52. IWK

Internationales Wissenschaftliches Kolloquium

International Scientific Colloquium

PROCCEDINGS | **10 - 13 September 2007**

FACULTY OF
COMPUTER SCIENCE AND AUTOMATION

COMPUTER SCIENCE MEETS AUTOMATION

VOLUME I

Session 1 - Systems Engineering and Intelligent Systems

Session 2 - Advances in Control Theory and Control Engineering

Session 3 - Optimisation and Management of Complex Systems and Networked Systems

Session 4 - Intelligent Vehicles and Mobile Systems

Session 5 - Robotics and Motion Systems

TECHNISCHE UNIVERSITÄT
ILMENAU

Bibliografische Information der Deutschen Bibliothek
Die Deutsche Bibliothek verzeichnet diese Publikation in der deutschen Nationalbiografie; detaillierte bibliografische Daten sind im Internet über **http://dnb.ddb.de** abrufbar.

ISBN 978-3-939473-17-6

Impressum

Herausgeber:	Der Rektor der Technischen Universität Ilmenau Univ.-Prof. Dr. rer. nat. habil. Peter Scharff
Redaktion:	Referat Marketing und Studentische Angelegenheiten Kongressorganisation Andrea Schneider Tel.: +49 3677 69-2520 Fax: +49 3677 69-1743 e-mail: kongressorganisation@tu-ilmenau.de
Redaktionsschluss:	Juli 2007
Verlag:	Technische Universität Ilmenau/Universitätsbibliothek Universitätsverlag Ilmenau Postfach 10 05 65 98684 Ilmenau www.tu-ilmenau.de/universitaetsverlag
Herstellung und Auslieferung:	Verlagshaus Monsenstein und Vannerdat OHG Am Hawerkamp 31 48155 Münster www.mv-verlag.de
Layout Cover:	www.cey-x.de
Bezugsmöglichkeiten:	Universitätsbibliothek der TU Ilmenau Tel.: +49 3677 69-4615 Fax: +49 3677 69-4602

Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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Paper submitted after copy deadline

2 Advances in Control Theory and Control Engineering

R. Knauf

Compiling Experience into Knowledge

Abstract

TYPICAL application fields of Knowledge Based Systems are a usually characterized by having human expertise as the only one source to specify their desired behavior. Therefore, their design, evaluation and refinement has to make effective use of this valuable source. After an introduction to the concept of collecting validation experience in a Validation Knowledge Base (VKB), the paper introduces an estimation of the significance of the cases collected in the VKB. A high significance signalizes that a VKB should not longer serve as a case-based source of external (outside the Knowledge Base) knowledge, but compiled into the Knowledge Base instead. Based on this significance estimation, a technology to compile well selected cases into the Knowledge Base of the system under evaluation is presented.

1 Introduction

The purpose of refinement approaches is to adjust a system according to new insights. Such insights may be uncovered by detecting invalidities when applying a validation technology, but also by gaining experience when considering cases. In particular, they aim at a knowledge base reconstruction so that the input–output behavior and, in some approaches, the complete rule trace is adapted to the new insights.

There is a history of attempts to face this problem for rule–based systems. A quite comprehensive digest about pros and cons of systems like TEIRESIAS [1], SEEK/SEEK2 [2, 4], the *Reduced Theory Learning System* RTLS [3] with a so–called relaxed retranslation that has been criticized in [13] and [16], and KRUSTWORKS [15], e.g., is provided in [5].

Besides particular individual drawbacks, these approaches share the property that they can't produce a rule base which is 100 % correct. Correctness, in this context, means correctness w.r.t. a set of test cases. Furthermore, they may cover some inherent anomalies and may not be interpretable by topical human experts.

AI systems' design and maintenance heavily depends on the quality of the human expertise and effectiveness of its involvement in the system's design, evaluation, and refinement. For their validation and refinement, the authors introduced a case based technology [6, 7].

To make validation results less dependent on the experts' opinions and to decrease the workload of the experts, the authors developed a concept to collect case oriented experience in a Validation Knowledge Base (VKB) [8, 10].

These concepts have been involved in a validation framework [7]. To estimate the usefulness of these concepts and to reveal their weaknesses, a prototype test was performed [9].

The VKB concept so far utilizes the external knowledge in a VKB as an additional source of knowledge for system validation. It is organized in a case-based manner. However, at some point a VKB should not longer serve as a case-based source of external (outside the Knowledge Base) knowledge, but compiled into the Knowledge Base instead. If a VKB content turns out to be accepted by topical experts, it should be utilized to refine the Knowledge Base to beconme a source of knowledge for the system itself, not just for its evaluation. Especially the cases, which gained a high agreement in the expert community over a long period of time are worth to be included into the Knowledge Base. A technology to do so is introduced here.

The paper is organized as follows. Section two briefly introduces the VKB concept. In section three, the utilization of VKB for system refinement is outlined. Section four presents a technology to compile the cases of VKB into the rules of the Knowledge Base. The paper is finalized by a summary.

2 Collecting experience: The VKB approach so far

In spite of significant advances in recent years, validation of knowledge-based systems still requires significant involvement on the part of human validators. In contrast to verification, which seeks to assure compliance with specifications and the absence of specific errors without executing the system, validation typically involves rigorous and often extensive testing of the system.

The results of these tests are nearly always evaluated by expert validators who may not always agree among themselves. The size of the test case set, the frequency of the validation exercises and the number of expert validators required for each such exercise can combine to pose great burdens of time and effort on human expert validators. These expert validators are a scarce resource, have limited time, and are expensive to employ. These limitations have the potential to degrade a validation exercise.

Our concepts of a Validation Knowledge Base was originally proposed by Tsuruta et al. [14]. Tsuruta's work appears to be the first to specifically address the use of prior validation knowledge for improving the validation process. His work aimed at developing validation solutions for commercial applications, and he addresses this issue frequently [12].

Our work is implemented in the context of our previously described validation framework [7], which includes an expert validator review of test cases and results using a variation of a Turing Test for the validation of knowledge-based systems. In this step, humans play the role of expert validators as part of a validation panel. Their task is (1) to solve the test cases posed to the system under evaluation and (2) to review and provide their judgment on the correctness (the ratings) of all anonymous solutions (the system's as well as the panel's own).

To improve the validation process, the validation knowledge used in prior exercises, namely the set of test cases (the test inputs and the best rated solutions) along with their authors, must persist from one validation exercise to the next. This is effectively accomplished by the VKB.

The VKB and its historical validation knowledge can also significantly reduce the involvement of expert validators by eliminating their need to solve old test cases whose solutions are already found in the VKB. The expert validator panel needs only to solve new test cases created by the Validation Framework that are not already part of the VKB, because the VKB already have (formerly accepted) solutions available. However, they still have rate all solutions, because the former solution needs to be either confirmed or revised by the current expert panel to further "qualify" the VKB.

The VKB is a set of previous (historical) test cases and their best rated solutions, which can be described by 7-tuples $[t_j, E_{Kj}, E_{Ij}, sol_{Kj}^{opt}, r_{IjK}, c_{IjK}, \tau]$, in which

- t_j is a test case input,
- sol_{Kj}^{opt} is a solution associated to t_j, which gained the maximum experts' approval in a prior validation exercise,
- E_{Kj} is the list of experts who provided this particular solution,

- E_{Ij} is a list of experts who rated this solution,
- r_{IjK} is the rating of this solution, which is provided by the experts in E_I,
- c_{IjK} is the certainty of this rating, and
- τ is a time stamp associated with the validation session in which the rating was provided.

Table 1 shows how the VKB would appear for a simple application. Here, e_1, e_2 and e_3 are specific human expert validators. The outputs $o_1, \dots o_{25}$ are the test case outputs (solutions). The time stamps are denoted by natural numbers to indicate an unspecified time when the validation exercise was held in the right sequence.

The VKB is initially built as part of the first validation exercise. Here, each test case input used in the exercise, along with its optimal solution (as determined by the panel during that exercise), becomes a new entry. It is updated in subsequent validation exercises by adding all examined test cases of this session. New entries, however, do not supersede old entries. Instead, the 'updated information' is represented by the new entries with a more recent time stamp.

Table 1: An example for *VKB*'s entries

t_j	E_K	E_I	sol_{Kj}^{opt}	r_{ijk}	c_{ijk}	τ_S
t_1	e_1, e_3	$[e_1, e_2, e_3]$	o_6	$[1, 0, 1]$	$[0, 1, 1]$	1
t_1	e_2	$[e_1, e_2, e_3]$	o_{17}	$[0, 1, 0]$	$[1, 1, 1]$	4
t_2	e_1, e_3	$[e_1, e_2, e_3]$	o_7	$[0, 0, 1]$	$[0, 0, 1]$	1

The VKB functions in the second step, the test case experimentation. In the original approach, the test case generation procedure consists of two steps (1) generating a quasi exhaustive set of test cases $QuEST$ and (2) reducing it down to a reasonably sized set of test cases $ReST$ [7]. A test case is a pair $[TestData, Solution]$. Both $QuEST$ and $ReST$ are sets of such pairs. Exactly between these two sub–steps is the entry-point of the external validation knowledge stored in a VKB that has been constructed in prior validation sessions.

Both $QuEST$ and the historical cases in VKB are subjected to the criteria-based reduction procedure that aims to build a subset of test cases in $QuEST$ or VKB. The cases in VKB are included in the reduction process to (1) ensure that they meet the requirements of the current application and (2) their number is small enough to be the subject of the time consuming and expensive test case experimentation.

The VKB, therefore is a database of test cases and their associated solutions that received an optimal rating in previous validation sessions. These solutions are considered an additional (external) source of expertise that did not explicitly appear in the solving session, but it is a subject of the rating session.

Regardless of their former ratings, the cases originated from the VKB have to be rated by the current expert panel in the current session.

The set of solutions $ExtSol \subseteq \Pi_2(ReST)$, which are contributed by the VKB and which are subject of the rating process, is[1]

$$ExtSol := \{sol : \exists Entry : Entry \in VKB, \Pi_1(Entry) \in \Pi_1(ReST), sol = \Pi_4(Entry)\}$$

Because the criteria-based reduction process is controlled by a predetermined number m of cases that form the $ReST$, the **workload reduction factor** for the test case solving process for the expert validators can be quantified by the cardinality of $ExtSol$ divided by the cardinality of $ReST$: $workload\ reduction\ factor = \frac{|ExtSol|}{|ReST|}$

[1] Π_i is the projection of the i-th element, i.e. $\Pi_i(T)$ with T being a tuple denotes the i-th element of the tuple and $\Pi_i(M)$ with M being a set of tuples denotes the set of i-th elements of the tuples in M.

The best rated solutions associated with the test cases in the VKB represent an additional (external) source of expertise. It is different from both the current expert validators' and the system's knowledge. The **expertise gain factor** introduced by the VKB is: $expertise\ gain\ factor = \frac{|ReST|}{(|ReST| - |ExtSol|)}$

The usefulness of the VKB approach could be proven by an experiment with human experts. Starting with an initial rule base, validation sessions as described in [6] and [7] have been performed and a VKB has been built. [11] and [9] could impressively show the VKB's contribution to the validation knowledge in this experimental case study.

3 Evaluating experience: Estimating its significance by a metrics

In case the VKB contains cases with (1) an optimal solution that is different from the system's solution and (2) a certain significance that the optimal solution in VKB is correct, a system refinement based on the VKB's content is indicated.

Depending on the particular application, a minimum number n^{min} of entries for a test case input t_j and a minimum significance level $0 \ll sig^{min} \leq 1$ needs to be determined.

Indications for the correctness of an optimal solution sol_{Kj}^{opt} to a case input t_j in VKB are high values of the following metrics

- approval rate $app = \dfrac{\#\text{ of positive ratings } r_{ijk} = 1}{\text{total } \#\text{ of ratings to } t_j}$
- persistence rate $per = \dfrac{\#\text{ of entries for } t_j \text{ with } sol_{Kj}^{opt}}{\text{total } \#\text{ of entries to } t_j}$
- agreement rate $agr = \dfrac{\#\text{ of experts providing } r_{ijk} = 1}{\text{total } \#\text{ of experts providing a } r_{ijk}}$

In case (1) the minimum number n^{min} of entries for a test case input t_j is reached and (2) all three of the above rates exceed the minimum significance level sig^{min}, the pair $[t_j, sol_{Kj}^{opt}]$ is worth to be compiled into the Knowledge Base as its input/output behavior for t_j. This is performed by a technology similar to the refinement technology introduced in [7] and described in the following section.

After compiling a case into the Knowledge Base, its usage as a validation test case becomes obsolete. Therefore, the related entries in VKB need to removed.

4 Utilizing experience:Compiling it into knowledge

The refinement procedure looks for rule chains of cases in the VKB, which have a different solution in VKB than the rule chain ends up with. It starts with the last rule in this chain and analyses *all* VKB cases using this rule. It systematically constructs new rules as a substitute of it, which map the the cases that have a different solution to this different solution and keeps the mapping of all other cases (at all, not only those in VKB) as it was before the refinement. So it is pretty "conservative", because it changes the I/O behavior of the rule as few as possible, i.e. exclusively for cases that are shown to be solved wrong by the rule base. The technique is applicable to rule bases as introduced in [7] and consists of the following steps.

Identifying "Guilty Rules" If the last rule r_l in the rule trace for a case input $t_j \in \Pi_{inp}(T)$ infers a solution different from $sol_{Kj}^{opt} \in \Pi_{outp}(T)$, this rule r_l is "guilty" and therefore, subject of the following refinement technology. Let $T_l \subseteq T$ be the set of cases that have r_l as their last rule in the rule traces for the cases in T.

Table 2: Reduction rules to construct substitutes for an invalid rule

$R1$	$pos \in Pos$, s_{pos} has a value set with no $\leq$ relation, $\{s^1_{pos}, \ldots, s^m_{pos}\}$ are the values of s_{pos} occurring in T^s_l $[T^s_l, Pos, \{p_1, \ldots, p_n\}]$ $\hookrightarrow$ **1.** $[T^{s,1}_l \setminus \{[t_j, sol_s] \in T^s_l : s_{pos} \neq s^1_{pos}\}, Pos \setminus \{pos\}, \bigcup_{i=1}^n p_i \cup \{(s_{pos} = s^1_{pos})\}]$ ... **m.** $[T^{s,m}_l \setminus \{[t_j, sol_s] \in T^s_l : s_{pos} \neq s^m_{pos}\}, Pos \setminus \{pos\}, \bigcup_{i=1}^n p_i \cup \{(s_{pos} = s^m_{pos})\}]$ Continue with each $T^{s,i}_l$ $(1 \leq i \leq m)$ separately.
$R2$	$pos \in Pos$, s_{pos} has a value set with a $\leq$-relation, s^{min}_{pos} / s^{max}_{pos} are the smallest / largest value of s_{pos} within T^s_l $[T^s_l, Pos, \{p_1, \ldots, p_n\}]$ $\hookrightarrow$ $[T^s_l, Pos \setminus \{pos\}, \bigcup_{i=1}^n p_i \cup \{(s_{pos} \geq s^{min}_{pos}), (s_{pos} \leq s^{max}_{pos})\} \cup S_{excl}]$ S_{excl} is the set of excluded values for s_{pos}, which have to be mapped to a solution different from sol_s because of belonging to some other T^v_u with $v \neq s$: $S_{excl} = \{(s_{pos} \neq s^j_{pos}) : \exists [t_j, sol_s] \in T^s_l \exists [t_m, sol_v] \in T^v_u (v \neq s) \text{ with } \forall p \neq pos : s^j_p = s^m_p, s^{min}_{pos} < s^m_{pos} < s^{max}_{pos}\}$

Simple Refinement by Conclusion Replacement If all cases $t_j \in T_l$ have the same solution sol^{opt}_{Kj}, in rule r_l the conclusion part is substituted by sol^{opt}_{Kj}.

Reconstructing the Remaining Guilty Rules The remaining guilty rules are used by a set of cases T_l, which have different optimal solutions. The subsets with the same optimal solution are considered separately:

1. T_l of the rule r_l is split into subsets T^s_l $(1 \leq s \leq n)$ according to the n different solutions $sol^{opt,1}_{Kj}, ..., sol^{opt,n}_{Kj}$ for the cases $t_j \in T_l$.

   The if–part(s) of the new rule(s) that substitute r_l are expressions $e_i \in E$ of a set of p new alternative rules $\{r^1_l, r^2_l, \ldots, r^p_l\}$ for each T^s_l and will be noted as a set of sets $P^s_l = \{\{e^1_1, \ldots, e^1_{p_1}\}, \ldots, \{e^p_1, \ldots, e^p_{p_p}\}\}$. The corresponding rule set of P^s_l is

   $$r^1_l : \bigwedge_{i=1}^{p_1} e^1_i \rightarrow sol_s \qquad \cdots \qquad r^p_l : \bigwedge_{i=1}^{p_p} e^p_i \rightarrow sol_s$$

2. Pos is the set of Positions (dimensions of the input space), at which the input data $t_j \in \Pi_{inp}(T^s_l)$ of the test cases $t_j \in T^s_l$ are <u>not</u> identical.

   The generation of the p different if–parts in P^s_l is managed by a formal *reduction system*, which is applied to triples $[T^s_l, Pos, P^s_l]$ until Pos becomes the empty set $\emptyset$.

3. The initial situation is $[T^s_l, Pos, P^s_l]$ with $P^s_l = \{\{(s_1 = s^{ident}_1), \ldots, (s_q = s^{ident}_q)\}\}$

   $s_1, \ldots, s_q$ are those positions, at which all test data $t_j \in \Pi_{inp}(T^s_l)$ have the same value s^{ident}_i. Initially, P^s_l stands for just one rule: $r^1_l : \bigwedge_{i=1}^{q} (s_i = s^{ident}_i) \rightarrow sol^{opt,s}_{Kj}$

4. The reduction terminates with the situation $[T^s_l, \emptyset, P^s_l]$.

Table 2 shows the reduction rules applied to the triples. In [7] it is shown, that the reduction system is terminating, complete, and correct.

Recompiling the constructed rules The new rules generated so far are "one–shot–rules", i.e. they infer directly from a system's input to a system's output. These rules might be difficult to read, because they may have very long if–parts, and difficult to interpret by subject matter experts. This problem can be defused by introducing the intermediate hypotheses into the computed new rules.

5 Summary

The formerly developed concept of a Validation Knowledge Base (VKB) was intended to model collective best experience of several human experts. The VKB is constructed and maintained across various validation exercises. If the knowledge gained in a VKB turns out to be well accepted by the expert community over a long period of time, this knowledge is worth to be complied into the system's Knowledge Base. This way, the knowledge dedicated to evaluate a system shifts to knowledge used to improve the system. Therefore, the paper introduced a technology to compile the case based knowledge of a VKB into the rule based knowledge of the system's Knowledge Base.

References

[1] Davis, R. and Lenat, D.B.: *Knowledge–Based Systems in Artificial Intelligence.* New York: McGraw Hill Int. Book Company, 1982.

[2] Ginsberg, A.: *Automatic Refinement of Expert System Knowledge Bases.* London: Pitman Publishing, 1988.

[3] Ginsberg, A.: Theory Reduction, Theory Revision, and Retranslation. *Proc. of the 9th National Conference on Artificial Intelligence (AAAI–90)*, Boston, MA, pp. 777–782, 1990.

[4] Ginsberg, A., Weiss, S.M., and Politakis, P.: Automatic Knowledge Base Refinement for Classification Systems. *Artificial Intelligence*, 35(1988), pp. 197–226, 1988.

[5] Kelbassa, H.–W. and Knauf, R.: A Process Approach to Rule Base Validation and Refinement. *Proc. of the Workshop on Knowledge Engineering and Software Engineering (KESE) at the 28th German Conf. on AI (KI 2005)*, University of Koblenz–Landau (2005), Fachberichte Informatik, ISSN 1860–4471, pp. 25–36, 2005.

[6] Knauf, R.: *Validating rule-based systems – A complete methodology.* Habilitation Thesis (2000), Technical University Ilmenau, Germany. Aachen (Germany): Shaker, ISBN 3–8265–8293–4, 2000.

[7] Knauf, R., Gonzalez, A.J., and Abel, T.: A Framework for Validation of Rule–Based Systems. *IEEE Transactions on Systems, Man and Cybernetics, Part B: Cybernetics*, vol. 32, # 3, pp. 281–295, 2002.

[8] Knauf, R., Tsuruta,S., Ihara,H., Gonzalez, A.J., and Kurbad,T. (2004): Improving AI Systems' Dependability by Utilizing Historical Knowledge. *Proc. of 10th International Symposium Pacific Rim Dependable Computing (PRDC)*, Papeete, Tahiti, French Polynesia, pp. 343–352, IEEE Computer Society Press, 2004.

[9] Knauf, R., Tsuruta, S., and Gonzalez, A.J. (2005): Towards Modeling Human Expertise: An Empirical Case Study. *Proc. of the 18th International Florida Artificial Intelligence Research Society Conference 2005 (FLAIRS–2005)*, Clearwater Beach, FL, USA, pp. 232–237, ISBN 1–57735–200–9, Menlo Park, CA: AAAI Press, 2005.

[10] Knauf, R., Tsuruta, S., and Gonzalez, A.J. (2005): Overcoming Human Weaknesses in Validation of Knowledge-Based Systems. Jantke / Faehnrich / Wittig (eds.): *Marktplatz Internet: Von e–Learning bis e–Payment. 13th Leipzig Informatic Days 2005 (LIT 2005)*, Lecture Notes in Informatics (LNI) – Proceedings, Series of the Gesellschaft fuer Informatik (GI), vol. P–72, pp. 254–263, ISBN 3–88579–401–2, ISSN 1617–5468, 2005.

[11] Knauf, R., Tsuruta, S., Uehara, K., Gonzalez, A.J. (2004) Validation knowledge bases and validation expert software agents : models of collective and individual human expertise. Technical Report # 01/04. Tokyo Denki University, School of Information Environment, Chiba, Japan, also available at *http://www.db-thueringen.de/servlets/DocumentServlet?id=4285*, 2004.

[12] Onoyama, T. and Tsuruta, S.: Validation method for intelligent systems. *Journal of experimental and theoretical Artificial Intelligence*, vol. 12, # 4, pp. 461–472, 2000.

[13] Liang, C.X.F. and Valtorta, M.: Refinement of Uncertain Rule Bases via Reduction. *International Journal of Approximate Reasoning.* 13(1995), pp. 95–126, 1995.

[14] Tsuruta, S., Onoyama, T., Kubota, S., and Oyanagi, K.: Validation method for intelligent systems, *Proc. of the 13th International Florida Artificial Intelligence Research Society Conference (FLAIRS–2000)*, pp. 361–365, Menlo Park, CA, AAAI press, 2000.

[15] Wiratunga, N., and Susan Craw, S.: Incorporating Backtracking in Knowledge Refinement. Vermesan / Coenen (eds): *Validation and Verification of Knowledge Based Systems – Theory, Tools and Practice. Proc. of the 5th Europ. Conf. on Validation and Verification (EUROVAV 99)*, pp. 193–205, Boston, MA Kluwer Academic Publishers, 1999.

[16] Zlatareva, N.P., Preece, A.D.: State of the Art in Automated Validation of Knowledge–Based Systems. *Expert Systems with Applications*, 7(1994), pp. 151–167, 1994.

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