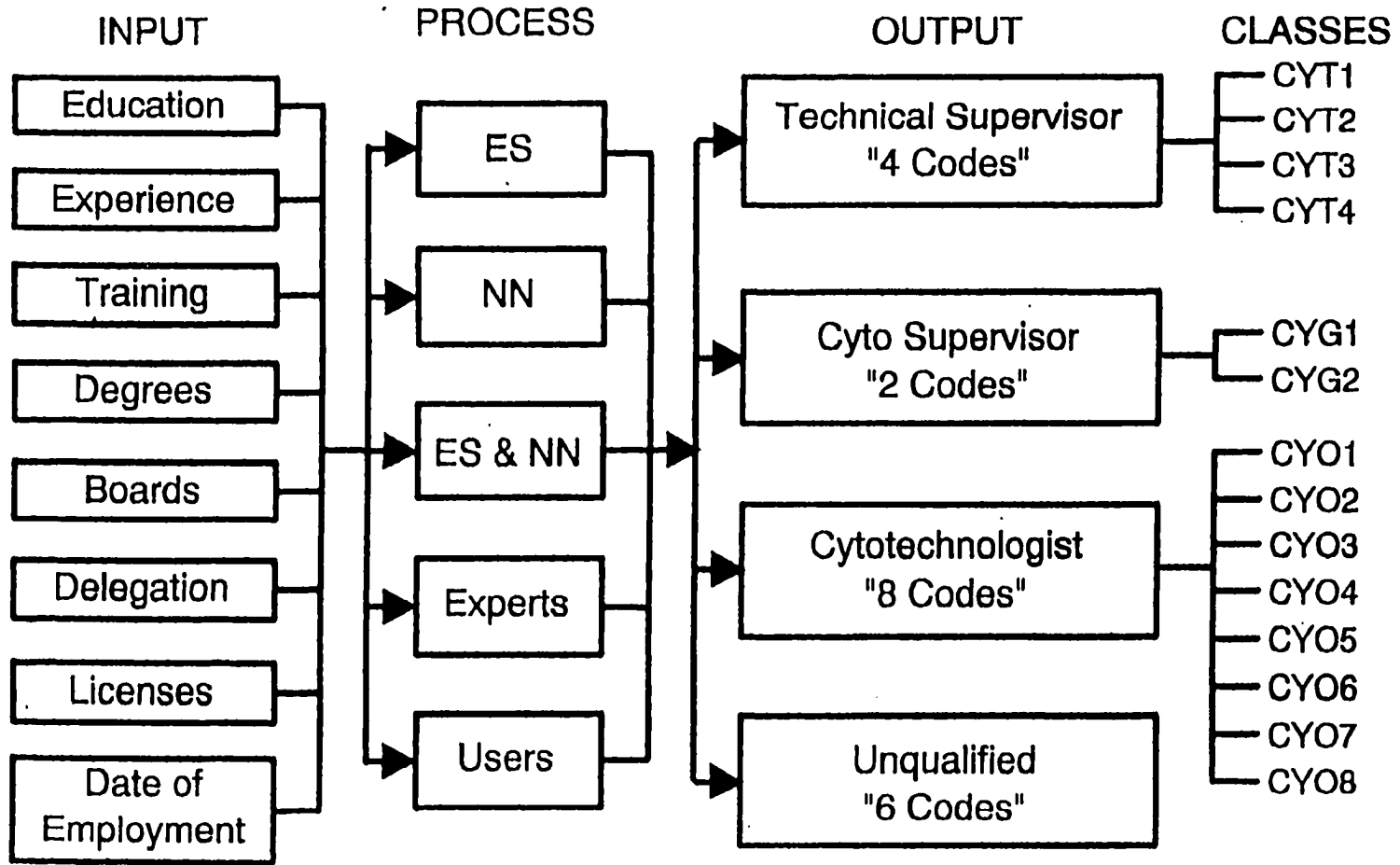
b. Process

The applicant's qualifications were introduced to these Artificial Intelligent systems (ES, NN, and ES&NN). The same qualifications were also evaluated by Human Experts (Certified Agency Evaluators), and Users (Clinical Laboratory Evaluators).

c. Output

The Intelligent Systems and Human Experts competed in evaluating cytology personnel according to CLIA'88 regulations. There are twenty codes (fourteen approved codes, and six unapproved codes). The success or lack of success in the Cytology personnel evaluations is used to determine the score of each system. The differences in evaluations between these systems were analyzed.

FIGURE 4
EXPERIMENTAL FRAMEWORK
(System Approach)



2.2. Procedure

The general method of this research is:

A. Define the steps for evaluating personnel according to CLIA'88 regulations. These steps are grouped in five modules.

B. Develop flow charts and decision tables for personnel classifications. Please see Figures 1, 2, 3, 4 & 5 in Appendix C.

“Refer to Appendix C”

C. Extract decision rules from the flow charts, as shown in Appendix D. This is an example of Expert System rules, which is a fragment of the ES program developed by the author in the language of VP-Expert shell. This represents two of the fifty-two rules which are contained in the ES knowledge base.

“Refer to Appendix D”

D. Build a knowledge data base for the Expert System.

E. Develop the connections between modules and rules through trial and error. Figure 6 in appendix C, shows the framework of the Expert System (ES). The system will ask the operator, “what is the applicant’s education?” then the system will approve or disapprove according to the applicant's data. The system will terminate the evaluation if the applicant does not have an approved education or has only foreign credentials. Then the

system will ask about training and/or experience. Finally the system will ask about licensing.

According to the approval or disapproval of the technical supervisor by the system, the ES has three outputs. The first output indicates that the applicant is evaluated as unqualified cytology personnel. If the applicant is not approved as a technical supervisor, and does not possess the required training, experience, or licensing requirements, the evaluations for these applicants will be ended through exit 1. The second output is that the applicant is qualified as a technical supervisor. If the applicant is approved as a technical supervisor, the evaluation code will be stored in TempExit 1, then the data will go to the Cyto5 module for cytosupervisor evaluation. If the applicant is approved as a general cytosupervisor, then the ES evaluation is a technical supervisor and cytosupervisor which will be ended through exit 2. If the applicant is not approved, the data will go to the cytosupervisor module for further evaluation. If the applicant is approved, the applicant's evaluation will exit as a technical supervisor and a cytosupervisor through exit 2. If the system did not approve, the applicant's evaluation will exit as a technical supervisor and a cytotechnologist through exit 5.

The third output is that the applicant is not approved as a technical supervisor, but has the applicable training, experience and license. Then the data will go to the Cyto5 module. If the system did not approve the applicant as a cytotechnologist, then the applicant's evaluation will exit as unqualified through exit 1. If the system approves the applicant as a cytotechnologist, the data will

be stored in Temp Exit 2, then go to the cytosupervisor module. If the applicant is approved as a cytosupervisor, the applicant's evaluation will exit the system as a cytosupervisor and a cytotechnologist through exit 4. If the applicant is not approved, it will exit as a cytotechnologist only through exit 3.

This design will enable the evaluators to solve a complex problem as the personnel evaluations' problem.

“Refer to Appendix C”

F. Verify, evaluate, and test the system.

Verification refers to building the expert system right. It is a process of ensuring that each component of the system is traceable to a specification. Verification refers to the system's fulfillment of its purposes and User requirements (Liebowitz, 1989). The VP-Expert shell has a verification command build in it to identify any discrepancies in the program.

Validation refers to building the right system which, has an acceptable level of accuracy. Validation ensures that the system is consistent and complete. Evaluation is assessing the Expert System's overall value. Besides exhibiting acceptable performance levels, the Expert System must be usable, efficient and cost effective. Evaluation enables a feedback process to take place by which the comments serve as a basis for iterative refinement (Liebowitz, 1989 & 1997). Evaluations help to detect the accuracy of the embedded knowledge

and the accuracy of any advice or conclusions that the system provides (Gasching et al, 1983). Bellman (1990) defines validation as the determination of the correctness of the software. Testing means running test cases on the system and comparing the results with Human Experts (Bahill, 1991).

The author modified the knowledge base modules as required by the validation/evaluation process by adding, changing and deleting module components.

G. Compare the results of ES with Human Experts. Refine the system by comparing its explanation with the actual and correct decisions according to CLIA`88 regulations. This validation/evaluation process is repeated until the ES model can make acceptable decisions as judged by a panel of four Human Experts from New York State Department of Health.

H. Build the NN system by writing examples in Excel 5 and transfer them to Excel 3 because the BrainMaker shell is compatible only with Excel 3. Then transfer the data to the NetMaker in which, the author specified the inputs and outputs. Please see Appendix E. After transferring the data to the BrainMaker shell, the training and testing of the system will take place. This training process is repeated until the NN model has made acceptable identification of the Cytology personnel codes with small errors.

The NN credentials module has seventy-one examples as shown in Appendix E. The cytology NN includes five modules, namely the credentials, license, technical supervisor, Cyto5, and cytosupervisor modules. These modules have from seventy to one hundred examples. The credentials module

contains nine inputs: education, required training, applicant's training, required experience, applicants' experience, HHS certificate, transcript, HHS examination, and cytology job. It has only one output (the applicant has complete credentials).

If the applicant has these credentials a value of (1) will be assigned in the NN shell, or (-1), if the applicant does not have these credentials, or (0) which means that these credentials are not applicable. The BrainMaker shell requires this scoring system.

“Refer to Appendix E”

I. Construct the ES&NN system as shown in Figure 7 in Appendix C. CLIA'88 codes' identifications are made in the NN system, and the explanation of the rejections are then provided by the ES system.

As shown in Figure 7 in Appendix C the data are presented to the credentials, license, and physicians NN modules. If the applicant is not approved as complete, the data is transferred to the credentials and license ES modules in order to give the reasons for rejections. If there are discrepancies, the data are introduced to Human Experts for further investigations. If the applicant has a complete file, the data will go through the technical supervisor, Cyto 5 and cytosupervisor NN modules for codes identifications.

If the applicant is classified as not qualified, the data will transfer to the applicable ES modules for generating the reasons for rejection. If the applicant

is classified as qualified, the codes will be exited from the NN modules. The final data are introduced again to the technical supervisor, Cyto5, and cytosupervisor ES modules. If there are discrepancies between the ES and NN, the data are introduced to the Human Experts for solving any discrepancies.

“Refer to appendix C”

J. In experiment one, fifty random cases (applicants) from New York State Department of Health files were introduced to the ES, NN, and ES&NN systems. These cases contain the twenty Cytology personnel codes (fourteen approved codes and six unapproved codes). Four Human Experts working in the New York State Department of Health evaluated the same cases without being aware that they were competing with the three Artificial Intelligent (AI) systems developed in this research.

K. Another experiment was undertaken. ES, NN, and ES&NN evaluated sixty-four previously evaluated cases from Smith Kline, Metpath and Enzo clinical laboratories, which were submitted to the Federal Government. The personnel evaluation comparison among ES, NN, ES&NN and users were analyzed.

L. In the third experiment a questionnaire for Cytology personnel evaluations was developed. The questionnaire contains fifteen cases (applicants), covering the twenty possible codes, as an applicant can have more

than one code. Please see Appendix F. Three hundred questionnaires were sent to Human Experts(Certifying Agency Evaluators) and Users (Clinical Laboratory Evaluators). Eighty six-valid questionnaires were received and analyzed.

“Refer to Appendix F”

The results of these previous experiments are shown in Chapter 3 (Research Results).

2.3. Statistical Analyses.

The statistical analyses were done in order to evaluate the performance of ES, NN, ES&NN, Human Experts and Users. The statistical methods that were used in this research are done for experiments J, k, and l in section 2.2.

a. Descriptive analysis

1. Standard deviations, and scores,
2. Confidence intervals, which are the range on the sample mean, are calculated by this formula:

$$95\% \text{ confidence level} = \bar{x} + 1.96 * \sigma / n$$

Where:

σ = Standard Deviation

n = Number of units in the sample

\bar{x} = The sample mean

b. Hypotheses testing

A grading system made up of three groups were used:

1. Underassessment with the score of two
2. Correct assessment with the score of three
3. Overassessment with a score of one

Underassessment has the score of two because it has less potential to do damage than overassessment which has a score of one. Overassessment will introduce unqualified cytotechnologists into the laboratories, which will increase the error rates. Underassessment will decrease the number of qualified personnel, who have the option of appealing for reevaluations.

The SPSS for windows release 6.0 package was used to compute the t-test for independent -samples, and F Ratio to evaluate these hypotheses: 1a, 1b, 2, 3a, 3b and 3c. Descriptive analysis will compare the performance between ES, NN, ES&NN, Human Experts, and Users which will evaluate the above hypotheses besides hypotheses 4a, 4b and 4c.

The Independent-samples t-test formula is:

$$t_{\text{obt}} = \frac{(\bar{X}_1 - \bar{X}_2)}{\sqrt{(S^2_1 + S^2_2) / (n_1 + n_2)}}$$

Where t_{obt} is the t value obtained by calculation, \bar{X}_1 is the sample mean of group

1, S^2_1 is the variance, and n_1 is the sample size of group 1.

The F Ratio is calculated by this formula:

$$F_{\text{obt}} = \frac{\text{between-groups variance estimate } (S^2_B)}{\text{within-groups variance estimates } (S^2_W)}$$

$$\text{If } F_{\text{obt}} \geq F_{\text{crit}} \quad \text{reject } H_0$$

$$\text{If } F_{\text{obt}} < F_{\text{crit}} \quad \text{fails to reject } H_0$$

Where F_{obt} is the F value obtained by calculation, and F_{crit} is the critical values of F for the specified degrees of freedom.

$$\text{The equation for } S^2_B \text{ is } = n \sum (\bar{X}_B - \bar{X}_G)^2 / K - 1$$

Where

$$\bar{X}_G = \text{grand mean (overall mean of all the scores combined)}$$

$$K = \text{number of groups}$$

The Within groups sum of squares (S^2_W) is calculated by multiplying each of the group variances (the squares of standard deviations) by the number of cases in the group minus one, and then adding up the results.

2.4. The Cytology Expert System

A Knowledge-Based System (KBS) that evaluates the technical personnel according to CLIA`88 regulations was developed and tested. This ES assigns codes depending on the applicants credentials and licenses. ES shows the reasons for disqualification.

2.4.1 The Situation to be Prototyped

The general area under study is identifying the technical personnel codes according to CLIA`88 regulations. There are ninety-three different codes or routes for the technical personnel working in clinical laboratories as shown in Appendix A. Every code or route has a specific education, training, experience, and license requirements.

2.4.2. The Cytology Expert System

As shown in Figure 6 in Appendix C, the applicant's qualifications are introduced to ES step by step. The module will ask questions and the users will give responses. According to the information given by the user, the ES system will evaluate the Cytology personnel into fourteen qualified codes and six unqualified codes. The ES will explain how it arrived at decisions upon request. Please see Appendix G2. Software consists of a knowledge base and inference engine.

The knowledge base contains a well-defined body of knowledge about a subject. Here, the cytology personnel classification criteria are included. The

inference engine guides the program during the consultation. The prototype was developed using the VP-Expert professional shell and took about nine months to complete. This Expert System consists of fifty-two IF-THEN rules. Appendix D shows two license rules, as an example.

The design follows user interface principles (Handler and Lewis, 1988). Handler and Lewis advocate frequently-reported interim conclusions and explanations during a consultation. The final recommendation screen includes a concluding message and the applicant's codes or reasons for rejection. The conclusion can be printed as reports, which can be sent to the applicants and/or kept in the Credential's Agency. Please see Appendix G1.

ES contains five modules. The author verified, validated and tested every KBS individually and collectively on several levels. Actual historical data was used in the preliminary tests. The cytology personnel evaluations made by the ES were then compared with the actual evaluations carried out by Human Experts. The prototype was field tested by the users (Clinical Laboratory Evaluators).

2.4.2.1. The Credentials Module

The Credentials Module contains nine production rules. It evaluates the completeness of the applicants credentials according to education, training, and experience as shown in figure 1 of Appendix C.

“Refer to Appendix C”

2.4.2.2. The License Module

The License Module is constructed of fourteen rules. It matches the state's license requirements with the applicant's license. Cytology personnel evaluations depend on the license requirements and the cytology job.

Four categories emerge from the consultations with the credentials and license modules:

- a. Cyto-requirement is approved because of complete credentials and a complete license.
- b. Cyto-requirement is not approved because of incomplete credentials only.
- c. Cyto-requirement is not approved because of incomplete credentials and unapproved license.
- d. Cyto-requirement is not approved because of unapproved license only.

2.4.2.3. The Technical Supervisor Module

This module contains seven production rules. It evaluates the applicant according to their medical degrees, permits, professional boards, training, and delegations from approved technical supervisor. Figure 3 in Appendix C describes the flow chart for the evaluation process. This system's module

identifies the four technical supervisors' codes.

2.4.2.4. The Cyto 5 Module

This module contains nineteen rules. It coded the applicant according to education, experience, training, professional examinations, technical supervisor evaluations, and Cyto-requirement status. Figure 5 in Appendix C describes the flow chart for this module evaluation process. Eight cytotechnologist codes and two cytosupervisor codes are identified in this module.

2.4.2.5. The Cytosupervisor Module

This module contains three rules. This module evaluates the technical personnel according to the applicant cytotechnologist credentials, a cytosupervisor job held, and the applicant experience after qualifying as a cytotechnologist. It identifies only one cytosupervisor code, which is qualified by the experience track.

2.4.3. Expert System Connectivity

Due to the complexity of the personnel requirements, the author used two types of connections in designing the Expert System. Modules and rule connections were used.

2.4.3.1. Modular connections

The author made connections from the credential module to the license module to the technical supervisor module to the Cyto5 module, and ended in

the cytosupervisor module. Please see Figure 6 in Appendix C. All the information is saved and transferred to the next module by using the commands embedded in the VP-Expert professional shell.

“Refer to Figure 6 in Appendix C”

2.4.3.2. Rule Connections

These connections enable the system to exit when the evaluation is completed, as shown in Figure 6. For example, ES ends the evaluation in the credentials module, if the applicant has a foreign education.

2.5. The Cytology Neural Network

BrainMaker V3.1 for Windows "Neural Network Simulator" by California Scientific Software was used to identify the technical personnel codes of CLIA`88 Regulations. When setting up a Neural Network, one must decide how many nodes to have in the input and hidden layers. Once the number of layers and nodes per layer had been decided, then the weights assigned to each node were adjusted. Initially, weights were chosen at random, and then were refined through training.

The input nodes are equal to the CLIA`88 requirements, which differ from one module to the other. The output nodes match the evaluation codes, which also differ from one module to the other. The number of input nodes ranges from

seven nodes in the License module to fifteen nodes in the Cyto 5 module. Also, the output nodes differ from one output in the License module to eleven nodes in the Cyto 5 module.

Assignments of input and output nodes were done in the BrainMaker spread sheet of NN. BrainMaker has the capacity to use eight hidden layers. Only one hidden layer was used in this research. A comparison study was undertaken in this dissertation, which showed no substantial differences by using more than one hidden layer. Please see Section 3.3. The more hidden layers, the more connections NN will use to arrive at decisions, and the more time for training.

2.5.1. Neural Networks Advisor (NN)

NN contains these five modules: The credentials module, license module, technical supervisor module, Cyto 5 module and cytosupervisor modules. Examples are used to construct the knowledge base for NN. The examples were written in Excel 5 Version, then the data was translated to Excel 3 version work sheets as shown in Appendix E. Inputs and outputs were assigned by the author in the NetMaker shell, and then transferred to the BrainMaker for training and testing.

“Refer to Appendix E”

2.5.2. Neural Network Connectivity

Neural Networks do not use rules. Only modular connections are used. The credentials module is connected to the licence module, to the technical supervisor module to the Cyto 5 module, and ends at the cytosupervisor module.

2.6. The Cytology ES & NN Advisor (ES&NN)

Most Expert Systems use a deterministic approach. Some Expert Systems use classical probability for the treatment of uncertainty. ES relies on deductive reasoning in that the knowledge and facts were given to the system (Zahedi, 1991).

NN uses statistical approach (White, 1989). It assumes the existence of errors and ambiguity in its underlying foundation. Also, NN uses an inductive approach, and it is driven by data. NN and ES have different data requirements. ES requires that the knowledge be coded in advance as production rules. NN on the other hand, requires data in its raw form, and occasionally it needs a massive amount of data.

The integration of ES and NN has enabled the author to combine the advantages of these two different technologies. There are many different combinations of assembling the ES & NN systems. The ES & NN system that is developed in this research, is shown in Figure 7 in Appendix C. The personnel classifications are done in the NN, and the unqualified cases will be connected to ES for explaining the causes of rejection.

“Refer to Figure 7 in Appendix C”

3. Research Results

There are two areas in which the results will be interpreted in this dissertation. The first will be the examination of the performance of ES, NN and ES&NN systems. The second area will be the comparison of the performance of the above systems with the performance of Humans. The evaluations of these systems were completed by performing three experiments as shown in Steps J, K and L in the procedure (Section, 2.2). As described in Section 1.5, the three level grading system has three outputs (underassessment, correct assessment and overassessment).

Underassessment will decrease the number of qualified personnel, who have the options of appealing for reevaluation. Some Human evaluators are risk seeking. They try to underestimate in their evaluations. Other evaluators are risk averse. They try to avoid complaints. They tend to overestimate in their personnel evaluations. Unqualified cytology personnel will be introduced in the system because of the personnel overvaluation, which will increase the error rates in cytology screening. These errors can cause death or injury to patients. Under evaluating the cytology specimens will cause late treatments of cancer, which can cause death. Over evaluating the cytology specimens can cause unnecessary surgery. Some patients have lost healthy organs due to these errors. These errors will increase malpractice suits, which will increase the health care costs.

The introduction of Artificial Intelligence systems in this study, will ultimately decrease these errors in interpreting cancer cells, by helping clinical laboratories to employ only qualified personnel. Also, the cytology personnel evaluations will be more consistent, when performed using Artificial Intelligence systems.

The score of every system is calculated by dividing the total grades by the number of cases. For example if the system correctly evaluated a case, it will obtain a grade of 3, and if the system under evaluated a case, it will obtain the grade of two. The score measures the accuracy of the system. The higher the score, the more accurate the system. Consistency or precision is measured by the standard deviation and confidence intervals. The lower the previous measures, the more consistent and precise the system.

3.1. Discussions and analysis

Table 2
Comparison of ES, NN, ES&NN and Human Experts

| | Score Nominal Scale (1 to 3) | Standard Deviation | 95% Confidence Interval Length | 99% Confidence Interval Length | 95% Range | 99% Range |
|--------------------------------|---|-------------------------------------|---|---|----------------------------|------------------------------|
| ES | 2.79 | 0.48 | 0.13 | 0.18 | 2.66-2.92 | 2.61-2.97 |
| NN | 2.56 | 0.50 | 0.14 | 0.19 | 2.42-2.70 | 2.37-2.75 |
| ES&NN | 2.96 | 0.36 | 0.10 | 0.14 | 2.86-3.00 | 2.82- 3.00* |
| Human Experts | 2.21 | 1.15 | 0.16 | 0.22 | 2.05-2.37 | 1.99-2.43 |

Sample Size (ES, NN and ES&NN) = fifty cases chosen at random from New York State Department of Health files.

The sample sizes of four real experts are four multiplied by fifty cases.

*** The perfect score is 3**

The scores, standard deviations, the confidence intervals, and the ranges for fifty cases for ES, NN, ES&NN and four Human Experts are calculated in the above table. The results indicate that ES, NN and ES&NN are more accurate (higher scores) in cytology personnel evaluation than Human Experts. These

support hypotheses 3a, 3b and 3c. These results show that, ES&NN is more accurate than either of the ES or NN systems, which supports hypotheses 1a and 1b. The standard deviations, and confidence intervals for ES, NN and ES&NN are lower than those for the Human Experts which shows that these Artificial Intelligence systems are more consistent in their evaluations than Human Experts. According to Table 2, about 99% of ES&NN evaluation scores will be from 2.82 to 3.00, if we repeat the experiment again. In the mean time the score of Human Experts is from 1.99 to 2.43 with 99% certainty. These support partially hypotheses 4a, 4b and 4c. Three hundred questionnaires were sent to Human Experts and Users in order to get more data to support the above hypotheses.

Table 3
Comparison of ES, NN, ES&NN and Users

| | Score Nominal Scale (1 to 3) | Standard Deviation | 95% Confidence Interval Length | 99% Confidence Interval Length | 95% Range | 99% Range |
|------------------|---|-------------------------------|---|---|----------------------|----------------------|
| ES | 2.58 | 0.37 | 0.09 | 0.12 | 2.49-2.67 | 2.46-2.70 |
| NN | 2.46 | 0.38 | 0.09 | 0.12 | 2.37-2.55 | 2.34-2.58 |
| ES&NN | 3.00 | zero | zero | zero | 3.00 | 3.00* |
| Users | 1.77 | 0.87 | 0.21 | 0.29 | 1.56-1.98 | 1.48-2.06 |

Sample Size = 64

The perfect score is 3

Sixty-four actual cases were evaluated by ES, NN, and ES&NN systems. Three Clinical Laboratories (Users) previously reported these cases to the Health and Human Services department as required by Law. The statistical analyses were done as above. In Table 3, ES, NN and ES&NN systems are more accurate in cytology personnel evaluations than Users. These findings support hypotheses 3a, 3b and 3c. Artificial Intelligence systems are more consistent in personnel evaluations than Users, as evidenced by their low standard deviations and confidence intervals. These support hypotheses 4a, 4b and 4c.

Table 4
Summary of t-test Results
(ES, NN, ES & NN and Humans)

| System | NN | ES&NN | Human Experts | Users | Humans and Users |
|------------------|------------------------------------|------------------------------------|------------------------------------|------------------------------------|------------------------------------|
| ES | Reject H_0 ... | Reject H_0 ... | Reject H_0 ... | Reject H_0 ... | Reject H_0 ... |
| NN | | Reject H_0 ... | Reject H_0 ... | Reject H_0 ... | Reject H_0 ... |
| ES&NN | | | Reject H_0 ... | Reject H_0 ... | Reject H_0 ... |

Sample size (Human Experts) = fifty

Sample size (Users) = sixty-four

*** Means significantly differently at a $p \leq .05$, two-tail test.**

**** Means significantly different at $p \leq .01$, two-tail test.**

***** Means significantly different at $p \leq .001$, two-tail test.**

For each measure of effectiveness, the following information will be presented:

The null hypothesis H_0 , for hypothesis 1a, 1b, 2, 3a, 3b, 3c, 4a, 4b and 4c is that there were no differences between the groups in the measure being tested.

The alternative hypothesis, H_1 , for hypothesis 1a, 1b, 2, 3a, 3b, 3c, 4a, 4b and 4c is that ES, NN, and ES&NN systems displayed better performances than human experts.

The t-test for independent samples were calculated to show the relationships between the Artificial systems, Human Experts, and Users. The following results were indicated:

1. ES is better than NN in the cytology personnel evaluations with t-test of 3.49 and probability of 0.001.
2. ES&NN is better than ES in the cytology personnel evaluations with t-test of 3.06 and probability of 0.0036.
3. ES is better than Human Experts the cytology personnel evaluation with t-test of 6.10 and probability of less than 0.00005.
4. ES is better than Users in the cytology personnel evaluations with t-test of 6.05 and probability of less than 0.00005.
5. ES is better than Humans and Users in the cytology personnel evaluations with t-test of 6.10 and probability of less than 0.00005.

6. ES&NN is better than NN in the cytology personnel evaluation with t-test of 3.61 and probability of 0.0007.
7. NN is better than Human Experts in the cytology personnel evaluation with t-test of 4.06 and probability of 0.0002.
8. NN is better than Users in the cytology personnel evaluation with t-test of 6.09 and probability of less than 0.00005.
9. NN is better than Human Experts and Users in the cytology personnel evaluation with t-test of 6.00 and probability of less than 0.00005.
10. ES&NN is better Human Experts in the cytology personnel evaluation with t-test of 6.10 and probability of less than 0.00005.
11. ES&NN is better than Users in the cytology personnel evaluation with t-test of 6.15 and probability of less than 0.00005.
12. ES&NN is better than Human and Users in the cytology personnel evaluation with t-test of 6.20 and probability of less than 0.00005.

In order to compare Human Experts, Users, and the AI systems in every class (unapproved personnel, cytotechnologists, and supervisors), the percentage of the correct evaluations was computed for every class. There are six codes for unapproved personnel class, four codes for cytotechnologists class, and six codes for cytosupervisors class. For example, the proportion of each class was calculated as if a system evaluates six codes correctly from the total of six codes, then the score is one, and if the system evaluates four cases correctly from six cases, then the score is 0.67. Then scores were transformed by using Sin^{-1} transformation as shown in Tables 5 and 6. The F ratios, and t-test were

calculated by SPSS software for the three groups (unapproved personnel, cytotechnologists, and supervisors), between Experts and Users as shown in Table 7. Three hundred questionnaires were sent to Human Experts and Users. Forty-two valid questionnaires were received from Human Experts, and forty-four valid questionnaires were received from users. Each questionnaire contains sixteen cases. The statistical results of the comparison between the performance of Human Experts and Users are shown in Tables 7 and 8 as follow:

Table 7
Comparison between Experts and Users

| Evaluators | unqualified Personnel | cytotechnologist | cytosupervisor | All Personnel |
|--------------------------|----------------------------------|-------------------------|-----------------------|----------------------|
| Human Experts | 0.64 | 0.72* | 0.61 | 0.65* |
| Users | 0.63 | 0.57* | 0.59 | 0.60* |
| Average | 0.64 | N/A | 0.60 | N/A |

The Credentials Agency Evaluators (Human Experts) are better than Clinical Laboratory Evaluators (Users) in evaluating the Cytotechnologist personnel with (0.0395) significant F Ratio and t-test.

The Human Experts are better than Users in evaluating the total Cytology personnel with (0.0144) significant F Ratio and t-test.

The author calculated the scores of every class as shown in Tables 5 and 6. The Sin^{-1} transformations were calculated in order to obtain whole numbers. There are no significant differences between the personnel evaluations of Experts and Users in evaluating unqualified personnel, and cytosupervisors with (0.9267, and 0.1219) as calculated by F Ratio and t-test. On the other hand, there are significant differences in evaluating cytotechnologists by Human Experts and Users as the probability is 0.0395 as calculated by the F ratio, and t-test. Certified Agency Evaluators are more accurate in evaluating cytotechnologists than Clinical Laboratory Evaluators, because cytotechnologists evaluations are more complex than the other classes. The personnel evaluations of the cytotechnologists' class involve many factors, some of which are not mutually exclusive. Because of the fact that Human Experts have more experience than Users, they are more superior in evaluating the cytotechnologist class than Users.

Table 5
Comparison between Human Experts

| Human Experts | Unqualified Correct : Total | Cytotechnologist Correct : Total | Supervisor Correct : Total | Total Personnel Correct : Total |
|---------------|--------------------------------|-------------------------------------|-------------------------------|------------------------------------|
| 1 | 6 : 6 | 2 : 4 | 3 : 6 | 11 : 16 |
| 2 | 5 : 6 | 3 : 4 | 2 : 6 | 10 : 16 |
| 3 | 6 : 6 | 1 : 4 | 3 : 6 | 10 : 16 |
| 4 | 4 : 6 | 3 : 4 | 4 : 6 | 11 : 16 |
| 5 | 4 : 6 | 4 : 4 | 3 : 6 | 11 : 16 |
| 6 | 2 : 6 | 4 : 4 | 6 : 6 | 12 : 16 |
| 7 | 3 : 6 | 2 : 4 | 5 : 6 | 10 : 16 |
| 8 | 5 : 6 | 3 : 4 | 5 : 6 | 13 : 16 |
| 9 | 3 : 6 | 2 : 4 | 5 : 6 | 10 : 16 |
| 10 | 2 : 6 | 2 : 4 | 3 : 6 | 7 : 16 |
| 11 | 4 : 6 | 4 : 4 | 3 : 6 | 11 : 16 |
| 12 | 4 : 6 | 2 : 4 | 3 : 6 | 9 : 16 |
| 13 | 3 : 6 | 3 : 4 | 4 : 6 | 10 : 16 |
| 14 | 3 : 6 | 3 : 4 | 2 : 6 | 8 : 16 |
| 15 | 4 : 6 | 3 : 4 | 3 : 6 | 10 : 16 |
| 16 | 3 : 6 | 2 : 4 | 2 : 6 | 7 : 16 |
| 17 | 6 : 6 | 1 : 4 | 2 : 6 | 9 : 16 |
| 18 | 2 : 6 | 3 : 4 | 3 : 6 | 8 : 16 |
| 19 | 5 : 6 | 1 : 4 | 4 : 6 | 10 : 16 |
| 20 | 5 : 6 | 4 : 4 | 3 : 6 | 12 : 16 |
| 21 | 4 : 6 | 2 : 4 | 3 : 6 | 9 : 16 |
| 22 | 5 : 6 | 2 : 4 | 4 : 6 | 11 : 16 |
| 23 | 2 : 6 | 2 : 4 | 5 : 6 | 9 : 16 |

Table 5 (Continued)

| Human Experts | Unqualified Correct : Total | Cytotechnologist Correct : Total | Supervisor Correct : Total | Total Personnel Correct : Total |
|-------------------|--------------------------------|-------------------------------------|-------------------------------|------------------------------------|
| 24 | 3 : 6 | 3 : 4 | 5 : 6 | 11 : 16 |
| 25 | 4 : 6 | 4 : 4 | 2 : 6 | 10 : 16 |
| 26 | 6 : 6 | 3 : 4 | 2 : 6 | 11 : 16 |
| 27 | 5 : 6 | 2 : 4 | 3 : 6 | 10 : 16 |
| 28 | 2 : 6 | 3 : 4 | 4 : 6 | 9 : 16 |
| 29 | 4 : 6 | 3 : 4 | 3 : 6 | 10 : 16 |
| 30 | 5 : 6 | 3 : 4 | 4 : 6 | 12 : 16 |
| 31 | 4 : 6 | 4 : 4 | 4 : 6 | 12 : 16 |
| 32 | 2 : 6 | 4 : 4 | 5 : 6 | 11 : 16 |
| 33 | 3 : 6 | 3 : 4 | 3 : 6 | 9 : 16 |
| 34 | 4 : 6 | 4 : 4 | 4 : 6 | 12 : 16 |
| 35 | 3 : 6 | 3 : 4 | 4 : 6 | 10 : 16 |
| 36 | 3 : 6 | 4 : 4 | 4 : 6 | 11 : 16 |
| 37 | 2 : 6 | 3 : 4 | 5 : 6 | 10 : 16 |
| 38 | 3 : 6 | 3 : 4 | 3 : 6 | 9 : 16 |
| 39 | 5 : 6 | 4 : 4 | 2 : 6 | 11 : 16 |
| 40 | 4 : 6 | 4 : 4 | 6 : 6 | 14 : 16 |
| 41 | 6 : 6 | 3 : 4 | 4 : 6 | 13 : 16 |
| 42 | 4 : 6 | 3 : 4 | 6 : 6 | 13 : 16 |
| Total | 162 : 252 | 121 : 168 | 153 : 252 | 436 : 672 |
| Average | 3.86 : 6 | 2.88 : 4 | 3.64 : 6 | 10.38 : 16 |
| Percentage | 0.64 | 0.72 | 0.61 | 0.65 |

Table 6
Comparison between Users

| Users | Unqualified Correct : Total | Cytotechnologist Correct : Total | Supervisor Correct : Total | Total Correct : Total |
|--------------|--|---|---------------------------------------|----------------------------------|
| 1 | 2 : 6 | 2 : 4 | 5 : 6 | 9 : 16 |
| 2 | 4 : 6 | 3 : 4 | 3 : 6 | 10 : 16 |
| 3 | 4 : 6 | 1 : 4 | 4 : 6 | 9 : 16 |
| 4 | 4 : 6 | 3 : 4 | 2 : 6 | 9 : 16 |
| 5 | 3 : 6 | 1 : 4 | 5 : 6 | 9 : 16 |
| 6 | 3 : 6 | 3 : 4 | 6 : 6 | 12 : 16 |
| 7 | 3 : 6 | 3 : 4 | 4 : 6 | 10 : 16 |
| 8 | 3 : 6 | 1 : 4 | 2 : 6 | 6 : 16 |
| 9 | 3 : 6 | 3 : 4 | 3 : 6 | 9 : 16 |
| 10 | 3 : 6 | 2 : 4 | 3 : 6 | 8 : 16 |
| 11 | 2 : 6 | 4 : 4 | 2 : 6 | 8 : 16 |
| 12 | 2 : 6 | 3 : 4 | 3 : 6 | 8 : 16 |
| 13 | 2 : 6 | 3 : 4 | 2 : 6 | 7 : 16 |
| 14 | 2 : 6 | 3 : 4 | 4 : 6 | 9 : 16 |
| 15 | 5 : 6 | 1 : 4 | 5 : 6 | 11 : 16 |
| 16 | 4 : 6 | 2 : 4 | 2 : 6 | 8 : 16 |
| 17 | 2 : 6 | 2 : 4 | 3 : 6 | 7 : 16 |
| 18 | 3 : 6 | 1 : 4 | 3 : 6 | 7 : 16 |
| 19 | 5 : 6 | 2 : 4 | 2 : 6 | 9 : 16 |
| 20 | 3 : 6 | 2 : 4 | 3 : 6 | 8 : 16 |
| 21 | 2 : 6 | 2 : 4 | 5 : 6 | 9 : 16 |
| 22 | 5 : 6 | 1 : 4 | 2 : 6 | 8 : 16 |
| 23 | 4 : 6 | 2 : 4 | 4 : 6 | 10 : 16 |
| 24 | 5 : 6 | 3 : 4 | 3 : 6 | 11 : 16 |

Table 6 (Continued)

| Users | Unqualified Correct : Total | Cytotechnologist Correct : Total | Supervisor Correct : Total | Total Correct : Total |
|-------------------|--------------------------------|-------------------------------------|-------------------------------|--------------------------|
| 25 | 5 : 6 | 2 : 4 | 3 : 6 | 10 : 16 |
| 26 | 2 : 6 | 3 : 4 | 3 : 6 | 8 : 16 |
| 27 | 6 : 6 | 1 : 4 | 3 : 6 | 10 : 16 |
| 28 | 3 : 6 | 2 : 4 | 2 : 6 | 9 : 16 |
| 29 | 4 : 6 | 4 : 4 | 4 : 6 | 12 : 16 |
| 30 | 5 : 6 | 2 : 4 | 4 : 6 | 11 : 16 |
| 31 | 4 : 6 | 3 : 4 | 6 : 6 | 13 : 16 |
| 32 | 2 : 6 | 2 : 4 | 2 : 6 | 6 : 16 |
| 33 | 5 : 6 | 1 : 4 | 3 : 6 | 9 : 16 |
| 34 | 4 : 6 | 4 : 4 | 5 : 6 | 13 : 16 |
| 35 | 6 : 6 | 1 : 4 | 4 : 6 | 11 : 16 |
| 36 | 4 : 6 | 2 : 4 | 3 : 6 | 9 : 16 |
| 37 | 3 : 6 | 3 : 4 | 3 : 6 | 9 : 16 |
| 38 | 5 : 6 | 4 : 4 | 4 : 6 | 13 : 16 |
| 39 | 6 : 6 | 2 : 4 | 3 : 6 | 11 : 16 |
| 40 | 5 : 6 | 3 : 4 | 4 : 6 | 12 : 16 |
| 41 | 5 : 6 | 3 : 4 | 5 : 6 | 13 : 16 |
| 42 | 4 : 6 | 2 : 4 | 4 : 6 | 10 : 16 |
| 43 | 5 : 6 | 1 : 4 | 5 : 6 | 11 : 16 |
| 44 | 4 : 6 | 3 : 4 | 5 : 6 | 12 : 16 |
| Total | 165 : 264 | 101 : 176 | 155 : 264 | 423 : 704 |
| Average | 3.75 : 6 | 2.30 : 4 | 3.52 : 6 | 9.61 : 16 |
| Percentage | 0.63 | 0.57 | 0.59 | 0.60 |

Table 8 shows the scores and the 95% confidence intervals of the cytology personnel evaluations among ES, NN, ES&NN, Users, and Experts as explained in Experiment 3, Step I in Section 2.2.

Table 8
Comparison of ES, NN, ES&NN, Users, and Experts

| Evaluators | unqualified Personnel (6 Cases) | cytotechnologist (4 Cases) | cytosupervisor and Technical Supervisor (6 Cases) | All Personnel (16 Cases) |
|--------------------------|---|--|---|--|
| ES | 1.00 | 0.75 | 0.75 | 0.84 |
| NN | 0.65 | 0.90 | 1.00 | 0.82 |
| ES&NN | 1.00 | 1.00 | 1.00 | 1.00 |
| Users | 0.66 (0.60-0.72) | 0.59* (0.55-0.63) | 0.62 (0.58-0.66) | 0.61* (0.57-0.65) |
| Human Experts | 0.69 (0.65-0.73) | 0.80* (0.76-0.84) | 0.64 (0.59-0.69) | 0.66* (0.62-0.70) |

* 95% Confidence

Three hundred questionnaires were sent to Users and Human Experts. Eighty-six valid questionnaires were received and analyzed. Each questionnaire contains fifteen cases with sixteen codes (six unapproved personnel codes, four cytotechnologists codes, and six cytosupervisors codes). The scores of the personnel evaluations for each group were obtained. The 95% confidence intervals for Users and Human Experts were calculated. Since AI systems have

100% precision, only the scores were calculated.

From the above Table, ES&NN again performs the best among the other AI systems, Users, and Human Experts with the score of 100%. The three AI systems perform better than Users and Experts for all the cytology personnel evaluations. As shown in the above Table ES score is 0.84, NN score is 0.82, and ES&NN score is 1.00 against Users score of 0.61, and Experts score of 0.66. ES&NN and ES systems perform better than NN, Users, and Experts for unqualified personnel. The Cytology personnel evaluations for unqualified personnel are almost the same for NN, Users, and Experts. This confirms that NN tends to over evaluate rather than to under evaluate, because of the parallel nature of its process, which identifies more codes than ES. The NN parallel approach will identify all the possible codes, and sometimes add wrong codes in its evaluation, which made NN evaluations less accurate than ES in the unqualified personnel evaluations.

ES&NN and NN cytotechnologists personnel evaluations are superior to ES, Users, and Experts. The evaluations of ES and Experts are better than Users. Experts tend to solve more complex decisions than Users because of their more intensive training in personnel evaluations. The errors in cytotechnologist evaluations range from underassessment to overassessment.

ES&NN performs better in the cytosupervisor personnel evaluations than the other AI systems, Users, and Experts. NN performs better than ES in cytosupervisor personnel evaluations, because of the tendency of ES to under evaluate than to over evaluate. ES evaluates serially (step by step), which can

miss some codes. The ES personnel evaluations will be terminated when a decision is reached. . All the errors in the cytosupervisor evaluations are under assessments.

Table 9 shows the comparison of ES, NN, ES&NN, and Human Experts in cytology personnel evaluations as described in experiment one, step J section 2.2.

Table 9
Comparison of ES, NN, ES&NN, and Human Experts
(Fifty cases * Four Respondents)

| Evaluators | unqualified personnel (20 cases) | cytotechnologist (15 cases) | supervisor (15 cases) | All Personnel (50 cases) |
|--------------------------|--|---|---------------------------------------|--|
| ES | 1.00 | 0.91 | 0.86 | 0.93 |
| NN | 0.80 | 0.78 | 1.00 | 0.85 |
| ES&NN | 1.00 | 0.96 | 1.00 | 0.99 |
| Human Experts | 0.70* (0.62-0.78) | 0.83* (0.73-0.93) | 0.69* (0.60-0.78) | 0.74* (0.69-0.79) |

*** 95% Confidence**

Four questionnaires containing fifty cases were sent to four Certifying Agency Evaluators (Human Experts). ES&NN performs better in personnel evaluations than the other AI systems and Human Experts.

ES&NN, ES, and NN are superior in the unqualified personnel evaluations than Experts. ES performs better than NN in the unqualified personnel

evaluation, which agrees with the findings in Table 8.

The ES&NN cytotechnologist personnel evaluations are superior to ES, and NN systems. The cytotechnologist personnel evaluation by ES, NN, and Human Experts are almost the same. These findings agree with Table 8, when forty-two evaluators were involved. ES, NN, and ES&NN personnel evaluations are superior to Human Experts in the cytosupervisor personnel evaluations, which agrees with the findings in Table 8.

Table 10 shows the comparison of ES, NN, ES&NN and Users in the cytology personnel evaluations as described in experiment 2, step K in section 2.2.

Table 10
Comparison of ES, NN, ES&NN and Users
(64 cases)

| Evaluators | unqualified Personnel (14 cases) | cytotechnologist (25 cases) | cytosupervisor (25 cases) | All Personnel (64 cases) |
|-------------------|---|---|---|--|
| ES | 1.00 | 0.84 | 0.80 | 0.86 |
| NN | 0.70 | 0.70 | 1.00 | 0.82 |
| ES&NN | 1.00 | 1.00 | 1.00 | 1.00 |
| Users | 0.60* (0.48-0.72) | 0.62* (0.50-0.74) | 0.55* (0.45-0.65) | 0.59* (0.49-0.69) |

* 95% Confidence

Sixty four-actual cases were obtained from three Clinical Laboratories. These cases were evaluated by ES, NN, ES&NN Artificial Intelligent systems, and Users.

In this Table, the ES&NN system is more accurate than ES, NN, and Users in all personnel evaluation groups. ES and NN systems perform better than Users in all personnel evaluation groups. ES performs better than NN in unqualified personnel evaluations, and worse than NN in the cytosupervisor evaluations. These results agree with the previous findings in table 8, when forty-four users were involved.

3.2. Cytology Personnel Evaluations Comparison

The misclassification errors were plotted in a 4 by 4-grid. The degrees of correspondences for ES, NN, ES&NN, and four Human Experts were calculated against accurate assessment. For example, if the system correctly evaluates a code, the values will be between brackets. If the system correctly evaluates forty codes, then the grid will shows ten incorrect entires, and the corrected forty codes will be between brackets. The entries will be placed in the grid according to under evaluations or over evaluations. Fifty cases were evaluated individually by the three Artificial Intelligence systems and Humans as described in Experiment 1, Step J in Section 2.2. The results are tabulated in the following Tables, 11,12, 13, 14, 15, 16, and 17.

Key Words:

1. TS means a technical supervisor
2. GS means a general cytosupervisor
3. CT means a cytotechnologist
4. UN means unqualified personnel

Table 11**ES&NN EVALUATIONS**

| Classes | TS | GS | CT | UN | Actual Evaluation |
|---------------------------------|------------|------------|-------------|-------------|------------------------------|
| UN | | | | (20) | 20 |
| CT | | | (15) | | 15 |
| GS | | (7) | 2 | | 9 |
| TS | (6) | | | | 6 |
| ES&NN Evaluation | 6 | 7 | 17 | 20 | 50 |

Sample Size = Fifty Cases

The ES&NN Cytology personnel evaluation's score is 98.70%. From the above table, only two errors are detected. ES&NN under evaluated two candidates from general cytosupervisor to cytotechnologists. ES&NN evaluated 48 candidates correctly according to CLIA'88 regulations.

Table 12
ES EVALUATIONS

| Classes | TS | GS | CT | UN | Actual Evaluation |
|-------------------|------------|------------|-------------|-------------|------------------------------|
| UN | | | | (20) | 20 |
| CT | | | (11) | 4 | 15 |
| GS | | (3) | 6 | | 9 |
| TS | (6) | | | | 6 |
| ES | 6 | 3 | 17 | 24 | 50 |
| Evaluation | | | | | |

Sample Size = Fifty Cases

The ES Cytology personnel evaluation's score is 93.30%. ES evaluated 40 candidates correctly according to CLIA'88 regulations. ES under evaluated four candidates from cytotechnologists to unqualified cytology personnel. It also, under evaluated six general cytosupervisors to cytotechnologists.

Table 13
NN EVALUATIONS

| Classes | TS | GS | CT | UN | Actual Evaluation |
|-------------------|------------|------------|-------------|-------------|------------------------------|
| UN | | | 6 | (14) | 20 |
| CT | | 5 | (10) | | 15 |
| GS | | (9) | | | 9 |
| TS | (6) | | | | 6 |
| NN | 6 | 14 | 16 | 14 | 50 |
| Evaluation | | | | | |

Sample Size = Fifty Cases

The NN cytology personnel evaluation's score is 85.30%. NN evaluated 39 candidates correctly according to CLIA'88 regulations. This system over evaluated six unqualified applicants to cytotechnologists. It also over evaluated five cytotechnologists to general cytosupervisors. These over evaluations are more serious than under evaluations, because they permit unqualified personnel to screen cancer cells.

Table 14
HUMAN EXPERT 1

| Classes | TS | GS | CT | UN | Actual Evaluation |
|--------------------------------|-----------|-----------|-----------|-----------|------------------------------|
| UN | 1 | 1 | 7 | (11) | 20 |
| CT | 4 | 1 | (5) | 5 | 15 |
| GS | | (5) | 3 | 1 | 9 |
| TS | (5) | | | 1 | 6 |
| Expert 1 Evaluation | 10 | 7 | 15 | 18 | 50 |

Sample Size = Fifty Cases

Expert 1 evaluated the same fifty cases, which the Artificial Intelligence systems previously evaluated. He has a score of 74.70%. From the above table, expert 1 correctly evaluated 26 candidates. Expert 1 had over evaluated fourteen applicants, and ten candidates were under evaluated.

Table 15
HUMAN EXPERT 2

| Classes | TS | GS | CT | UN | Actual Evaluation |
|--------------------------------|-----------|-----------|-----------|-----------|------------------------------|
| UN | | 1 | 10 | (9) | 20 |
| CT | | 5 | (6) | 4 | 15 |
| GS | | (3) | 6 | | 9 |
| TS | (4) | | 2 | | 6 |
| Expert 2 Evaluation | 4 | 9 | 24 | 13 | 20 |

Sample Size = Fifty

Expert 2 score is 70.70%. Expert 2 correctly evaluated 22 candidates according to CLIA'88. Expert 2 over evaluated sixteen applicants, and twelve applicants were under evaluated as shown in the previous Table.

Table 16
HUMAN EXPERT 3

| Classes | TS | GS | CT | UN | Actual Evaluation |
|--------------------------------|-----------|------------|------------|-------------|------------------------------|
| UN | | 2 | 6 | (12) | 20 |
| CT | | 6 | (7) | 2 | 15 |
| GS | | (6) | 2 | 1 | 9 |
| TS | | | 4 | 2 | 6 |
| Expert 3 Evaluation | | 14 | 19 | 17 | 50 |

Sample Size = Fifty Cases

Expert 3 score is 74.00%. Expert 3 evaluated 25 candidates correctly, according to CLIA'88 regulations. From the above table fourteen candidates were over evaluated, and eleven cases were under evaluated.

Table 17
HUMAN EXPERT 4

| Classes | TS | GS | CT | UN | Actual Evaluation |
|-----------------|------------|------------|------------|-------------|--------------------------|
| UN | | 1 | 7 | (12) | 20 |
| CT | | 5 | (8) | 2 | 15 |
| GS | | (2) | 5 | 2 | 9 |
| TS | (4) | | | 2 | 6 |
| Expert 4 | 4 | 8 | 20 | 18 | 50 |

Sample Size = Fifty Cases

Expert 4 score is 76.00 %. Expert 4 evaluated correctly 26 from 50 candidates. Thirteen over evaluation errors and eleven under evaluation errors were detected. One unqualified candidate was over evaluated as a general cytosupervisor, and seven unqualified candidates were over evaluated as cytotechnologists. Five cytotechnologists were over evaluated to general cytosupervisor, and two cytotechnologists were under evaluated to unqualified personnel. Five general cytosupervisors were under evaluated to cytotechnologists, and two general cytosupervisors were under evaluated to unqualified personnel. Two technical supervisors were under evaluated to unqualified personnel.

ES&NN is better at cytology personnel evaluations than ES or NN. These findings support hypotheses 1a and 1b. ES is more accurate than NN in Cytology personnel evaluations, which supports hypothesis 2. Human Experts' personnel evaluations are less accurate than any of the Artificial Intelligence

systems. The average score for Human Experts is 73.80%. On the other hand, ES&NN score is 98.70%, ES score is 93.30%, and NN score is 85.30%. These findings agree with hypothesis 3a, 3b, and 3c. The Artificial Intelligence (AI) systems are consistent in cytology personnel evaluations by their nature.

3.3. Comparison among Neural Networks with different hidden layers.

Neural Networks use a single hidden layer or multiple hidden layers in their classifications. The use of many hidden layers will increase connections and increase the training time.

After experimentation with two, three, and four middle layers (hidden layers) as shown in Table 18, there are no improvements over the NN with one hidden layer. This was consistent with the finding of many researchers using NN for classification problems with more than one hidden layer (Salchenberger et al-1992, Wang et al-1997, and Dutta et al-1988). Table 18 represents the personnel evaluations comparison between NN with different hidden layers for fifteen cases. The following table shows that there are no significance differences in personnel evaluations between NN's with one and two hidden layers. The accuracy is diminished, when using more than two hidden layers, as the score go from 0.80 to 0.73. The cytology personnel classification problem is best fitted with using only one hidden layer. There is no formal theory for determining the optimal number of hidden layers, so decisions for determining

the appropriate number of hidden layers must be determined using experimentation (Salchenberger-1992). Table 18 shows that even though the score of NN with one hidden layer is the same as NN with two hidden layers (0.80), there are personnel evaluations differences between the two NNs. Cases no 6 and 9 were evaluated correctly by NN (1) but were over evaluated by NN (2). By contrast, cases 12 and 15 were evaluated correctly by NN (2) but over evaluated by NN (1). The use of more than one NN, will increase the accuracy of the personnel evaluations by detecting any discrepancy, which will require the intervention of Human Experts. A single hidden layer was used In this research.

Table 18

Comparison between NN's with different hidden layers

| Cases | NN' | NN* | NN [~] | NN [~] |
|--------------|--------------------------|--------------------------|-----------------------------|----------------------------|
| | with one hidden layer | with two hidden layer | with three hidden layers | with four hidden layers |
| 1 | 3 | 3 | 3 | 3 |
| 2 | 3 | 3 | 3 | 3 |
| 3 | 3 | 3 | 3 | 3 |
| 4 | 3 | 3 | 3 | 3 |
| 5 | 3 | 3 | 3 | 3 |
| 6 | 3 | 1 | 3 | 1 |
| 7 | 1 | 1 | 1 | 1 |
| 8 | 3 | 3 | 3 | 3 |
| 9 | 3 | 1 | 1 | 1 |
| 10 | 3 | 3 | 3 | 3 |
| 11 | 3 | 3 | 1 | 3 |
| 12 | 1 | 3 | 3 | 3 |
| 13 | 3 | 3 | 3 | 3 |
| 14 | 3 | 3 | 3 | 3 |
| 15 | 1 | 3 | 1 | 1 |
| Score | 0.80 | 0.80 | 0.73 | 0.73 |

* NN with one or two hidden layers evaluates 12 correct cases from 15

cases which gives the score of 80%.

[~] NN with three or four hidden layers evaluates 11 correct cases from 15

cases which gives the score of 0.73%.

3.4. Respondents' profiles

Eighty-six valid questionnaires were received (forty-two from Human Experts and forty-four from Users). Tables 19, 20, and 21 describe the differences in education, clinical laboratory experience and clinical laboratory personnel evaluation experience.

Table 19
Highest Degrees Attained

| Degrees | Bachelors | Masters | Doctorates |
|---------------------------------------|------------------|----------------|-------------------|
| Accrediting Agency evaluators | 47% | 44% | 9% |
| Clinical Laboratory evaluators | 63% | 33% | 4% |

Three hundred questionnaires were sent to Human Experts, and Users. Forty- two Human Experts (Accrediting Agency evaluators), and forty-four Users (Clinical Laboratory evaluators) sent valid responses. 53 % of the Human Experts have above Bachelors, which is higher than Users(37%).

Table 20
Years of Laboratory Experience

| Years of Experience | Less than five years | Five to ten years | More than ten years |
|---------------------------------------|-----------------------------|--------------------------|----------------------------|
| Accrediting Agency Evaluators | 6% | 43% | 51% |
| Clinical Laboratory Evaluators | 3% | 62% | 35% |

Forty-two Accrediting Agency Evaluators

Forty-four Clinical Laboratory Evaluators

The majority of Accrediting Agency evaluators (51%) have more than ten years experience. The majority of Clinical Laboratory evaluators (62%) have from five to ten years experience, and only 35% have more than ten years clinical laboratory experiences.

Table 21**Years of Clinical Laboratory Personnel's Evaluation**

| Years of Personnel Evaluation Experience | Less than five years | Five to ten years | More than ten years |
|---|---------------------------------|--------------------------|--------------------------------|
| Accrediting Agency Evaluators | 58% | 31% | 11% |
| Clinical Laboratory Evaluators | 76% | 19% | 5% |

Forty-two Accrediting Agency Evaluators

Forty-four Clinical Laboratory Evaluators

Table 21 shows that 24% of Clinical Laboratory Evaluators and 42% of Accrediting Agency evaluators have more than five years experience in evaluating clinical laboratory personnel.

4. Conclusions and future Research

The application of Expert system and Neural Network technology in evaluating the cytology personnel according to CLIA'88 requirements is investigated in this dissertation. At present, the cytology personnel evaluations according to CLIA'88 requirements are done manually. The results of this study showed that ES, NN, and ES&NN made more accurate and consistent assessments than Human Experts and Users. The findings can be generalized and then can be applied to the 300,000 technical personnel evaluated yearly according to CLIA'88 regulations. The program can also be expanded to cover similar situations where personnel evaluations or any classification problems are required (Dologite and Mockler-1995).

Tversky et al (1995) indicated that traditional notions of how a rational person makes decisions will almost certainly have to be revised to take account of subtle psychophysical factors that are often ignored. These findings have profound implications for understanding the behavior of the personnel evaluators. Kahneman and Amos Tversky (1991) suggested that people could be easily subjected to manipulation designed to play upon the psychological factors that influence decision making.

A preference or an emotional reaction is controlled by factors that may appear irrelevant or inconsequential. People could easily be subjected to manipulations designed to play upon the psychological factors that influence

decision making. Framing is an example of such impediments.

The evaluators are more sensitive to negative consequences than to positive ones. For example, they tend to over evaluate than to under evaluate personnel in order to avoid complaints. This allows under-qualified applicants to enter the field of screening cytology specimens, which will produce grave consequences in the welfare of patients. Manual personnel evaluations are inconsistent due to the preference or the emotional status of individuals. In contrast, the Artificial Intelligence systems are consistent by their nature.

It is often far from clear whether we should treat the effect of decision weights as errors or biases or whether we should accept them as valid elements of human experience (Tversky and Wakker-1995).

The advantages realized from ES, NN, and ES&NN Artificial Intelligence systems are:

They increase the efficiency of carrying out CLIA'88 regulations by decreasing the time scarce Human Experts spend on this knowledge and labor-intensive, yet routine, task (Cytology Personnel evaluations). Human Experts can concentrate on other operations that require their special skills, such as quality assurance and quality control requirements, which improve the quality of testing in the Clinical Laboratories.

They enhance consistency in decision-making, increasing both the accuracy and precision of personnel evaluations. This will reduce significantly the entrance of unqualified personnel in the field of Cytology. Ultimately, it will decrease the error rate in screening cancer cells, and save lives and decrease

the morbidity rate.

This prototype can be disseminated to all CLIA'88 personnel, improving the consistency and accuracy of service provided by the Accrediting Agencies. This could save tens of million dollars annually, by saving the salaries of the Accrediting Agency Evaluators, who spend about 25% of their time in personnel evaluations. ES&NN can be operated by clerks, and only the discrepancies will be referred to the Accrediting Agency Evaluators. The use of ES&NN will also, reduce complaints from under evaluated applicants. This will decrease the mortality and morbidity rates by decreasing the testing errors. Ultimately, the utilization of AI systems in evaluating the CLIA'88 personnel will decrease the health care cost by almost eliminating the malpractice suits that arise from Personnel classification errors currently occurred by manual personnel evaluations.

The utilization of Expert Systems and Neural Networks technologies can be expanded to any classification and pattern recognition problems. They can be used for screening candidates for employment, and for selecting students for undergraduate and graduate programs. AI systems will make contributions to any multiple-criteria decision-making problem.

These programs can be served as a training tool for new evaluators. Some experienced evaluators have a keen understanding of all of the evaluation variables and can arrive at good decisions unassisted. Others, however, have difficulty evaluating the entire situation and often narrow their focus only to selected factors. In these cases, optimal decisions may not be

made and unqualified personnel are approved and/or qualified workers are rejected (Mockler and Dologite - 1995).

Several enhancements to these Artificial Intelligence systems can be developed to make them more useful. One would be to provide access to data bases of all personnel evaluations to all Accrediting Agencies and Clinical Laboratories upon request. Another enhancement is to network these systems throughout the Accredited Agencies and Clinical Laboratories. The applicant data (education, training, and experience, which are used in personnel evaluations according to CLIA'88 regulations) will be updated continuously at any place and any time through the network system. Due to the networking, the system can update its records instantaneously. For example if a state revokes a license of a laboratory worker, this applicant will be prevented from working in another state. This will prevent frauds. Also, this will make it easier for the applicant to change jobs and to relocate. A falsification in documents or information will be detected by comparing the data submitted by the applicant with the data bases stored in the network.

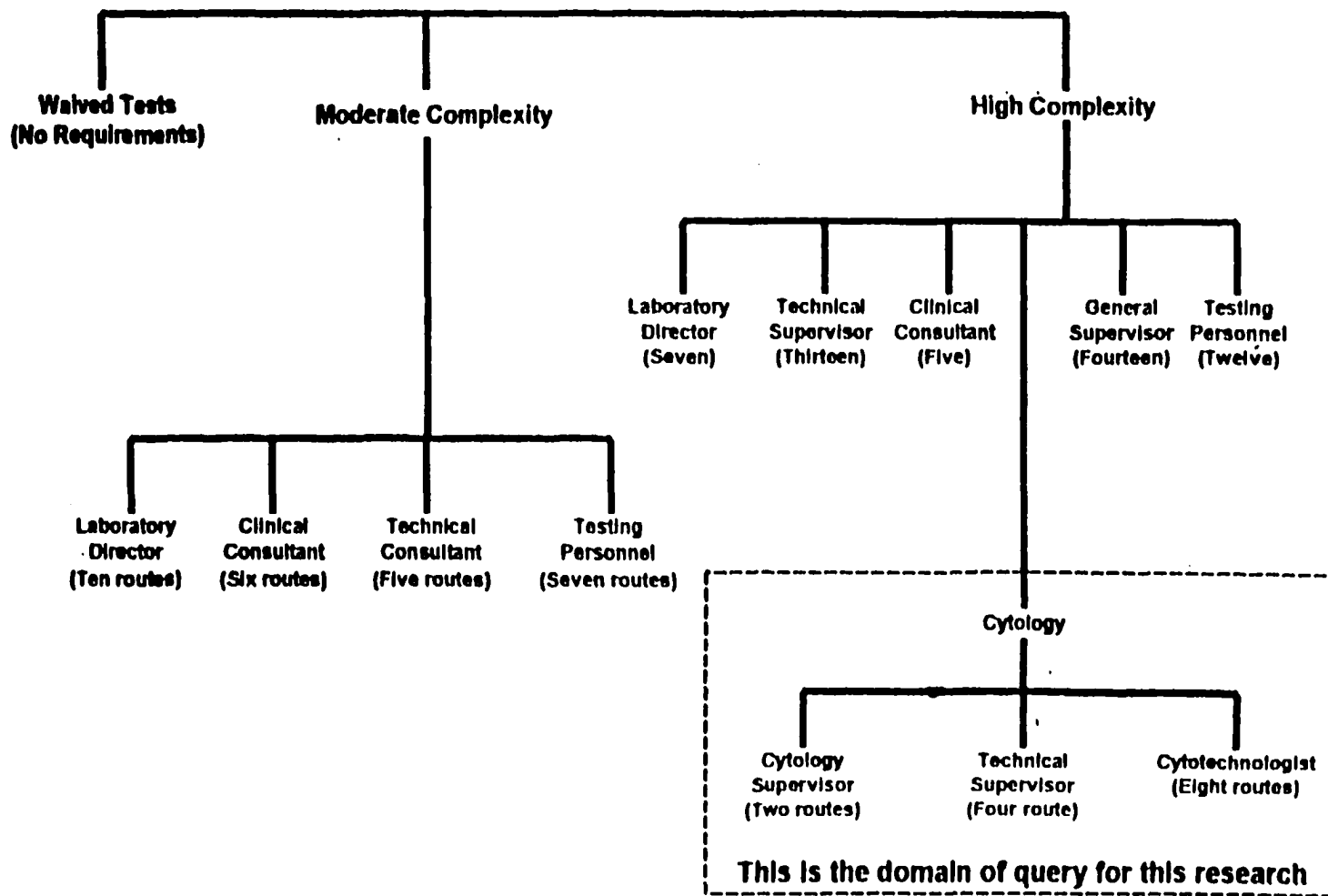
Appendix A

HCFA Personnel Requirements

CLIA'88 personnel requirements differ according to task complexity. Health Care Financial Administration (HCFA) has developed a seven-criterion model that measure the complexity of tasks. A weight of one to three was assigned by HCFA to each criterions: knowledge, training, experience, preparation, operational steps, quality control, and equipment maintenance. A weight of one indicates that a procedure is easy, and a weight of three indicates that a procedure is very difficult. These weights are multiplied to each criterion to get an adjusted weight. Adding these adjusted weights, one gets a score for each test procedure. A total score of 13 or more places the test in the high complexity category. A total score from eight to twelve places the test in a moderate complexity category. Waived tests have a score of seven.

This Appendix shows the different personnel codes under CLIA'88 regulations. Waived tests have no specific personnel codes. There are twelve classes-four in moderate complexity, and eight in high complexity, of which cytology has three classes. There are 93 different codes or routes - 28 in moderate complexity, 51 in high complexity, and 14 in cytology. Each code or route as it is sometimes called has different requirements of education, training, experience, and licenses according to CLIA'88 regulations. As shown in this Appendix, the general supervisor has fourteen codes or routes. This paper is focused in the cytology domain, which is under the high complexity model. It

APPENDIX A
HCFA PERSONNEL REQUIREMENTS
(CLIA'88)



contains three classes, which have fourteen codes as described in Appendix B.

Appendix B

Cytology Personnel Qualifications

The cytology personnel qualifications according to CLIA'88 regulations depend on the education, training, experience, and license of the applicant (Department of Health and Human Services-1992). There are three approved classes with 14 codes or routes, and one unapproved class with six codes or routes:

1. **Technical Supervisor**, is responsible for the technical and scientific oversight of the cytology category. The Technical Supervisor must be a Doctor of Medicine or Osteopath with a current medical license. There are four codes under which somebody can be qualified as a Technical Cytosupervisor. These include CYT 1, CYT 2, CYT 3, and CYT 4.

2. **General Cytosupervisor or General Supervisor or Cytosupervisor**, supervises cytology services. The General Cytosupervisor is responsible for the day-to-day supervision. This class includes two codes as shown in this Appendix:

- a. The applicant is qualified as a Technical Supervisor and has a license as a General Cytosupervisor,
- b. The applicant is qualified as a Technologist and has three years experience.

3. **Cytotechnologist**, is responsible for the interpretation of cytology slides. There are eight different codes in order to be qualified as a

Cytotechnologist.

4. Unqualified, is somebody who is not allowed to work in a cytology category. There are six reasons for disqualification. The applicant lacks one or more of these: education, training, experience, cytology job, license, and delegations.

SECTION VII. CYTOLOGY TESTING

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| Qualification Code | Qualifications (Education, Training and Experience) |
|-----------------------------|--|
| TECHNICAL SUPERVISOR | |
| CYT 1 | M.D.,D.O. w/current medical license in State of laboratory's location and certified in anatomic and clinical pathology by ABP or AOBP or equivalent qualifications OR |
| CYT 2 | M.D.,D.O. w/current medical license in State of laboratory's location and certified in anatomic pathology by ABP or AOBP or equivalent qualifications OR |
| CYT 3 | M.D.,D.O. w/current medical license in State of laboratory's location and certified in cytopathology by ASC OR |
| CYT 4 | Individual, in final year of training program leading to ABP or AOBP certification in anatomic and clinical pathology or anatomic pathology, who performs duties delegated by a qualified technical supervisor |
| GENERAL SUPERVISOR | |
| CYG 1 | Qualifies as a technical supervisor in cytology OR |
| CYG 2 | Cytotechnologist with 3 years of full-time experience (2080 hours per year) within the preceding 10 years |
| CYTOTECHNOLOGIST | |
| CYO 1 | Qualifies as a technical supervisor in cytology OR |
| CYO 2 | Graduated from a CAHEA-accredited school of cytotechnology OR |
| CYO 3 | Certified in cytotechnology by certifying agency approved by HHS OR |
| CYO 4 | BEFORE 9/1/92 -Completed 2 years in an accredited institution with at least 12 semester hours in science, 8 hours of which are in biology, AND -Completed 12 months of training in a school of cytotechnology accredited by an accrediting agency approved by HHS; OR |
| CYO 5 | -Completed 2 years in an accredited institution with at least 12 semester hours in science, 8 hours of which are in biology, AND -Received 6 months of formal training in a school of cytotechnology accredited by an accrediting agency approved by HHS and 6 months of full-time experience in cytotechnology; OR |
| CYO 6 | Achieved a satisfactory grade to qualify as a cytotechnologist in a proficiency examination approved by HHS; OR |
| CYO 7 | BEFORE 9/1/92 -Have at least 2 years of full-time or equivalent experience within the preceding 5 years examining slide preparations under supervision and before January 1, 1969 must have-- -graduated from high school -completed 6 months of training in a laboratory directed by pathologist or physician providing cytology services, and - completed 2 years of full-time supervised experience OR |
| CYO 8 | ON OR BEFORE 9/1/93 Have at least 2 years of full-time experience or equivalent examining cytology slide preparations within the preceding 5 years in the U.S. and on or before September 1, 1994 have either completed a CAHEA-accredited training program or become certified by an HHS-approved accrediting agency |

APPENDIX C

ES and ES&NN Designs

Appendix C describes the design of ES and ES&NN. There are five modules in the ES model. Figure 1 describes the Credentials module flow chart. The credentials module evaluates the applicants according to their degrees, education, training, and experience. Nine production rules were derived from the flow chart as shown in Figure 1.

Figure 2 describes the flow chart for the license requirements. The license module is constructed of fourteen rules. The license flow chart evaluates the applicant according to whether the state requires a license and if the applicant has this license or not. It also evaluates the applicant according to whether or not he or she has a cytology job.

Figure 3 describes the technical supervisors module flow chart. The system will ask the applicant if he has a medical degree. If the applicant does not have a medical degree, the system will exit as not qualified as a technical supervisor. If the applicant has a medical degree, the system will ask if the applicant has a physician license. If the applicant does not possess the license, the system will exit as not qualified as a technical supervisor. If the applicant has a physician license, the system will ask the applicant, if he is certified in Anatomic Pathology or the equivalent. If the applicant is certified, the system will exit as qualified as a technical supervisor with CYT2 code. If the applicant is not certified, the system will ask the applicant if he or she is certified by the American

Society of Cytology (ASC). If the applicant is certified by ASC, the system will exit as qualified as a technical supervisor with CYT3 code. If the applicant is not certified by ASC Society, the system will ask the applicant if he or she is certified by the Anatomic and Clinical Pathology Society (A&C-ABP.) If the applicant is certified by A&C-ABP, the system will exit as qualified as a technical supervisor with CYT 1 code. If the applicant is not certified by A&C-ABP Society, The system will ask the applicant if he or she is in the final year of training. If the applicant is not in the final year of training, the system will exit as not qualified as a technical supervisor. If the applicant is in the final year of training, the system will ask the applicant if he or she has the technical supervisors' delegation. If the applicant does not have such delegation, the system will exist as not qualified as a technical supervisor. If the applicant has a technical supervisor delegation, the system will exit as qualified as a technical supervisor with CYT4 code. The author developed seven production rules for the above module.

Figure 4 describes the cytosupervisor module. The module contains three production rules. The cytosupervisor module evaluates the candidate according to his or her cytosupervisor job and post experience.

Figure 5 describes the cyto 5 module. The cyto 5 module contains nineteen production rules. Eight cytotechnologists codes and two cytosupervisors codes are identified in this module. Please see pages 44, 45, and 46 for more details of the above modules.

Figure 6 shows the Expert System modules (ES) which contains five modules and two kinds of connections. The modular connection connects the

credentials module, to the license module, to the technical supervisor module, to the Cyto5 module, and ended in the cytosupervisor module.

The rules connections enable the ES to exit when the applicant's evaluation is finished. For example the ES ends the evaluation when the candidate is evaluated as a technical supervisor, cytosupervisor, and cytotechnologist through exit2. The candidate's evaluation will not go through the cytosupervisor module as shown in figure 6(C.) Please see the ES framework on pages 34, 35 and 36.

Figure 7 shows the Connectionist Expert System (ES&NN). The personnel evaluations are done in the NN modules, and the reasons for the rejections are explained in the ES modules. Human experts will resolve any discrepancies between the two Artificial Intelligent systems (ES and NN). Please see pages 38 and 39 for the descriptions of ES&NN operations. The design of ES&NN system will enable the author to solve the Cytology personnel evaluations problem in a more accurate and consistent way. It will benefit from the advantages of the two approaches of ES and NN technologies. ES&NN system utilizes the parallel approach of NN to identify the different codes. It also uses the explanatory characteristics of ES to explain the reasons of the rejections. Human Experts will be used to solve any discrepancy in personnel evaluations between ES and NN.

Figure 3 (C)

THE TECHNICAL SUPERVISOR MODULE (a)

THE TECHNICAL SUPERVISOR MODULE (b)

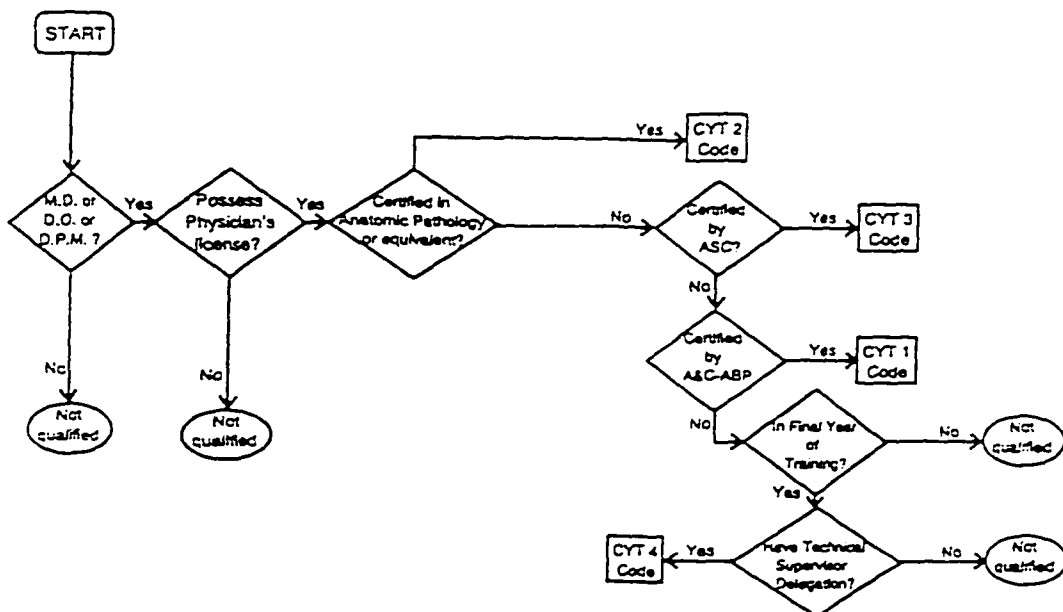


Figure 4 (C)

THE CYTOSUPERVISOR MODULE

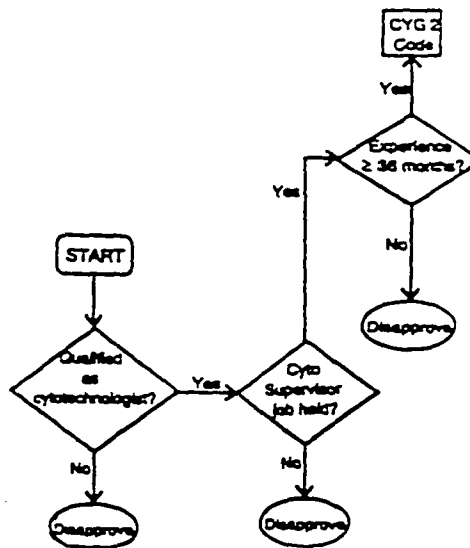


FIGURE 5 (C)

THE CYTO 5 MODULE

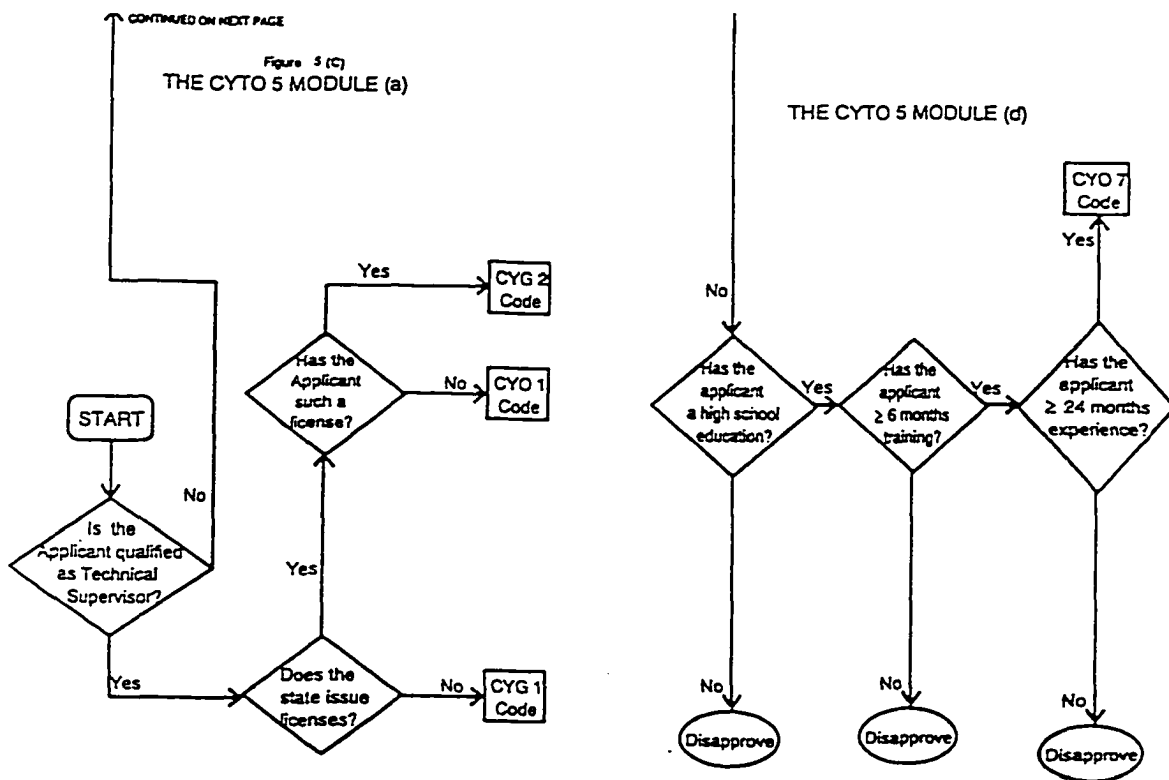
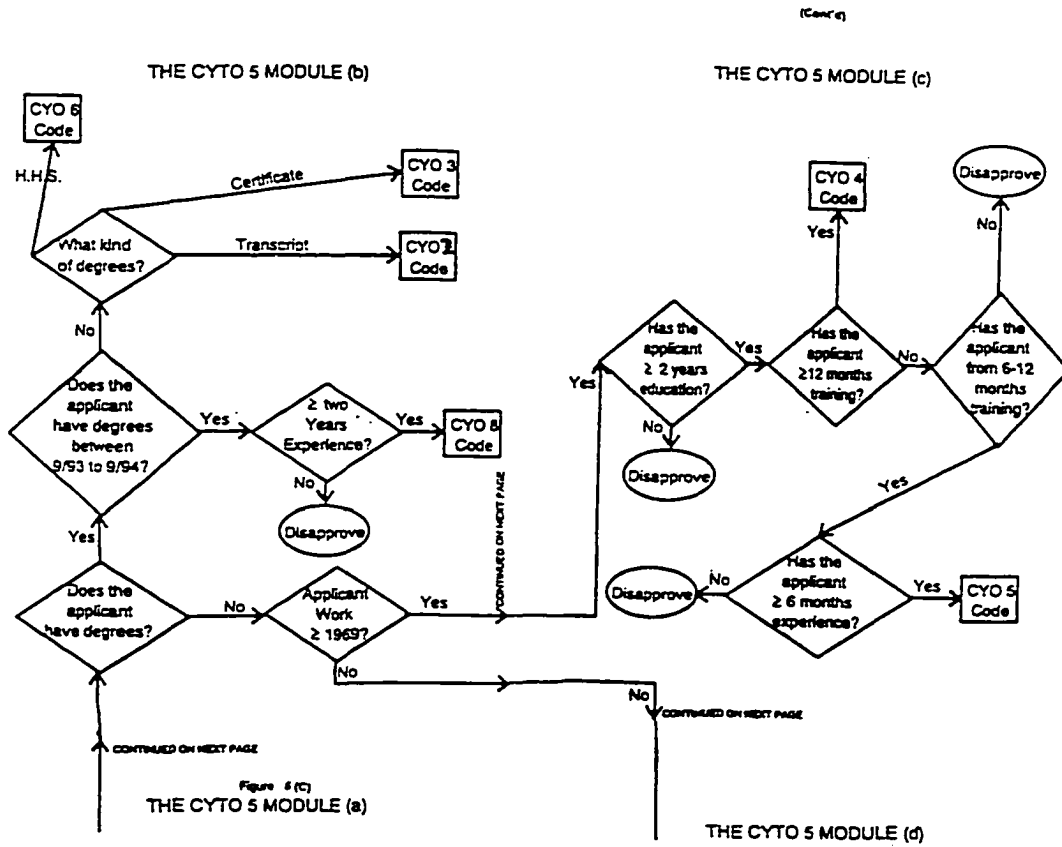


FIGURE 5 (C)
(Cont'd)

THE CYTO 5 MODULE



FIGURES six & seven

| | |
|--------------------|---|
| Q | = Questions asked by the ES user |
| A | = Answers by the ES to questions by the user |
| Approved 1 | = Applicant's Educations is OK |
| Approved 2 | = Applicant's Credentials are OK |
| Approved 3 | = Applicant's Licenses are OK |
| Approved 4 | = Technical Supervisor is OK |
| Approved 5 | = Cytotechnologist is OK |
| Approved 6 | = Cytosupervisor, Cytotechnologist, and Technical Supervisor is OK |
| Approved 7 | = Cytosupervisor and Cytotechnologist are OK |
| Temp Exit 1 | = Qualified as Technical Supervisor and Cytotechnologist |
| Temp Exit 2 | = Qualified as Cytotechnologist |
| Exit 1 | = Not Qualified |
| Exit 2 | = Qualified as Technical Supervisor, Cytosupervisor, and Cytotechnologist |
| Exit 3 | = Not approved as Cytosupervisor, but still qualified as Cytotechnologist only |
| Exit 4 | = Qualified as Cytosupervisor, and Cytotechnologist |
| Exit 5 | = Qualified as Technical Supervisor, and |

Cytotechnologist

- Exit 6** = **Not Qualified for Cyto Codes (Figure 7)**
- Exit 7** = **Approved Cyto Codes (Figure 7)**

Figure 6 (C)
EXPERT SYSTEM MODEL

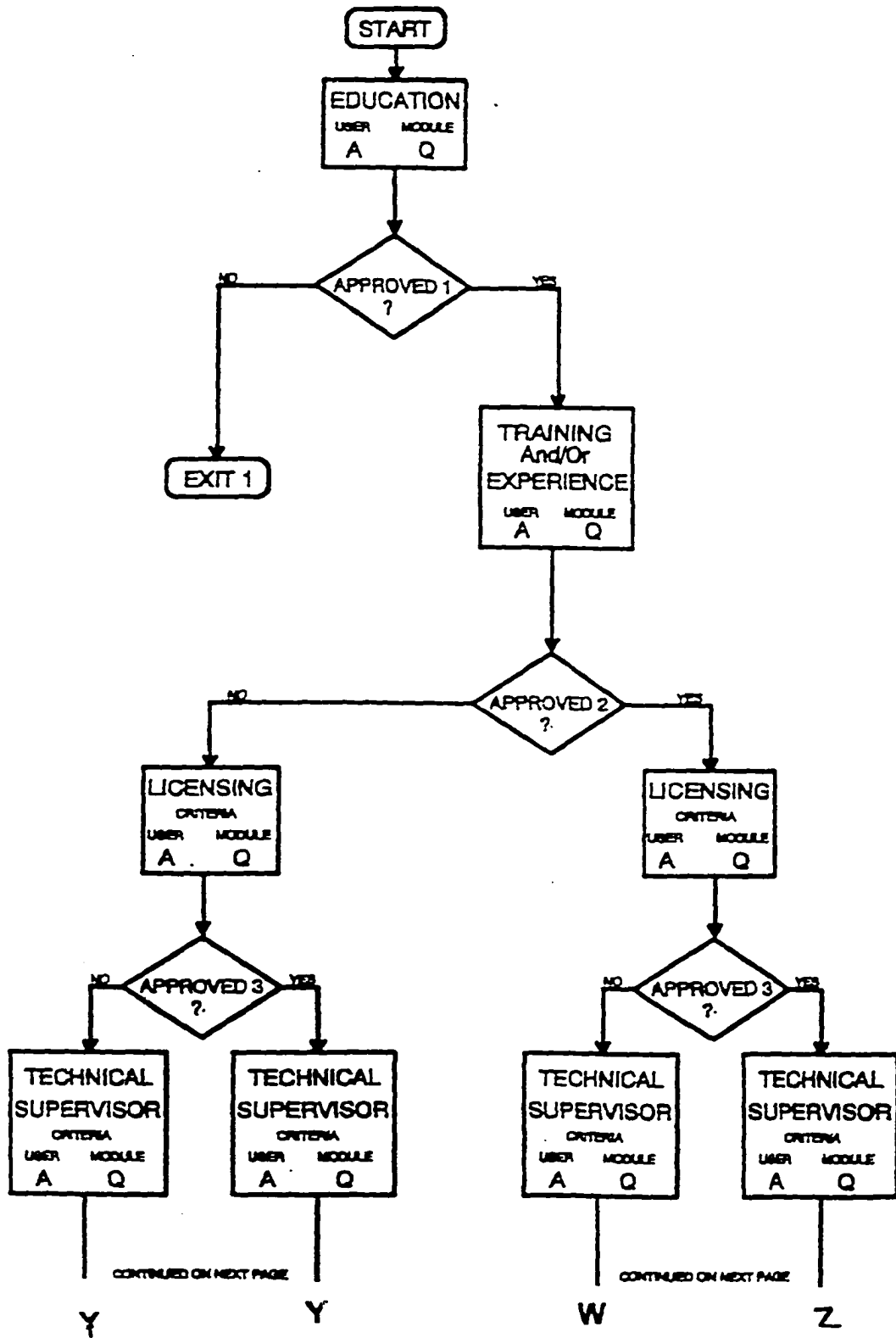
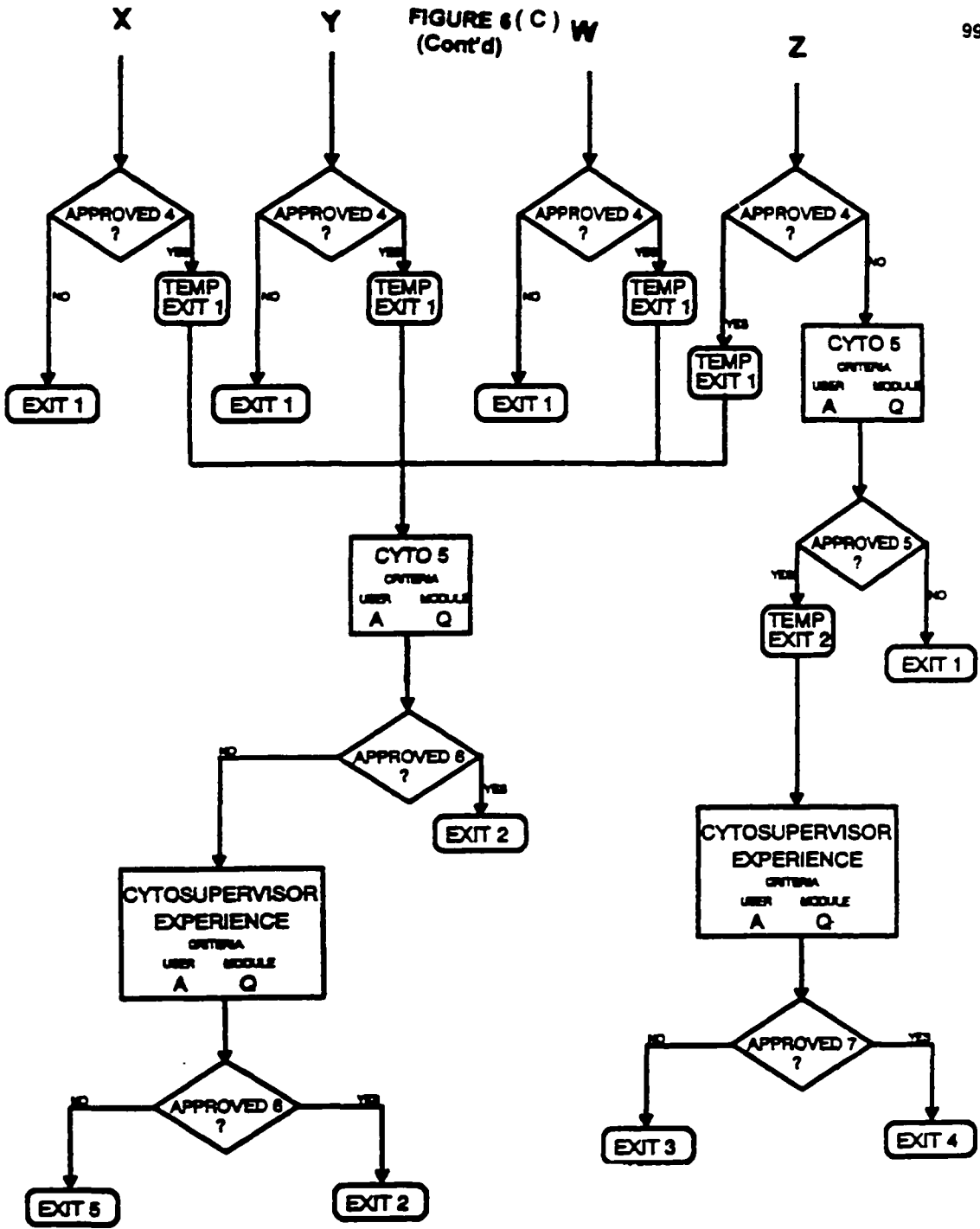
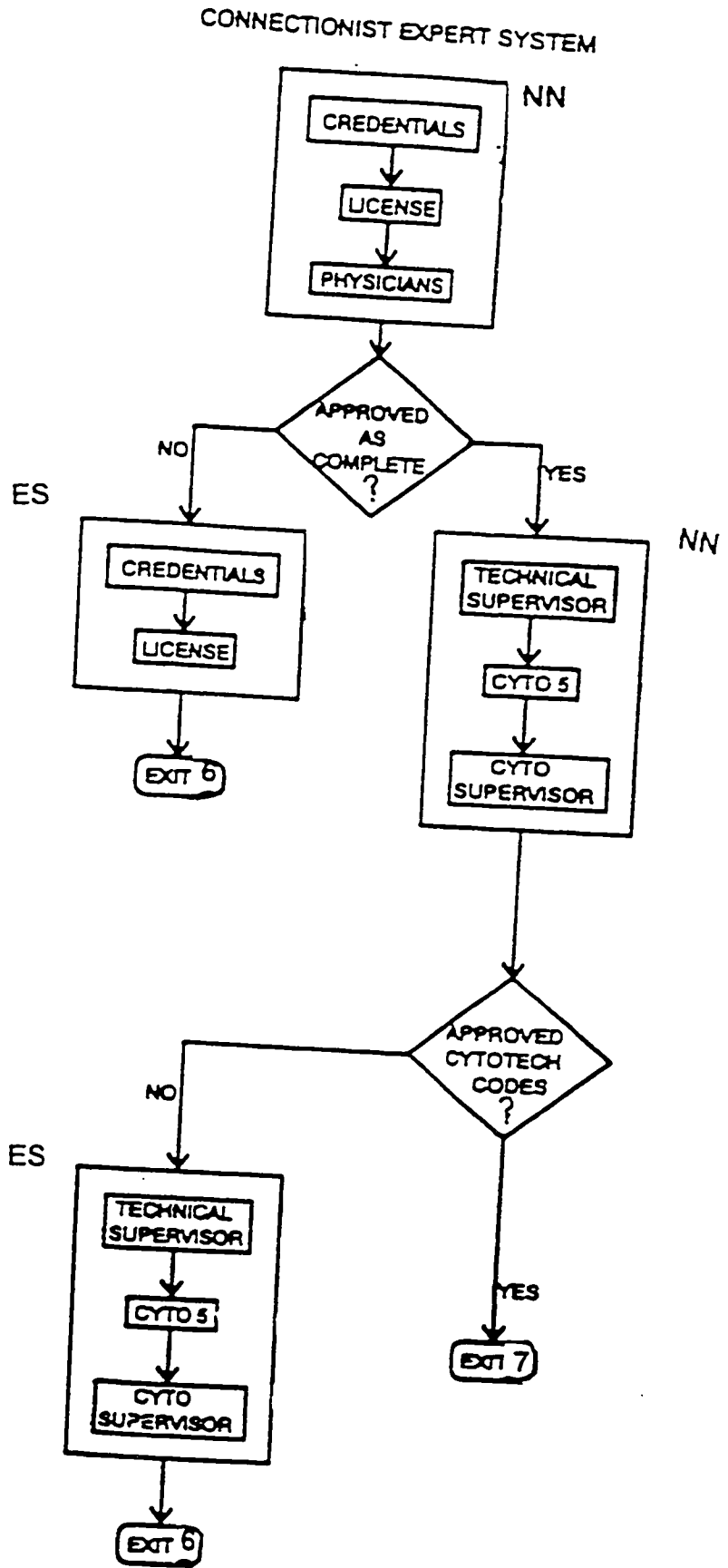


FIGURE 6(C) W
(Cont'd)





EXIT 6 = Not Qualified
EXIT 7 = Approved Cyto Codes

APPENDIX D

The Expert System Rules (An Example)

A partial rule base from ES is shown in appendix D. The Expert System shell used is VP-Expert. The IF-THEN rules in the knowledge base are written to reflect the relationships in the flow charts. The ES has fifty-two production rules. The two license module rules shown in this Appendix is one of the simplest rules, and determine the license status of an applicant working in a state, that does not require any licensing for Cytology personnel.

Rule 1 state that if the applicant has complete credentials and is working in the Cytology field, then the applicant's Cyto-requirements will be accepted.

Rule 2 states that if the applicant has complete credentials, but does not have a Cytology job, then the applicant's Cyto-requirements will not be accepted.

Please see page 45 for Cyto-requirements categories.

The knowledge base file of VP-Expert contains three basic elements: ACTIONS Block, Rules, and Statements (WordTEch Systems-1993).

The ACTIONS Block consists of keyword ACTIONS, one or more clauses, and semicolons as described in the first five lines of this Appendix. The ACTIONS Block tells the inference engine what it needs to find out, and in what order. This is accomplished with FIND clauses that instruct VP-Expert to find the value of one or more goal variable (s).

The rules stated as IF/THEN propositions, contained the actual knowledge or expertise of the knowledge base. Each rule has four essential

elements: the rule name, the rule premise, the rule conclusion, and a semicolon at the end of the rule.

Whereas rules contain the “expertise” of the knowledge base, statements generally contain information pertinent to the consultation itself. For example the endoff statement will eliminate the need to press END to finalize the menu. The runtime statement will eliminate the two rectangular shapes which, surrounded the screen during a VP-Expert consultation. The execute statement will cause a consultation to begin automatically upon execution of the Main Menu consult command. When a bkcolor statement is included in a knowledge base, it sets the background display of the color corresponding to the given number. Number seven corresponds to the white background.

The autoquery statement causes VP-Expert to automatically address a question to the user. The actions' statement is followed by one or more clauses. The CLS clause will clear the consultation window, so that the next display clause will begin on a blank screen. The wopen clause is used with a corresponding Active clause to generate windows around the text displayed to the user during a consultation. Windows can optionally be removed using the Wclose clause. The active clause causes all subsequent display text to appear in the specified window. The Display clause is used to display messages to the users. This clause is important for the conclusion messages that inform the user of the consultation results.

The Chain clause, used in combination with the Savefacts and Loadfacts clauses, permits the use of a large knowledge base. With these clauses the

author chained two or more knowledge bases for use in a single consultation.

The printon clause allows the print of the report during the consultation as shown in Appendix G 1.

Appendix D

THE CYTOLOGY ADVISOR

THIS SYSTEM EVALUATES THE CYTOI

```
endoff;
runtime;
execute;
bkcolor=7;
autoquery ;
  actions
  cls
wopen 1,2,5,10,65,3
active 1
display "
```

The LICENSE CHECK

Please have all documents pertaining to your evaluation ready
Press any key to continue."

```
wclose 1
  cls
  loadfacts lcomp

  find accept
  chain ltech;
! rules block
!.....
rule 1
if    state-license = no
      and complete = yes
      and cyto-job = yes
then  accept = yes
cls
wopen 2,2,5,10,65,4
active 2
Display "      E V A L U A T I O N  S T A T U S
-----"
```

The applicant's requirements for cytotechnologist and/or
cytosupervisor are met."

```
wclose 2;
!.....
rule 2
if    state-license = no
      and complete = yes
      and cyto-job = no
then  accept = no
cls
wopen 2,2,5,10,65,5
active 2
printon
Display "      E V A L U A T I O N  S T A T U S
-----"
```

The applicant's license requirements are not met until
a job in the field of cytotechnology is obtained.
Please send a letter to the lab "

APPENDIX E

The NN Credential module

The Cytology NN includes five modules, namely the credentials, license, technical supervisor, Cyto5, and Cytosupervisor modules. Appendix E represents the credential's module. The above modules contain from seventy to one hundred examples. The credentials module has seventy-one examples as shown in this Appendix. The credentials module contains nine inputs: education, required training, applicant training, required experience, applicant experience, HHS Certificate, Transcript, HHS Examination, and Cytology Job. It has only one output (the applicant has complete Credentials). The input nodes were designed to represent the CLIA'88 requirements. The output nodes match the evaluation codes.

According to the BrainMaker NN, there are three scores for defining inputs and outputs. The requirements are presented as follows:

1. The applicant has these credentials (1.00)
2. The applicant does not have these credentials (-1.00)
3. There is no information available for these credentials (0)

This grading system follows the BrainMaker V3.1 shell requirements for developing Neural Networks. The credentials module would have hundreds of possibilities. Fortunately the tree can be pruned. Through the NN training and testing, only seventy-one cases gave good evaluations. This Appendix represents the credentials module translated to Excel 3 spread sheet. These

data were transferred to the NetMaker spread sheets into which the author specified the input and output. Then the data was introduced to BrainMaker shell for training and testing.

APPENDIX E

CREDENT

| EDUCAT | REQ-EX | APL-EX | REQ-TRA | APL-TRA | HHS | TRANS | EXAM | CYT-JOB | Comple |
|--------|--------|--------|---------|---------|-------|-------|-------|---------|--------|
| 1.00 | -1.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 |
| 1.00 | 1.00 | 1.00 | -1.00 | 0.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 |
| 1.00 | -1.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 |
| 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 |
| 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 | 1.00 |
| 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 | -1.00 | 1.00 | 1.00 |
| 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.00 | 1.00 | -1.00 | 1.00 | 1.00 |
| 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.00 | -1.00 | 1.00 | 1.00 | 1.00 |
| 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | -1.00 | -1.00 | 1.00 | 1.00 |
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | -1.00 | -1.00 |
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | -1.00 | -1.00 |
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | -1.00 | -1.00 |
| 1.00 | 1.00 | 1.00 | -1.00 | -1.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 |
| 1.00 | -1.00 | -1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 1.00 | -1.00 |
| -1.00 | 0.00 | 0.00 | 0.00 | 0.00 | -1.00 | -1.00 | -1.00 | 0.00 | -1.00 |
| 1.00 | 1.00 | -1.00 | 0.00 | 0.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 |
| 1.00 | 1.00 | 1.00 | 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 |
| 1.00 | 1.00 | -1.00 | 0.00 | 0.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 |
| 1.00 | -1.00 | -1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 |
| 1.00 | -1.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | -1.00 | -1.00 |
| 1.00 | 1.00 | 1.00 | -1.00 | 0.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 |
| 1.00 | 1.00 | 1.00 | -1.00 | 0.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 |
| 1.00 | -1.00 | -1.00 | 1.00 | 1.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 |
| 1.00 | -1.00 | 0.00 | 1.00 | 1.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 |
| 1.00 | 1.00 | 1.00 | -1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 |
| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | -1.00 | -1.00 |
| 1.00 | -1.00 | 0.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 |
| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.00 | -1.00 | -1.00 |
| 1.00 | -1.00 | 0.00 | 1.00 | 1.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 |
| -1.00 | 1.00 | 1.00 | 1.00 | 1.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 |
| -1.00 | -1.00 | 0.00 | 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 |
| 1.00 | -1.00 | 0.00 | 1.00 | 1.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 |
| 1.00 | 1.00 | 1.00 | 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 |
| 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 |
| 1.00 | -1.00 | 0.00 | 1.00 | 1.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 |
| 1.00 | 1.00 | 1.00 | -1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 |
| 1.00 | 1.00 | 1.00 | 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 |
| 1.00 | 1.00 | -1.00 | 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 |
| 1.00 | 1.00 | -1.00 | 1.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 | 1.00 |
| 1.00 | -1.00 | 0.00 | -1.00 | 0.00 | 0.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| 1.00 | -1.00 | 0.00 | -1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 |
| 1.00 | -1.00 | 0.00 | -1.00 | 0.00 | 0.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| 1.00 | -1.00 | 0.00 | -1.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 1.00 |
| 1.00 | -1.00 | 0.00 | -1.00 | 0.00 | 1.00 | 0.00 | 0.00 | -1.00 | -1.00 |
| 1.00 | -1.00 | 0.00 | -1.00 | 0.00 | 0.00 | 1.00 | 0.00 | -1.00 | -1.00 |
| 1.00 | -1.00 | 0.00 | -1.00 | 0.00 | 0.00 | 0.00 | 1.00 | -1.00 | -1.00 |
| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 |

APPENDIX E

(Cont'd)

CREDENT

| EDUCAT | REQ-EX | APL-EX | REQ-TRA | APL-TRA | HHS | TRANS | EXAM | CYT-JOB | Comple |
|--------|--------|--------|---------|---------|-------|-------|-------|---------|--------|
| 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 | -1.00 | 1.00 | 1.00 |
| 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 | 1.00 | 1.00 |
| 1.00 | 1.00 | -1.00 | 1.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 | 1.00 |
| 1.00 | -1.00 | -1.00 | 1.00 | -1.00 | 1.00 | -1.00 | -1.00 | 1.00 | 1.00 |
| 1.00 | -1.00 | -1.00 | 1.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 | 1.00 |
| 1.00 | 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 | 1.00 |
| 1.00 | 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 | -1.00 |
| -1.00 | 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 | 1.00 | -1.00 |
| 1.00 | 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 | -1.00 |
| 1.00 | 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 | -1.00 | -1.00 |
| 1.00 | 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 | -1.00 | -1.00 |
| -1.00 | 1.00 | 1.00 | 1.00 | -1.00 | 1.00 | -1.00 | -1.00 | -1.00 | -1.00 |
| 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | -1.00 |
| 1.00 | 1.00 | 1.00 | -1.00 | -1.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 |
| 1.00 | 1.00 | -1.00 | 1.00 | 1.00 | 1.00 | -1.00 | -1.00 | 1.00 | 1.00 |
| -1.00 | 1.00 | -1.00 | 1.00 | -1.00 | 1.00 | -1.00 | -1.00 | 1.00 | -1.00 |
| -1.00 | 1.00 | -1.00 | 1.00 | -1.00 | -1.00 | 1.00 | -1.00 | 1.00 | -1.00 |
| -1.00 | 1.00 | -1.00 | 1.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 | -1.00 |
| 1.00 | 1.00 | -1.00 | 1.00 | -1.00 | 1.00 | -1.00 | -1.00 | 1.00 | -1.00 |
| 1.00 | 1.00 | -1.00 | 1.00 | -1.00 | -1.00 | 1.00 | -1.00 | 1.00 | 1.00 |
| 1.00 | 1.00 | -1.00 | 1.00 | -1.00 | -1.00 | -1.00 | 1.00 | 1.00 | 1.00 |

- CREDENT .. Credentials Module.
- EDUCA Education
- REQ-EX ... Required Experience
- AP-EX Applicant Experience
- REQ-TRA .. Required Training.
- AP- TRA .. Applicant Training.
- HHS Health And Human Services Certificate
- TRANS School of Cytotechnology Transcript
- EXAM Health and Human Services Examination
- CYT-JOB .. Cytology Job.
- COMPLETE ... Complete Documentation
- 1.00..... The applicant has these credentials
- 0.00..... Not Applicable
- 1.00..... The applicant does not have these credentials



Grants Office

Appendix F 1

Baruch College
 The City University of New York
 17 Lexington Avenue Box 514
 New York, New York 10010
 212 387-1120

MEMORANDUM

To: Professor George Schneller IV, Department of Management
 Mr. Mohamed El Etribi, Department of Management

From: Betty Farbman *B. Farbman*

Subject: Human Subjects Approval: An Exploratory Study of the Use of an
 Expert System....

Date: May 7, 1996

On May 2, 1996 David O'Brien, Chair of the Baruch College Human Subjects
 Committee, approved the protocol related to the above named project.

Please call this office if you have any questions.

cc: David O'Brien, Chair, Human Subjects Committee

Appendix F 2

April 1996

Dear Colleague:


According to our conversation, I am enclosing questionnaires for cytology personnel evaluations in accord with CLIA'88 regulations. In our profession we are concerned with finding ways to both increase evaluation accuracy and to reduce the time and efforts of our professional people. Participation in this study may help in the development of a tool that may accomplish the above objectives. We will make copies of the final work available to all participants upon request.

Recognizing the imposition on the valuable time of evaluations, we have attached a token honorarium of one dollar to each questionnaire. We hope to get your response as soon as possible.

Again, our sincere thanks for your help.

Mohamed El Etribi
Clinical Laboratory Consultant
38 Timbercrest Lane

South Setauket, NY 11720
Phone # 516-7361317

Dr. George Schneller , Ph.D.
Associate Professor of Management
Baruch College, CUNY, F-1831
17 Lexington Avenue
New York, NY 10010
Phone # 212-8026884

Appendix F 3**INSTRUCTIONS**

Please fully evaluate the fifteen personnel cases on the attached questionnaire in accordance with CLIA 88. It probably should not take more than a few minutes of your valuable time.

We greatly appreciate your help, and to partly compensate for your efforts, have enclosed a token honorarium of one dollar. We assure you that all individual responses will be kept confidential.

1. Highest degree obtained _____
2. Years of experience in the medical technology field _____
3. Years of experience evaluating laboratory personnel _____
4. Number of technical personnel working in the laboratory _____

Please indicate whether you would like to receive a copy of the results:

Yes —

No—

If you have any questions about completing this survey, please call:

Mohamed EL Etribi, (516)736-1317

Appendix F 4

Personnel Evaluations Sheet

| Case | State License (1) | Applicant License (1) | Education (Degree or Years after High School) | Experience (months) | Training (months) | Accreditation (2) | Cyto-Job (3) | Experience after Cytotechnologist qualification (Months) | Medical Permit |
|------|----------------------|--------------------------|---|---------------------|-------------------|-------------------------|-----------------|--|----------------|
| 1 | Cyto | Cyto | 6 | | | Transc | A&C | | |
| 2 | Cyto | Cyto | 1 | | | Certific | A&S | | |
| 3 | Cyto | None | M.D. | | | | | | Y |
| 4 | None | Cyt-Su | 2 | 25 | 12 | | B&S | 40 | |
| 5 | None | None | None | 30 | 12 | | B&S | | |
| 6 | Cyto | Cyto | Ph.D. | 6 | 11 | | A&S | | |
| 7 | Cyto | None | 10 | 18 | 18 | | B&C | | |
| 8 | Cyt-Su | Cyt-Su | M.D. | | | Cytology and A. Patholo | | | Y |
| 9 | Cyto | Cyt-Su | M.D. | | | | A&S | | Y |
| 10 | Cyto | Cyto | B.Sc | 30 | 30 | Exam | B&C | | |
| 11 | Cyto | None | D.O. | | | A&C Patholo | | | Y |
| 12 | None | Cyt-Su | M.S. | 7 | 6 | | None | 32 | |
| 13 | None | Cyt-Su | M.D. | 7 | 9 | | A&S | 36 | None |
| 14 | Cyto | Cyto | 2 | 3 | 2 | Exam | O&C | 40 | |
| 15 | Cyt-Su | Cyt-Su | M.S. | 23 | 6 | | B&S | | |

Legends:

(1) License

Cyto = Cytotechnologist
 Cyt-Su = Cytosupervisor

(2) Accreditation

Transc = CAHEA-accepted Cyto School
 Certific = Certified by HHS approved agency
 Exam = HHS Proficiency Exam
 A.Patholo = Anatomic Pathology
 A&C Patholo = Anatomic and Clinical Pathology
 Cytology = American Society of Cytopathology

Appendix G

An Example of the ES Report

Appendix G represents an example of the ES report. The applicant's specifications, and the evaluation status are shown in Appendix G 1. It shows that this applicant is qualified as a cytosupervisor and cytotechnologist only. This applicant is not qualified as a technical supervisor because he or she does not have a technical supervisor's delegations.

Appendix G 2, shows the explanation of how ES arrived at a decision.

1Comp2. KBS explained the steps for approval or disapproval of the applicant's credentials. In this example, the ES approved the applicant's credentials with 100% certainty.

1 Lic. KBS explained the steps for approval or disapproval of the applicant's license. The applicant has approved licence requirements in this example.

1 Tech. KBS shows the technical supervisor approval or disapproval status. The ES disapproved that the applicant is qualified as a technical supervisor because of the lack of the technical supervisor's delegation.

1 Cyto5. KBS shows the approval or disapproval of the applicant's cytotechnologist status. In this example, the ES approved that the applicant is qualified as a technologist.

Cyto1. KBS shows the approval or disapproval of the applicant's cytosupervisor status. The ES approved the applicant as qualified as a cytosupervisor. The final results of the ES evaluations are indicated in Appendix G 1.

WELCOME to

The Cytology Advisor

developed by:

Mohammed A. El Etribi

press any key to continue...

THE CYTOLOGY ADVISOR

116

THIS SYSTEM EVALUATES THE CYTOLOGY PERSONNEL
ACCORDING TO CLIA-88 REGULATIONS.

THE APPLICANT LAST NAME :
THE APPLICANT FIRST NAME :
THE APPLICANT I.D :
THE LABORATORY NAME :
THE LABORATORY ADDRESS :
THE LABORATORY CODE :
DATE :
THE OPERATOR NAME :

SPECIFICATION

| | |
|----------------------------|------------------|
| EDUCATION, | M.D. |
| STATE-LICENSE, | Cytotechnologist |
| APPLICANT-LICENSE, | Cytosupervisor |
| MONTHS OF TRAINING, | 6 |
| MONTHS OF EXPERIENCE, | 12 |
| CERTIFICATE, | |
| TRANSCRIPT, | |
| H.H.S EXAM, | |
| CYTO-JOB, | |
| CYTO-WORK, | Yes |
| MEDICAL-PERMIT, | No |
| DELEGATION, | |
| MONTHS OF POST-EXPERIENCE. | 39 |
| EVALUATION STATUS | |

The applicant's requirements as a technical supervisor
are not met until the applicant obtains delegation.
EVALUATION STATUS

The applicant's evaluation is approved as a cytotechnologist
(493.1483.b.3.i.b).
EVALUATION STATUS

The applicant's evaluation is approved as
cytosupervisor (493.1469.b).

C Y T O - C O N C L U S I O N S
APPLICANT LAST NAME :
APPLICANT FIRST NAME :
APPLICANT I.D :
LABORATORY NAME :
LABORATORY ADDRESS :
LABORATORY CODE :

| | |
|----------------------|-----|
| QUALIFIED AS : | |
| CYTOTECHNOLOGIST | Yes |
| CYTO-SUPERVISOR | Yes |
| TECHNICAL-SUPERVISOR | No |

NOT QUALIFIED BECAUSE OF :

```

Testing lcomp2.kbs
(= yes CNF 0 )
#3INTRO.exe
!   complete
!   !   Testing 1
!   !   !   hhs-exam
!   !   !   !   (= no CNF 100 )
!   !   !   !   school-of-cytotechnology-transcript
!   !   !   !   (= no CNF 100 )
!   !   !   !   hhsctotechnology-certificate
!   !   !   !   (= no CNF 100 )
!   !   Testing 2
!   !   !   education
!   !   !   !   (= USA CNF 100 )
!   !   Testing 3
!   !   !   required-training
!   !   !   !   (= yes CNF 100 )
!   !   !   !   approved-training
!   !   !   !   (= yes CNF 100 )
!   !   Testing 4
!   !   Testing 5
!   !   !   required-experience
!   !   !   !   (= yes CNF 100 )
!   !   !   !   approved-experience
!   !   !   !   (= yes CNF 100 )
!   !   Testing 6
!   !   Testing 7
!   !   (= yes CNF 100 )
Testing llic.kbs
(= yes CNF 0 )
!   accept
!   !   Testing 1
!   !   !   state-license
!   !   !   !   (= cytotechnologist CNF 100 )
!   !   Testing 2
!   !   Testing 3
!   !   Testing 4
!   !   Testing 5
!   !   !   applicant-license
!   !   !   !   (= cytosupervisor CNF 100 )
!   !   Testing 6
!   !   !   cyto-job
!   !   !   !   (= yes CNF 100 )
!   !   (= yes CNF 100 )
Testing ltech.kbs
(= yes CNF 0 )
!   qualify
!   !   Testing 1
!   !   !   degree
!   !   !   !   (= MD CNF 100 )
!   !   Testing 2
!   !   !   permit
!   !   !   !   (= yes CNF 100 )

```

```

! ! !   Anatomic-Pathology-Board
! ! !   !   (= no CNF 100 )
! ! !   Anatomic-Pathology-Equivalent
! ! !   !   (= no CNF 100 )
! ! Testing 4
! ! !   American-Cytology-Board
! ! !   !   (= no CNF 100 )
! ! !   American-Cytology-Equivalent
! ! !   !   (= no CNF 100 )
! ! Testing 5
! ! !   Pathology-Board
! ! !   !   (= no CNF 100 )
! ! !   Pathology-Equivalent
! ! !   !   (= no CNF 100 )
! ! Testing 6
! ! !   Residency-completion
! ! !   !   (= 12 CNF 100)
! ! Testing 6
! ! !   delegation
! ! !   !   (= no CNF 100 )
! ! !   (= no CNF 100 )
Testing lcyto5.kbs
(= yes CNF 0 )
!   approve
! !   Testing 2.1
! ! !   cyto-requirement
! ! !   !   (= yes CNF 100 )
! ! !   technical-supervisor
! ! !   !   (= no CNF 100 )
! ! Testing 2.2
! ! Testing 2.3
! ! !   school-of-cytotechnology-transcript
! ! !   !   (= no CNF 100 )
! ! Testing 2.4
! ! !   hhsctotechnology-certificate
! ! !   !   (= no CNF 100 )
! ! Testing 2.5
! ! !   hhs-exam
! ! !   !   (= no CNF 100 )
! ! Testing 2.6
! ! Testing 2.7
! ! !   work
! ! !   !   (= after_1-1-69 CNF 100 )
! ! Testing 2.8
! ! Testing 2.9
! ! Testing 2.10
! ! Testing 2.11
! ! !   education
! ! !   !   (= Doctrates CNF 100 )
! ! Testing 2.12
! ! !   training
! ! !   !   (= 6 CNF 100)
! ! Testing 2.13

```

```
!   !   !   !   (= 12 CNF 100)
!   !   (= yes CNF 100 )
Testing cytol.kbs
(= yes CNF 0 )
!   confirm
!   !   Testing 1
!   !   !   cyto-supervisor_job
!   !   !   !   (= yes CNF 100 )
!   !   Testing 2
!   !   !   post-qualification_experience
!   !   !   !   (= 39 CNF 100)
!   !   (= yes CNF 100 )
```

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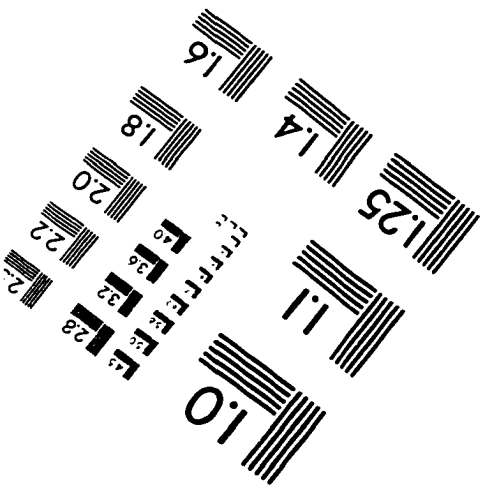
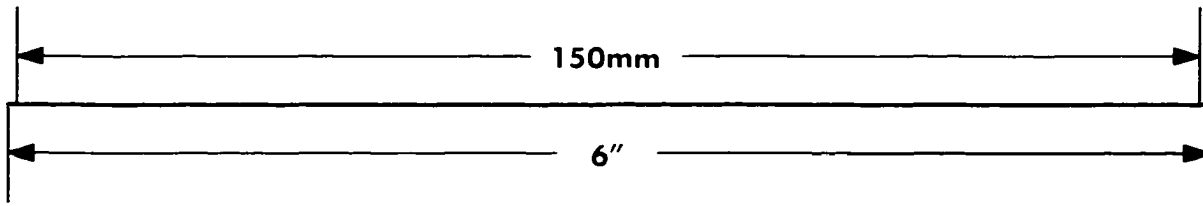
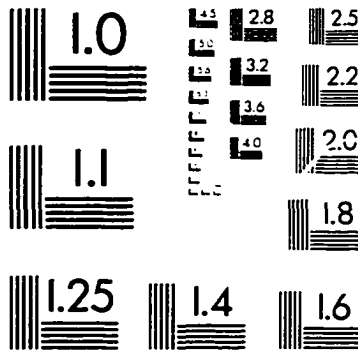
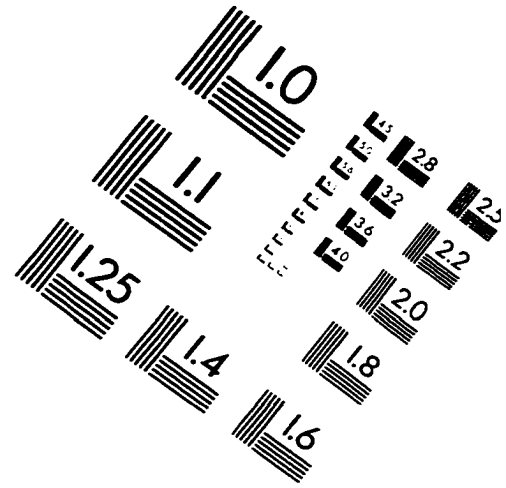
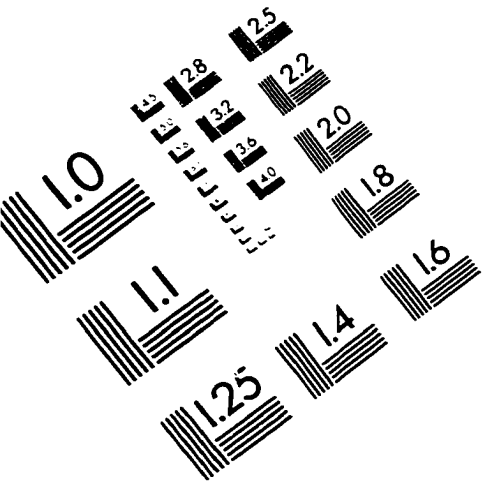
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IMAGE EVALUATION TEST TARGET (QA-3)



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