EVALUATING AI-ESTATE STANDARDS COMPLIANCE USING A FUNCTIONAL INTELLIGENCE RATIO

by

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ABSTRACT

Recent work by the IEEE Standards Coordinating Committee-20 (SCC-20) has included the establishment of a subcommittee known as AI-ESTATE. AI-ESTATE is responsible for specifying new standards for interfacing artificially intelligent systems with automatic test equipment (ATE). Associated with the establishment of these new standards, AI-ESTATE must establish guidelines for determining whether or not AI based ATE systems comply with the IEEE standards. Past approaches to determining standards compliance are problematic when applied to heterogeneous AI systems. Thus, we propose a new approach to evaluating AI based ATE systems under AI-ESTATE using what we call a functional intelligence ratio (FIR). In this paper, we describe the problems associated with evaluating AI systems, describe the role of AI-ESTATE as part of SCC-20, and present the FIR with a sample list of base requirements.

BACKGROUND

Recent work by the IEEE Standards Coordinating Committee 20 (SCC-20), has included the specification of standards for artificially intelligent automatic test equipment (ATE). The SCC-20 established a subcommittee known as AI-ESTATE (Artificial Intelligence-Expert System Tie to Automatic Test Equipment), and in February of 1990, the IEEE approved a project authorization request (PAR-1232)[1] authorizing the SCC-20 to develop the new standard under AI-ESTATE. Currently there are three major interfaces that comprise the AI-ESTATE standard (see Figure 1).

- Human Services - To provide an interface between human operators and the ATE, operating system, and any of the reasoning systems.
- Communication Services - To provide machine-to-machine services between ATE, operating system and other associated users.
- Information Services - To provide access to associated data bases.

In defining the interface to the knowledge based systems, AI-ESTATE is concerned with the functionality of the knowledge based systems in relation to the goals of ATE systems. Determining the compliance of any AI ATE system with the AI-ESTATE must include this AI functionality in determining the appropriateness and applicability to the ATE problem.

One approach to measuring compliance with a voluntary standard is to build a series of levels or subsets. These subsets become progressively more robust until achieving full compliance. In some cases, an implementor will define the subset of functions that they choose to include. If the implementor chooses to include all functionality then full compliance with the standard will be achieved. Such a process works well for languages, and is used in the standards for ATLAS-626[2] and VHDL[3]. This approach may not work well in a definition of interfaces where minimum compliance may be viewed as meeting the interface protocols. It would not make sense to claim minimal compliance with AI-ESTATE where little or no AI functionality was present.

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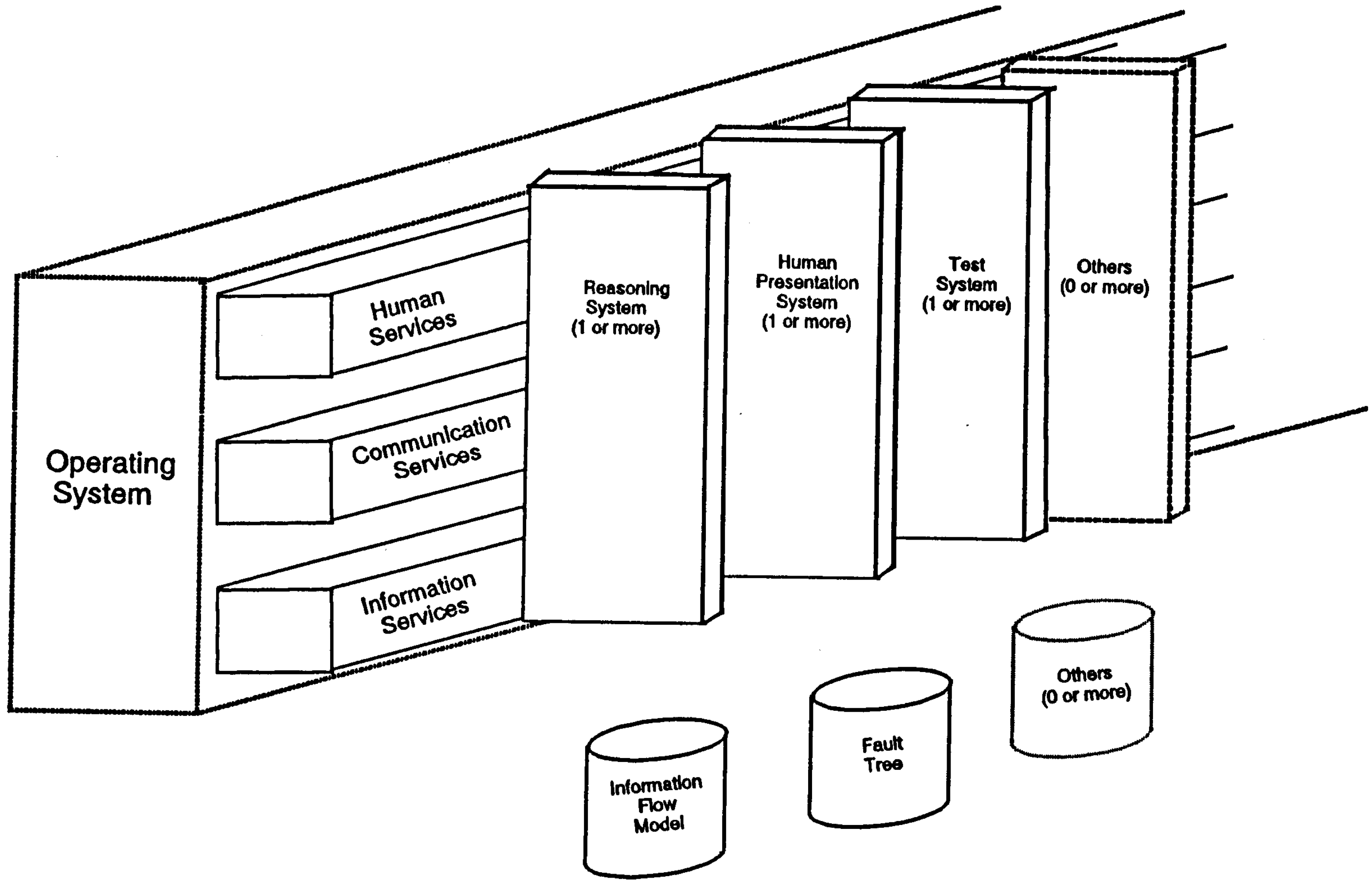

Figure 1. AI-ESTATE Architectural Concept

One problem of specifying standards for artificially intelligent automatic test equipment lies in dealing with a large number of systems to solve automatic testing problems that have little in common. The processes embodied in such varying techniques as rule-based expert systems[4], model-based reasoners[5], or neural networks[6] can be evaluated at several different levels. In developing a standard such as AI-ESTATE in which we are attempting to address many different types of information processing systems, the question of determining how to measure compliance to the standard is a key issue.

As mentioned above, one approach to solving the problem is to specify various levels at which AI systems can comply. For example, minimal compliance may be achieved through using a pre-computed fault isolation strategy, such as the fault tree. By incorporating a single knowledge based system such as an expert system or a model based reasoner, the ATE may provide explanations, user interaction, and some learning. We may consider this level of functionality to be AI-ESTATE Level 2 compliant. Alternatively, if we include multiple cooperating knowledge based systems, providing a multitude of capabilities and functions, they may be Level 3 compliant. we believe this approach to standards compliance is unsatisfactory because defining the boundaries of various levels becomes problematic. Not all expert systems provide learning, and not all multiple cooperating knowledge base systems provide the user with several options.

An alternative approach would be to evaluate the knowledge bases used by the reasoning system. When considering the types of knowledge base systems available from AI we face a difficult situation of determining which techniques adequately satisfy the requirements of the ATE system. For example, neural networks apply very well in low level situations in which we are attempting to recognize a pattern. They have shown themselves to be very useful in electronic circuit diagnosis, wave form analysis, and in other similar tasks; however, their "reasoning process" is difficult to interpret. The rule based expert system, on the other hand, works very well at a high level by relying on heuristics gleaned from expert diagnosticians to diagnose a problem; however, they may not handle pattern recognition tasks well. Typically this is not what we might expect from an ATE system, but it is certainly applicable. Combining rule based expert systems and neural networks provides an added capability in that we can now interpret low level information and use that information to feed the high level rule based system. Evaluating the level at which a system is AI-ESTATE compliant when this multitude of techniques is available is problematic because it is difficult to ascertain which of the techniques most significantly contribute to the performance of the ATE.

THE FUNCTIONAL INTELLIGENCE RATIO

The idea of measuring the reasoning power of an AI system has an intuitive appeal. Minsky proposed a machine intelligence quotient (MIQ) that paralleled the human IQ measure.[7] Since we are limited to the specific domain of ATE, we concentrated on the functions that a reasoning system may provide within this domain. We propose a weighted evaluation function based upon the functional capabilities of the AI system called the Functional Intelligence Ratio (FIR).

We intend the functional intelligence ratio to measure various functional capabilities of the AI-ESTATE system. The goal is to consider specific functions that arise due to incorporating artificial intelligence techniques. Therefore the functionality such as the ability to probe a board at the request of the ATE system, should not be considered an intelligent function because of the fact it is standard and in many cases required for traditional ATE systems. On the other hand the ability to control the sequence of test events dynamically may be considered an intelligent function. Using the idea of defining intelligent functions (which we view to be functions that increase the adaptability or flexibility of the system or provide significant performance improvement over time), we attempt to combine the various functions provided by an ATE system to determine the overall functionality of that system. We call the resulting metric the functional intelligence ratio. Table 1 provides a subset of the functions currently under consideration.

These functions are currently undergoing refinement and evaluation. Most appropriate functions will be listed, although their weights may be low. For example, some functions may include: identification of a defective part prior to the ATE testing using historical system failure data, or performing predictive diagnostics at any point during testing based on the current test results and other factors. Of course, significant functions to be included would

Table 1
AI Functions to be Considered

Function	Base Requirement	Weight (0-1.0)
Incorporate learned experiences in isolation strategy	No	TBD
Allow user to control ATE	Yes	TBD
Access historical data	No	TBD
Allow user to guide test strategy	Yes	TBD
Full hypermedia interface	No	TBD
Supply user with status of diagnosis	Yes	TBD
Predict failure(s) from any point in diagnosis	No	TBD
Explain why tests are being executed	No	TBD
Continue isolation with failed or unavailable instruments	No	TBD

be the ability to adapt the fault isolation strategy based on known information and the current context, to explain its reasoning process, to allow human intervention, etc.

COMPUTING THE FIR

To calculate the FIR, first measure the functionality of the target system using a list of possible functions to be considered. Weights are assigned to each of these functions corresponding to their significance under the AI-ESTATE standard. Weights are also applied to the individual functions of the target system to determine how well they perform that function. A minimal set of functions (base requirements) will be specified in order to characterize what we consider to be minimally AI-ESTATE compliant. A total functionality metric will be computed for the target system by combining the two weights and summing them over the set of possible functions. A minimal compliance metric will be computed by summing the weights of the minimum required functions for the AI-ESTATE system. The functional intelligence ratio is the ratio of these two metrics.

$$\mathbf{FIR} = \frac{\sum_{i=1}^{n} w_i \hat{w}_i}{\sum_{i \in base} w_i}$$

where *base* is the set of base functions, the FIR is computed over the number of entries in Table 1, w_i is the weight provided in Table 1 (when available), and $\hat{w}_i$ is the degree of completeness of function i. The denominator is simply the weighted sum of the base requirements. Obviously, if we treat the denominator as a normalizer (i.e., the weights sum to 1.0), the we only need to compute the numerator to give the FIR. Note that in a good system, FIR should exceed 100%.

The advantage of the functional intelligence ratio is that some systems may comply by nature of their capability even though they may be deficient in particular areas. Rather than requiring compliance to each minimal function, we allow compliance to some subset of these functions in addition to other functions that compensate for the deficiencies. The resulting metric contains a threshold that enables us to determine not only whether a system complies with the AI-ESTATE standard but how well that system complies.

CONCLUSION

This paper has described the functional intelligence ratio as an alternative approach to evaluating compliance with the AI-ESTATE standard. The problem facing the AI-ESTATE subcommittee is evaluating systems that may incorporate multiple technologies to achieve some minimal set of functions considered to be "intelligent." Rather than specifying individual functions and capabilities or specifying levels of compliance, the functional intelligence ratio enables the developer to incorporate whatever resources are available and still be able to conform to the AI-ESTATE standard. In addition, the functional intelligence ratio, by its very nature, is extensible to the development of new technologies and is not limited to any one technology.

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