The validation of ASExpert-an expert system proposed for use in activated sludge wastewater treatment plants

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An expert system is mainly developed to include a representation of the experience, knowledge and reasoning process of a human expert in a specific field. Thus its goals are usually more ambitious than those of algorithmic programs which calls for an accurate system testing before implementation. However there is little consensus in the field of expert systems on what testing is or how to perform it. Problems related to the nature of expert systems themselves make the direct application of many conventional validation methods infeasible. This paper documents the approach followed for ASExpert's validation, a system proposed for use in activated sludge plants, where a 3-phase methodology was followed. First the employment of the expert system was justified. Then the completeness and consistency of the knowledge base was validated. Finally the system's overall performance was verified using a functional set of trial cases. Results obtained were compared against those documented in a reliable trouble-shooting reference. This approach proved to be very adequate. It by-passed the need for domain experts as evaluators especially as it is not possible at the present to run ASExpert in an actual plant to test it.

يتم تطوير أي نظام خبير بصفة أساسية ليتضمن تمثيلا لخبرة و معرفة و أسلوب تفكير خبير بشرى في مجال معين. و على هذا فإن أهداف مثل هذا النظام تكون عادة أكثر طموحا عن أهداف البرامج التقليدية القائمة على المنطق الحسابي مما يستدعى إجراء اختبار دقيق للنظام قبل تطبيقه. وبينما يعد قياس كفاءة أداء النظام خطوة مكملة لابد من إتمامها بصورة مرضية قبل الاتجاه نحو التطبيق في علم هندسة البرمجيات التقليدية، فلا يوجد إجماع حتى الآن في مجال الأنظمة الخبيرة حول مفهوم قيـاس كفـاءة النظام أو حول كيفية أداء هذا القياس. و ذلك نظرا لوجود مشكلات ترجع لطبيعة الأنظمة الخبيرة ذاتها تجعل التطبيق المباشـر لكثير من وسائل تحقيق البرامج التقليدية غير ممكنة عمليا. و هذا البحث يسجل الطريقة التي اتبعت في تحقيق النظـام الخبير (ASExpert) -الذي نقترح استخدامه بمحطات معالجة المخلفات السائلة بواسطة الحمأة المنشطة- حيث تم اتباع منهج من ثلاثة أطوار لذلك. أولا تم التحقق عن صلاحية استخدام النظام الخبير من حيث المبدأ كأسلوب حل لمعالجة المشكلة القائمة. ثانيا جرى التحقق من اكتمال و تطابق قاعدة المعرفة الخاصة بالنظام. و أخيرا تم تقييم الأداء الكلي للنظام باستخدام مجموعة فعالـة مـن الحالات التجريبية حيث تم مقارنة النتائج التي حصلنا عليها بمثيلتها المسجلة بمرجع معتمد خاص بمعالجة مشـكلات التشـغيل المتعلقة بهذه المحطات. و قد أثبت هذا المنهج صلاحيته و أمكننا التغلب على مشكلة عدم توافر خبراء بشريين لتقييم أداء النظام المقترح خاصة أنه لا تتوافر حاليا الإمكانية لتجربته عمليا بإحدى محطات المعالجة العاملة.

Keywords: Expert systems, Testing, Validation, Activated sludge.

1. Introduction

The Activated Sludge Expert or ASExpert is a PC-based application made up of a rule-based expert system plus a complete database tool. It is proposed for use in conventional activated sludge plants. It serves as a decision aid tool dedicated to the operators of these plants to help them better diagnose operating conditions. It can also provide suggestions regarding suitable corrective remedies necessary to cope with problematic situations. ASExpert was developed using a Visual C ++ 5.0 interface and the Dynamic Link Library (DLL) of the "C Language Integrated Production System" (CLIPS) version 6.05, an expert system shell developed by NASA. It is an expanded prototype that can serve as a final delivery system after some customization to incorporate the site specific nature characteristics related to each treatment plant.

The expert system component of ASExpert allows for the inspection of problems related to 3 major problem detection methods that are usually used in activated sludge plants; observations, measurements and microscope analysis. In addition it allows for both quick

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and a detailed data analysis of the database records. The knowledge base is made up of 245 rules that cover up these aspects. ASExpert's basic architecture and description are presented in [1] and a full explanation of its development life cycle, knowledge base description, implementation technique, features and capabilities can be found in [2].

2. Background and basic definitions

In traditional software engineering where the life cycle model is usually followed for system development, system testing through verification, validation and evaluation is claimed to be an integral part of the design and development process. Thus the technical literature of software engineering provides accurate definitions of these terms. Accordingly verification is the task that determines whether the system is built according to its requirements specifications or not. Secondly validation is the determination whether the completed system performs the functions stated in its user's requirements and actually fulfills the purpose for which it was intended or not. Finally evaluation reflects the acceptance of the system by potential end users and its performance in the field [3].

Since ASExpert's goal is to perform as an intelligent assistant and a training aid, thus such an ambitious goal necessitates accurate system testing. However in the field of expert systems, there is little consensus on what testing is necessary or how to perform it. Actually expert systems are usually developed to handle ill-structured problems thus some vagueness in the specifications of these systems is inevitable and as a result difficulties arise if we try to directly use verification and validation methods based on the previous definitions. Further, many of the procedures that have been developed and used for verification, validation and evaluation of expert systems are so poorly documented that it is difficult, if not impossible, to reproduce these procedures by anyone other than their originator. Also many of these procedures were designed to be specific to a particular domain and are not easily transferable to other domains. Therefore the complexity and uncertainty related to these tasks has led to a situation where most expert systems are not adequately tested [3]. Thus although the terms; testing, verification, validation and evaluation are frequently used in the field of expert systems their exact definitions and the ways to achieve them are still unclear [4].

However, we share the opinion presented in [4] where Meseguer considers the previous definition for validation in software engineering, applicable for expert systems as well. From his point of view, an expert system is developed to perform some tasks aiming to satisfy the needs of potential users. Thus these needs have to be explicit in some way in order to allow for an effective definition of the system's purposes. Although these requirements can be unclear or ill defined or even cannot be completely translated into formal specifications due to the ill-structured nature of the current problem, all this can't deny the fact that user requirements play the same role that it holds in software engineering.

3. Validation of expert systems

Accordingly validation is determined with respect to user requirements that have -in the expert systems field- to be further classified to completely or partially formalize requirements depending on their complete or partial translation into specifications. This way the validation of an expert system should cover both the examination of technical correctness (i.e. verification) and other aspects that require subjective assessment (i.e. evaluation) [4]. Further to assess an expert system's overall performance, it has to be tested on sample cases and its results compared with the results obtained independently from other sources for the same cases. It is important then to use a test set that covers all the important cases and enough examples to ensure that the correct results are not just anomalies. However it bears mentioning here that as the scope of the specifications is rarely precise and it is practically impossible to test a system under all the rare events possible. Therefore it is impossible to have an absolute guarantee that a program satisfies its specification and only a degree of confidence that a program is valid can be obtained [3].

To sum up, this paper will similarly consider the validation of expert systems as a global task that embodies all other tasks as specific aspects. First it stresses the need for expert systems validation in general, and briefly presents related problems that arise because of the unique nature of these systems. Secondly it a presents the methodology selected for the validation of ASExpert. Finally the paper introduces a sample of the test cases and results obtained.

4. The need for expert systems validation

It is very important to validate expert systems especially when the software is part of a machine or a system that can cause death or serious injury. In fact there have already been many reported cases of expert systems and other software failures that have resulted in death. Current battle management systems employ advanced AI techniques, which necessitates accurate validation of these systems [3 & 5].

Another important reason that justifies the need for accurate validation is that an expert system like a human expert will be wrong some of the time even if the expert system contains no errors. The knowledge base on which the expert system is based -even if it is the best available- can not completely predict what will happen. It may not be sufficient for prediction in every case. One reason for this is that knowledge bases are usually confined to a limited amount of knowledge concentrated in carefully defined knowledge areas. Another reason is that current expert systems contain no "common sense" knowledge. They know only what has been put into their knowledge bases. They contain no underlying truth or fact structure to which to turn to in cases of ambiguity [3].

Thus an expert system with some errors in its knowledge base can make mistakes that would seem ridiculous to a human expert, and won't realize that a mistake has occurred [3]. Therefore it is important to validate that the advice being given by the expert system is sound, especially as the expert system may be used by persons with no expertise, who can not themselves judge the accuracy of the advice given to them.

5. Problems and special issues related to expert systems validation

As previously mentioned, due to the unique nature of expert systems, the complete translation of user requirements into specifications does not hold [4]. Thus expert systems specifications are usually vague and cannot provide precise criteria against which to test [3].

The knowledge base of an expert system plays a fundamental role in its function since all the system's actions have their origin in the interpretation of the knowledge base contents (rules). Thus its validation is an essential step in the global expert system validation. The knowledge base has to be designed before rule coding to assure that its organization is adequate to the problem to be solved. In addition to validating the knowledge base structure, its contents should also be validated and checked for correctness, completeness and consistency. However, to completely validate an expert system it is required to validate all its parts -the inference engine, the user-interface, explanation capabilities and input-output facilities- in isolation plus the validation of the system's overall performance [4].

Another problem may be related to expert systems languages that sometimes could not accommodate these relatively unstructured applications [3]. From the start the knowledge representation capabilities of the expert system language has to be evaluated with respect to the required problem. If the language does not provide facilities to represent the different aspects of the domain knowledge, the resulting knowledge base is unlikely to be adequate. For example if the problem at hand has to deal with uncertain or imprecise information then the used expert system language must support uncertainty [4].

In fact one of the reasons that promoted using the expert system shell CLIPS for ASExpert's implementation was that it includes a number of features to support the verification and validation of expert systems including support for modular design and partitioning of a knowledge base [2 & 6].

Although the validation of expert systems can be defined in the terms of user requirements similar to software engineering, this does not imply the direct applicability of many conventional validation methods to expert systems. The existing differences between both fields mainly regarding the kinds of problems addressed and the type of development techniques (languages) used, justify and demand the existence of specific validation methods for expert systems [3]. However the accumulated experience in conventional software validation must not be ignored in expert systems validation. This experience has to be applied considering the essential issues to be solved that are shared to a significant extent by both conventional software and expert systems regardless of the specific techniques employed that are usually bounded to the style of the programming languages used [4].

6. A 3-phase methodology for expert systems validation

The following section presents the methodology selected for ASExpert's validation (see Fig. 1) and very briefly reflects our experience in doing so. According to the cited reference [5] validation of an expert system must address the following 3 issues:

Phase 1: the justification for the employment of an expert system. The very first step in the validation of an expert system should take place even before the development process starts. From the very beginning an objective justification for the use of the expert system approach should be provided. One must be certain that such an approach is practical, appropriate and cost effective than any readily available alternative.

Phase 2: the validation of consistency and completeness of the expert system's rule base. This phase starts as soon as a portion of the rule base is ready (at the prototype development phase). The objective of this phase is to check the logic and integrity of the rule base against inconsistencies and incompleteness.

Phase 3: the verification of the overall performance of the expert system. The final aspect of expert systems validation is the verification of the performance or output of the expert system i.e. how well does it accomplish its intended role in actual practice.

7. Measures of performance

Depending on the system's intended role its measures of performance could then be identified, these include:

- Solution accuracy,
- Improvements over existing procedures,
- Clarity and timeliness of output,
- Ease of use,
- Ability to integrate more knowledge into the system, and
- Impact on personnel: whether the system will be widely accepted and whether any special training will be required to use it or not.

These measures indicate that although the main aspect of expert system verification is to ensure that the expert system replicates the advice that would be provided by the human expert to deal with a specific situation (accuracy of solution). However other aspects such as the timeliness of advice should not be neglected.

After determining the necessary measures, the final step should be to test the expert system. Two approaches may be followed [5].

- To let a human expert provide a set of trial cases (input/ expected output). Then to use these trial cases as an input to the expert system. The results produced by the expert system should then be compared with the ones initially provided by the human expert.
- Another approach could be to run the expert system in parallel with the current existing procedures and to compare results provided by both techniques.

8. Specific issues of expert systems testing

Expert systems testing is the process of examining expert system behavior by its execution on sample cases. It is a very

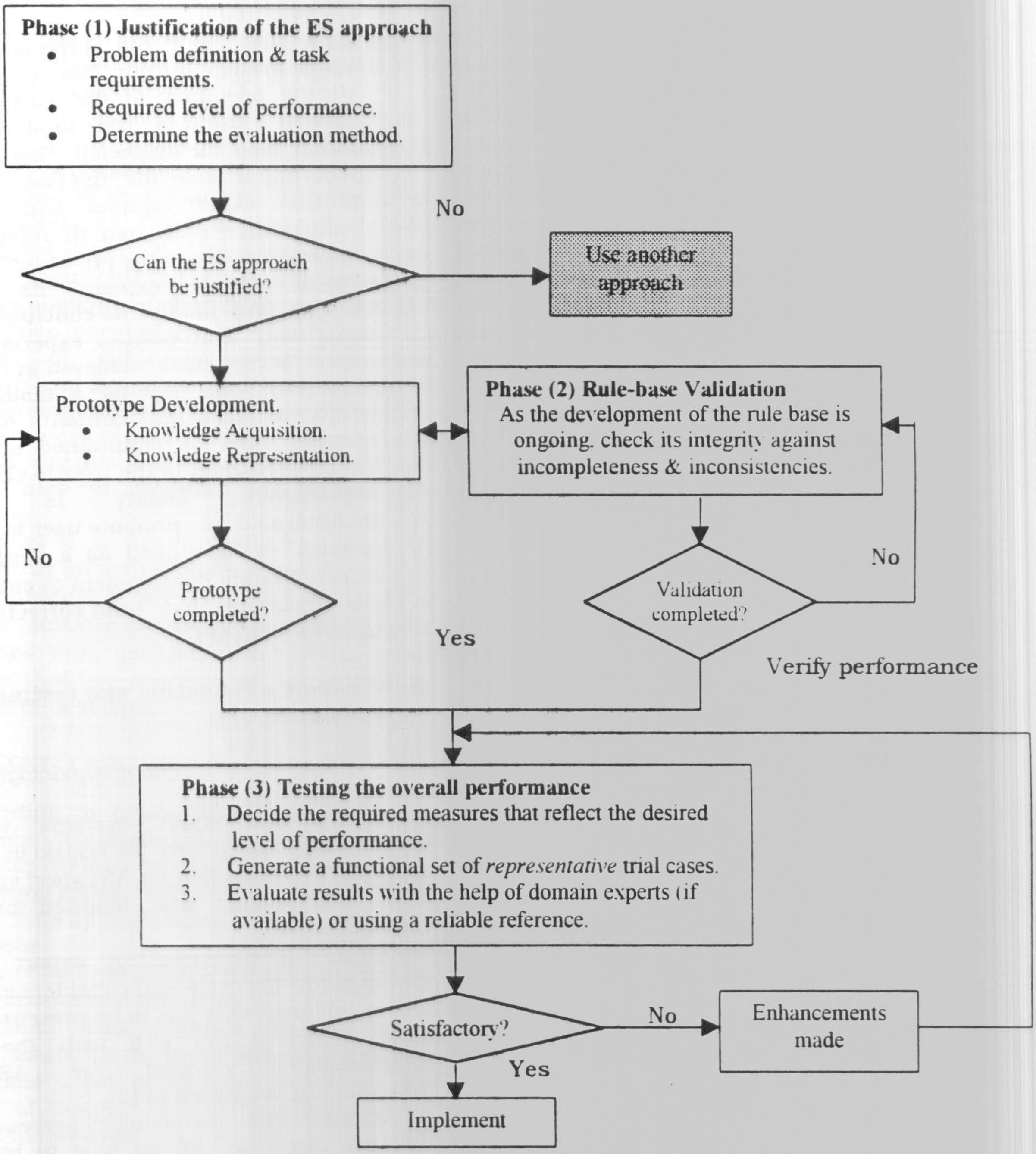

Fig. 1. A 3-phase methodology for ASExpert's validation.

important technique used to evaluate expert system correctness. The technical literature indicates that it has been used as a fundamental criterion for formal acceptance of expert systems and assessing performance [4].

- A central issue in testing, shared for both conventional software and expert systems is the selection of the test set. Random, structural and functional approaches have been developed for conventional software. In the expert systems domain, random testing is not considered adequate to check correctness, as a random input will probably be meaningless. However expert systems structural testing is performed using test-case generators and functional testing relies completely on the selection of test cases by human experts [4]. Historical data files on the domain of the expert system task are usually regarded as a source of potential test cases. As a result the quality of the test set depends largely on the accuracy of this recorded data.
- Second as mentioned earlier, to assess the behavior of an expert system, its performance has to be compared against human expert competence. Therefore the presence of human experts as evaluators is needed which raises new issues as human experts often disagree and can sometimes be prejudiced or inconsistent [4]. To prevent human prejudice Turing tests were introduced as a testing technique. This technique aims at making human evaluators unable to distinguish computer responses from human responses. It consists in the evaluation of the expert system output mixed with recommendations of human experts for a set of given cases without knowing which is the system and who are the humans. Another technique that is also used in the expert systems domain is called field tests. A field test is to regularly use the expert system in its target-working environment. Errors and users complaints are recorded and solved. Then the system is considered completely tested when these complaints have ceased. This test is especially suitable for assessing aspects of user interaction. However both testing techniques require an extensive involvement of human experts and potential users [4].
- Finally not only the correctness of the expert system output has to be checked but the adequacy of the deduction path followed towards the final conclusion should also be inspected. This aspect has great importance for the final acceptance of the expert system and has been traditionally evaluated in relation to its explanation capability [4]. In fact an expert system should explain its reasoning process and justify its conclusions in the same way that human experts do. This aspect is very easily achieved in rule-based expert systems because a history of the activated rules and contents of working memory can be maintained in a stack. Then presented to the user to check it. An explanation facility is primarily incorporated to promote user acceptance. Second to be used as a verifying tool during system development to confirm that the knowledge has been correctly entered into the system [7].

9. ASExpert's validation and testing experience

9.1. ASExpert's validation methodology

Thus the expert systems validation methodology suggested by Ignizio in the cited Ref. [5] was adopted for ASExpert validation. This methodology was followed for several reasons:

First, it proposes an expert systems development life cycle and considers validation as an element that has to be present in all its steps. Thus it fits well with the overall methodology adopted for ASExpert's development presented in [2].

Second, this methodology agrees with the maxims cited in [8] on how to build and evaluate expert systems and that reflect the experience of some of the pioneers in the expert systems field. These maxims state:

- The expert system task should be neither too difficult nor too hard for human experts. This task should be defined clearly.
- The way to be used for system evaluation must be identified early.

- As system reliability can only be ascertained in the presence of criteria for judging system's success. Thus a core set of representative problems and a library of cases must be presented to the system to test its reliability.

Third, as it is not currently feasible to run ASExpert in an actual plant to completely evaluate its performance.

The reasons that justified the use of an expert system as a solution approach were clearly stated in [1 & 2]. Also it was pointed out that the major bulk of ASExpert's knowledge base was made up of already documented and verified rules particularly to ensure that the used set of rules is correct, complete, consistent and free of contradiction in order to finally develop a powerful and reliable system. For the same reason ASExpert's knowledge base was organized in the form of 15 separate CLIPS's files to facilitate knowledge base validation.

Then as it is not currently feasible to run ASExpert in an actual plant, it was found that using a functional set of trial cases would be the most suitable alternative to test ASExpert. Trial cases were generated to cover the main problems that an operator of a conventional plant has to deal with.

9.2. ASExpert's test cases

According to reference [9] the most usual operational troubleshooting situations in a wastewater treatment plant correspond with the following cases:

Bulking: This appears when sludge setteability is very poor.

Foaming: The case when a lot of foam appears causing operational problems.

Overloading: This problem appears when organic matter at the input increases sharply. It provokes a set of annoying situations, like absence of oxygen, bad settleability and low yields of the process.

Toxic loading: In plants that receive wastewater from industrial towns, the presence of toxic compounds especially heavy metals at the inflow is rather frequent. Biomass cannot grow properly or even dies in the presence of heavy metals.

Storm: This problem appears in plants where collected rainwater uses the same sewage system as wastewater. Inflow and suspended solids have a very big increase, hydraulic retention time decreases and suspended solids at the output may be higher than the authorized levels.

Dissolved oxygen (DO) problems: Over-aeration provokes biomass flocs to break, while energy consumption is higher than necessary. A low value of DO does not allow the microorganisms to live in good conditions.

Thus as pointed out earlier, the chosen test cases will mostly cover these well-known trouble-shooting situations.

9.3. ASExpert's testing results

A set of 47 representative cases was used. These cases were presented to ASExpert to assess the status of a hypothetical plant under different operational situations and to provide assistance regarding the probable cause and corrective measures on how to cope with the current situation.

Then using a very reliable reference [10], the causes and recommendations documented on how to successfully cope with similar situations were sought. Comparing results proved that ASExpert's conclusions were consistent with those documented in [10].

ASExpert's suggestions regarding 46 cases were easily validated this way, leaving only 1 case for which no match was found in the previously mentioned reference. ASExpert's suggestion for that specific case (a case of turbulence presence in aeration basin) was quite obvious such that no further justification is required [2].

In all of these 46 cases ASExpert managed to provide either an assessment of the plant state or a suggestion regarding the corrective remedy necessary to cope with the present situation. In addition, in 38 cases ASExpert provided both (the assessment of plant state and the corrective remedy). In 20 cases ASExpert identified probable cause(s) that has or have led to the present situation [2].

This way ASExpert does not only provide the operators of the plant with the necessary corrective remedy but helps them gain a deep insight into the whole situation. In fact these (cause/effect/corrective remedy) triplets enhance the capability of using the system as an intelligent assistant or tutor. It can also facilitate the validation of the system's results and criticizing its performance by outside domain experts. Similarly it can facilitate comparing its results with those documented in other written references [2].

Reference [10] was chosen for its reliability, wide acceptance and most importantly for its easily used troubleshooting guide and accompanying figures that provide rapid access to the required information. Otherwise the evaluation of these cases would have necessitated the presence of one or more domain experts to assess the validity of ASExpert's suggestions or an exhaustive review of literature related to similar trouble-shooting situations.

As for testing the deduction path followed, it was mentioned in cited refs. [1, 2] that ASExpert is provided with a simple explanation facility (the menu selection "Why this diagnosis was reached?"). This explanation facility achieves its goal by taking advantage of CLIPS's (watch) command that can let us watch the rules firing on the agenda. Then by tracing these rules and similarly by watching facts that are either asserted or removed from the fact list (ASExpert's working memory), the reasoning process that led to the present conclusion becomes apparent [2].

Other measures of performance such as timeliness of response, ease of use, impact on users and the ability to integrate more knowledge into the system were also considered. ASExpert was developed using CLIPS an expert system shell based on the Rete algorithm. The Rete algorithm is recognized as the most efficient algorithm for production systems and its execution time is asymptotically independent of the number of rules [11]. A very flexible user friendly GUI was developed using Visual C++ 5.0 to ensure ease of use and promote user acceptance. Also a rule editor was incorporated to facilitate integrating new rules into the system with no need to have the knowledge engineer explicitly code these rules into the system's files [2].

9.4. A rapid insight into ASExpert's testing comparison study

The following tables present a sample made up of four trial cases. Table 1 summarizes ASExpert's results and Table 2 summarizes the causes, necessary checks and recommendations as documented in reference [10] for the same cases. A complete comparison study of the whole set of trial cases, assessment of results and conclusions can be found in [2].

10. Conclusions

The accumulated experience in conventional software validation cannot be ignored in expert system validation. Accordingly this experience has to be applied considering the essential issues to be solved that are significantly *shared* by both conventional software and expert systems regardless of specific techniques employed that are usually bound to the style of the used programming languages.

Validation of expert systems must be regarded as a fundamental part of the development process. The plan for validation must start as soon as a decision has been made to develop such a tool.

Although the knowledge base is considered to be the central component of the expert system, its validation is not synonymous to expert system validation. The complete validation of an expert system requires the validation of all its parts in isolation, plus the validation of the system's overall performance.

Validation of an expert system must fundamentally address three issues; first the justification of the use of an expert system for the current problem. Second the logic and integrity of the knowledge base. Thus checks for knowledge base completeness and consistency should start as soon as a portion of the knowledge base is developed and should continue until its completion. Finally the overall performance of the system should be evaluated according to specific measures and the used test cases must represent true situations of real problems that the system will eventually have to cope with.

Case No.	User Definition of problem			ASExpert definition of plant state, probable cause of problem and corrective action			
	Problem Detection Method	Location	Problem indications noticed by user	State	Probable Cause	Rules fired	ASExpert Suggestion
8	Observations	Aeration Basin	- Foam (Brown Scummy) - Scum coverage of tank surface = 20-90 % - Trend of problem is *increasing*	Actinomycetes Micro-organisms Growth with a suggestive evidence of 60%	Actinomycete source (Nocardia genus)	check37 al aeration5 initial9	Decrease Aeration/ Increase Wastage/ Skim Secondary Clarifier
24	Measurements (SVI test)	MLSS of Aeration Basin	- Solids are not settling normally in the SVI test. - Signs of Pin or Straggler floc are present. - Floc appearance is light & fluffy.	High F/M with young sludge	Presence of stragglers.	SVI1 SVI175 SVI181	Suggested corrective action: Decrease Wastage
34	Microscope Analysis of micro-organisms	MLSS of Aeration Basin	Predominating organism is *Amoeba* with a percentage greater than 15%.	High F/M with a strong suggestive evidence of 90%		Microscope1 Microscope52 Initial88	Suggested corrective action: Decrease Wastage
39	Data Analysis with ASExpert.	Secondary Clarifier Effluent.	An increase in ammonia conc.	Limited Nitrification.		Data1 DataNit1	Check MLSS Temperature & DO conc. in aeration basin. Proceed to Operator Data Analysis → Aeration Basin Menu
39.b		Aeration Basin	MLSS temperature has fallen significantly.	Fall in temperature is limiting nitrification.		Data1 DataAB5	Two approaches are possible: 1. Increase the nitrifying population by increasing the sludge age 2. Reduce heat loss by reducing aeration if possible Also some success in reducing heat loss has been achieved by covering aeration tanks.

Table (1) ASExpert's results when applied to a sample of the test set (trial cases) [2].

A selection of the Water Environment Federation (WEF) Troubleshooting guide & Troubleshooting figures [10].

No.	Validation of Cases	Observations	Probable Cause	Necessary Check	Remedies
1	8	Greasy, dark tan foam that is strong and carries over to the clarifier.	Filamentous organism (Nocardia).	Check results of microscopic examination of mixed liquor.	Control influent and recycled greases and fats, lower SRT to 2-9 days, and physically remove aeration tank foam and clarifier scum. Do not recycle removed foam and scum through the plant.
2	24	Settling test indicates: A slowly settling mixed liquor having light fluffy straggler floc in clear supernatant.	Presence of stragglers.	Check for too high F/M (overloaded process) with young under-oxidized sludge.	Decrease wasting.
3	34	Microscopic examination of indicator microorganisms & their activity: indicate the predominance of *amoeboids*.	High F/M (low SRT) typically during plant start-up or when the plant is recovering from an upset e.g. industrial, hydraulic or in-plant recycle shock load. After upsets the plant is actually starting over. Thus little or no sludge forms at this time.		- Under normal circumstances, the predominance of these organisms can be related to the SRT in the plant process. - An important operational philosophy that should be followed states: - As any microorganism predominates only in the environment that provides favorable conditions to it. - Thus to decrease this predominance, the operator need only to change this environment i.e. control the process to provide less favorable conditions. - If the environment is changed drastically, a different microorganism will quickly predominate (unless all microorganisms are destroyed). - A normal transition results in the gradual disappearance of one organism, while the other one gradually takes over.
4	39 & 39.b	Inability to completely nitrify. Effluent ammonia level exceeds permit value.	- Cold temperatures are limiting nitrification. - Increases in total daily influent nitrogen loads have occurred.	- Check nitrification rate and MLVSS concentration. - Check influent TKN concentration and flow.	- Decrease loading on nitrification system, or increase biological population (MLVSS) in nitrification tanks by raising MLVSS concentration or adding nitrification tanks. - Increase the MLVSS in nitrification tanks by increasing concentration or putting additional nitrification tanks on line. - Increase aeration.

Table (2) Common Causes, Process Occurrences & Remedies related to the trouble-shooting situations associated with the sample test cases [2].

12

Thus testing is the means to validate expert system behavior and real test cases are needed for a complete assessment. From this respect the functional generation of trial cases is considered to be the most adequate for expert systems testing. Since a functional set usually reflects the point of view of a domain expert in the field and as a result can be regarded as an actual test of the expert system's content of knowledge and experience on how to cope with representative problems. Whereas a random set can be a measure of nothing other than the robustness of the system's response.

Although the most recent references claim that computerized verification and validation tools are indispensable for real world expert systems that use knowledge bases made up of hundreds of rules, since it is difficult for human evaluators to assimilate and evaluate all these rules. Nevertheless the approach presented in this paper that reflects our experience in validating ASExpert proved to be very adequate. It by passed the need for the presence of domain experts to act as system's evaluators. Domain experts -despite their extreme importance- can not be always available or if they do exist, problems related to their disagreement or prejudice can *sometimes* hinder good efforts towards the satisfactorily completion of work.

This approach provided an alternative through which ASExpert's testing was accomplished since it is currently unfeasible to run ASExpert in an actual plant to test its performance under real working conditions. Finally, the initial testing of ASExpert using these *representative* trial cases provided a very promising indication of success. It proved that ASExpert could perform its intended role according to its user requirements and thus by definition was successfully validated.

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