Krassimir Markov, Vladimir Ryazanov,
Vitalii Velychko, Levon Aslanyan
(editors)

New Trends in Classification and Data Mining

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- questions of complexity of some discrete optimization tasks and corresponding tasks of data analysis and pattern recognition;
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- regressions, restoring of dependences according to training sampling, parametrical approach for piecewise linear dependences restoration, and nonparametric regressions based on collective solution on set of tasks of recognition;
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MULTIAGENT APPLICATIONS IN SECURITY SYSTEMS: NEW PROPOSALS AND PERSPECTIVES

Vladimir Jotsov

***Abstract**: The topic of the presented investigation is the contemporary threats, that will lead to big problems in the nearest future. The prevention of such threats is impossible without applications of intelligent agents.Even more, the multi-agent system should possess some features of knowledge discovery, web mining, collective evolutionary systems, and other advanced features which are impossible be applied in only one agent. Advantages and disadvantages of synthetic data mining methods are investigated, and obstacles are revealed to their distribution in information security systems. Original results for juxtaposing statistical vs. logical data mining methods aiming at possible evolutionary fusions are described, and recommendations are made on how to build more effective applications of classical and/or presented novel methods: caleidoscope, funnel, puzzle, frontal and contradiction. The usage of ontologies is investigated with the purpose of information transfer by sense in security agent environments or to reduce the computational complexity of practical applications. It is shown that human-centered methods are very suitable for resolutions in case, and often they are based on the usage of dynamic ontologies . Practical aspects of agent applications are discussed at the information security and/or the national security levels. Other cryptography applications, multiple software and e-learning research results are mentioned aiming to show that intelligent and classical technologies should be carefully combined in one software/hardware complex to achieve the goals of the security. It is shown that all the demonstrated advantages may be successfully combined with other known methods and information security techologies.*

***Key words:** agent, knowledge discovery, data mining, web mining, ontology, information security systems, national security, human-centered systems, knowledge management, automation of creative processes, human-machine brainstorming methods.*

1. Introduction

Contemporary Information Security Systems (ISS) and especially the web-based systems are a wide field for applications of modern methods and technologies.The need to create sufficiently effective and universal tools to protect computer resources grows every year in systems for detection and prevention from intrusions (Intrusion Detection Systems IDS, Intrusion Prevention Systems IPS). For this reason different applications of intelligent data processing are initiated based on a combination of methods from statistical and logical information processing [1,2]. Other elaborations with growing influence in this domain are artificial immune systems and multiagent systems [3,4]. The unifying factor is the longer life cycle, elaborations require bigger teams and time for introduction. Due to the complex structure the prevention from direct attacks against these systems is very challenging.

Modern applications of statistical methods are effective and convenient to use at the expense of information encapsulation. In other words, it is impossible to construct tools to acquire new knowledge or to solve other problems of logical nature in this area. If we split methods in two groups (quantitative and qualitative) then statistical methods belong to the first group and logical ones belong to the second group. For this reason, their mechanical union is of no perspective. We do not attempt to propose any isolated solutions, instead we offer a combination of novel methods that is well adjustable to the existing ones. Our research includes a new evolutionary metamethod for joint control of statistical and logical methods where the statistical approach is widely applied on the initial stage of the research when the information about the problem is scanty and it is possible to choose the solution arbitrarily [5]. The accumulation of knowledge makes logical applications more and more effective and more universal than the probabilistic ones, as well as fuzzy estimates and similar applications. The paper introduces the SMM (Synthetic MetaMethod) metamethod to control the process of consecutive replacement of applications by other ones and is synthetic by nature. The difference from the classical analytic methods is in the fact that the design of systems controlled by synthetic (meta)methods is not just science, sometimes it is an art. If we make an analogy with the set of traditional methods and fashion clothes then the synthetic method will apply the design of the display window with the fashion clothes. In the common case during intelligent data processing, there is no convergence of the results but this does not hamper practical applications of these systems. In other words, bad and good designers will arrange the display window in quite different ways and there is no guarantee that every user understands the technology and that his access to the system will have positive results.

The cited innovations are made and demonstrated here for the following reason. The problems presented above show that there is a need to introduce elements of machine creative work in ISS. It is demonstrated in the paper that this goal is accessible, if the usage of possibilities for human-machine contact and a set of comparatively simple intelligent technologies are done in the right way. On the other hand, the innovations can hardly be described in a single paper using the traditional academic style. For this reason, in the paper we avoided when possible the technical details and formalizations, and for the sake of the contents reduction descriptions by analogy are used, illustration visual aids and other nonstandard approaches.

How can security agents operate autonomously? In the first place this is because of the usage of neural networks where the agent most conscientiously copies the acts of the teacher. At that the agent itself does not understand the sense of teacher's transfer of knowledge, it operates as an universal approximator instead. It is shown schematically at Fig. 1 in the following way.

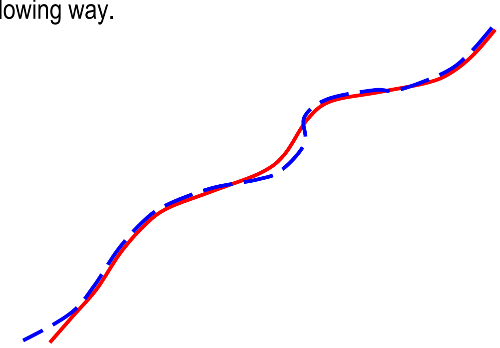

Fig. 1. Approximation of teacher's activities

Teacher's acts are principally presented as a dotted curve. The neural network approximates this curve via a continuous line on the same figure ; the deviation between the two lines must not exceed 3%. One of the main disadvantages of this approach is related to the necessity the agents in ISS to apply the learned knowledge in a rather creative way because frequently they operate in unexpected by the teacher situations. And as they are poorly trained or they are not at all trained how to act in unexpected situations, this approach as a whole is not very effective in its classical appearance. The presented approaches in anomaly ISS are combined with statistical applications which count for the normal traffic and other mean statistical values related to the operation of the guarded place. In Fig. 2 this process is schematically shown in the following way.

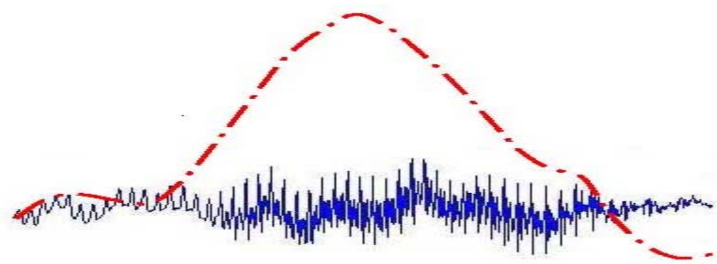

Fig. 2. Anomaly detection

The normal traffic is presented via a continuous line and the dotted line shows a case with drastic deviation from the normal traffic which is considered as an anomaly and it is analyzed whether it is a consequence from an intrusion. One of the disadvantages of this approach lies in the fact that intruder(s) know the principles of operation of such systems and they can 'fit' in the constraints of the normal traffic.

There is a variety of other applied approaches when the system is overloaded by heuristic information but they are not discussed here due to their evident weakness for ISS.

Here we introduce a new way for agents' operation. Best of all is the usage of ontologies to model the domain but this is not obligatory. On the other hand, as it is shown in the next section, the multiagent system functions more effectively if a system of ontologies is included.

But ontologies also do not contribute to a great extent in order to understand the sense of matters by the agents or with respect to transmit the sense of matters during communications between the agents. On the way to produce an analogy to how agents think we offer evolutionary methods to process data or knowledge because thinking (and understanding) is an evolutionary process. The problem is how to direct evolutionary methods with no exaggerations of heuristics, statistical information and other relative methods. Our approach is rather untraditional. We have elaborated for more than twenty years methods to detect and to resolve contradictions. A method for machine learning is built based on them. Searching and solving conflicts and contradictions the agent improves its knowledge and at the same time it may solve other problems. Detection of contradictions is based on using models of contradictions that can also be improved gradually. The agent may request an external help to solve the conflicts but this takes place only in extraordinary situations. At the same time it is shown how to change the reasoning component of security agents. Different logical methods are used that are rather analogous to means-ends analysis, constraint satisfaction, variable fitness function, brainstorming, and cognitive graphics. The combination of new methods to a great extent mechanizes creative efforts and also it serves agents' operation to improve the abilities of security experts working with similar types of systems.

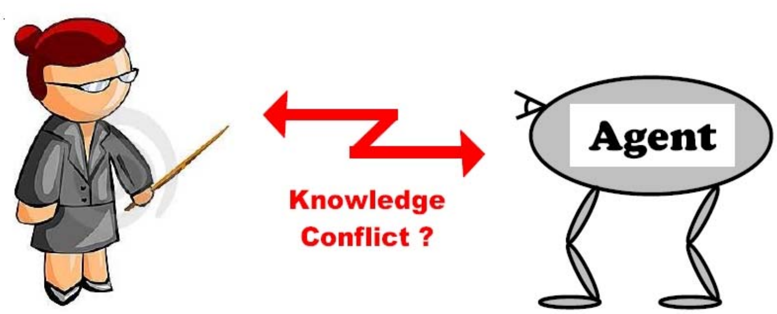

Fig. 3. Example of supervised learning by using critical analysis

Suggested innovations serve the more effective application of data mining, Web mining, collective evolutionary components in multiagent systems. They are very well combined especially for applications of evolutionary approaches with classical neuro-fuzzy, statistical applications, genetic algorithms, etc. methods for the domain. For example such systems critically accept teacher's acts in cases of supervised learning (Fig. 3): they may precise or argue teacher's acts and in this way they can learn more effectively and deep.

A wide application of intelligent agents is forecasted in the field of information security systems. This will lead to the situations when the agent has no possibility to learn from the expert (teacher) but should swiftly learn from other agents or should self-learn without teacher. Then the role of the above considered critical learning will significantly increase.

2. Knowledge Discovery Methods

A synthetic metametod (SMM) is elaborated and applied aiming at application of a set of 'creative' elements in agent environments. They work most effectively as a system, but even particular elements of them, let's say, applied in semantic reasoners, are proved to be very useful. Their principles are easy-to-be explained: bind the unknowln knowledge from the goal with the knowledge from the knowledge base, apply a flexible contraint system to manage a system of variable fitness/goal functions, make the goals automatically via self-improvement of the existing knowledge, etc. The consize goals are better applied in the intelligent agents.

2.1 Puzzle Method

The basic methods of the suggested metamethod SMM are presented below. Let the constraints connected to the defined problem form a line in the space described by the equation (1).

$$\frac{x-x_1}{x_2-x_1}=\frac{y-y_1}{y_2-y_1}=\frac{z-z_1}{z_2-z_1} \quad (1)$$

For example if a bachelor who has graduated SULSIT lives in Sofia and he/she does not want to work anywhere else, then the line restricts the search space and in this way a lot of unnecessary work is avoided. It is also possible to inspect a case when the constraint is defined as a type of surface but as a result a more general solution is obtained where a special interest is provoked by the boundary case of the crossing of two or more surfaces. When the common case is inspected in details, then in the majority of cases the problem is reduced to exploring the lines of type (1) or to curves with complicated forms obtained as a result of crossing surfaces by constraints. Therefore, below we investigate the usage in systems of constraints by lines of first or higher orders.

If the mentioned curves have common points of intersection and if they lie in a common plain so that a closed figure (triangle, tetragon, etc.) is formed then the search space is significantly reduced and it is searched much easier. The practical usage of the classical technology, as well as the constraint satisfaction, is complicated by the following. The viewed plains are not only nonlinear in the common case but they also include fuzzy estimates. The usage of fuzzy logic significantly raises the algorithmic complexity of the problem and it can make the application ineffective. Even when the usage of constraints significantly reduces the number of the inspected solutions, for example up to 10, this does not mean that the problem is solved and that all that must be done is to explore the possibilities one by one.

The following example below shows how the search process is reduced via using ontologies. Let's admit that the search space is presented on fig. 4 where statistical data about ISS are generalized about the regions depending on their price and quality. It is necessary to select an acceptable ISS to our project.

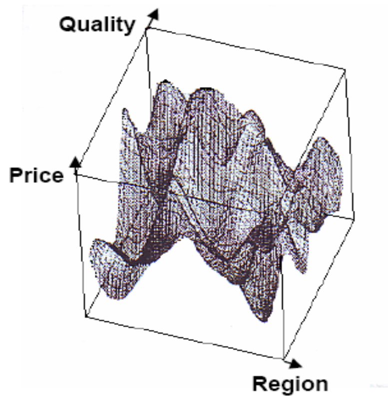

Fig. 4. Example of a space of solutions

In fig. 5 a subset of feasible solutions is chosen without ISS designed outside Europe. The space of feasible solutions is to the left of the separating surface that is depicted on the figure in blue color.

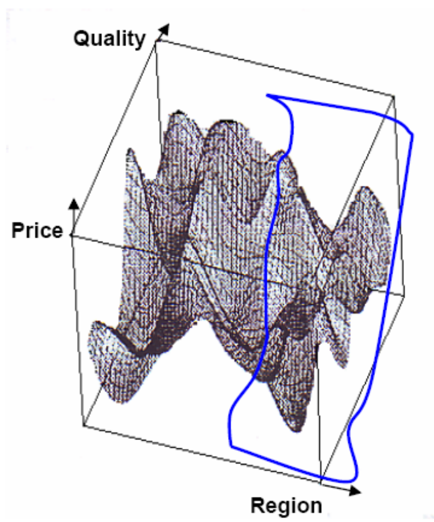

Fig. 5. Nonlinear space division(s) of the region

In fig. 6 another surface in green is shown delimiting the search space of the solutions. In our case it is 'systems with unknown principles of operation'. It is accepted that in the data bases there is no clear distinction related to the presented criteria so the search of the feasible solutions is nonlinear of high dimensionality and practically it cannot be solved using traditional methods. Nevertheless, by applying ontologies analogous to the ones from the previous section the problem is solvable via the PUZZLE method. There are two red dots on the same fig. 6 in its left corner. Each of them is a kind of constraint but of another type which we name a binding constraint and it is introduced by us. Its semantics is the following: it is not a solution but it resides close to the searched solution. For example we have the information that Fensel's elaborations are a good solution to the problem and that they define the left dot; the right dot has semantics of some other type. By introducing new constraints, our goal is to show that it is possible to use causal links that are different from implications.

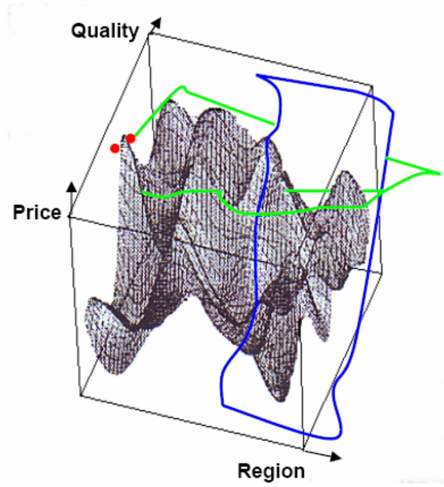

Fig. 6. Binding and other constraints

The same situation is presented on fig. 7 but some of the solutions are absent and this is evident in comparison to the images from the previous figures. It will be demonstrated below that the pointed incompletenesses are often met often and, even in this situation which is an obstacle for other existing methods, we offer an effective solution.

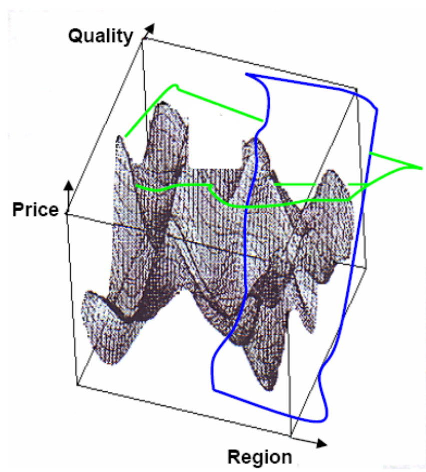

Fig. 7. Two nonlinear intersections best executed by using ontologies

2.2. Funnel Method

Below, we discuss in brief the next proposed FUNNEL method. Fig. 8 presents the main elements of the method: a system of constraints in the form of a funnel around a center which is a goal (fitness) function which points to the desired direction for information output or to search for new knowledge. As it is evident, the goal of this method is the gradual narrowing of the space of the feasible solutions, together with the progress of the dynamic information processes. Usually the FUNNEL method operates properly when combined with the other methods introduced here and that is why its peculiarities are viewed in detail in the next section where the interactions between the methods are examined. For example, it is convenient to concentrate on fig. 7 shown above over one of the peek values of the diagram by fixing a funnel above it.

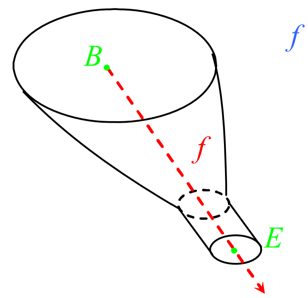

Fig. 8. Funnel system of constraints

2.3. Conflict Resolution Method and its Machine Learning Applications

Any lack of collaboration in a group of agents or intrusion could be found as an information conflict with existing models. Many methods exist where a model is given and every non-matching it knowledge is assumed as contradictory. Let's say, in an anomaly intrusion detection system, if the traffic has been increased, it is a contradiction to the existing statistical data and an intrusion alert has been issued. The considered approach is to discover and trace different logical connections to reveal and resolve conflict information. The constant inconsistency resolution process gradually improves the system DB and KB, and leads to better intrusion detection and prevention. Models for conflicts are introduced and used, and they represent different forms of ontologies.

Let the strong (classical) negation be denoted by '$\neg$' and the weak (conditional, paraconsistent) negation [6,7,8] be '~'. In the case of an evident conflict (inconsistency) between the knowledge and its ultimate form–the contradiction–the conflict situation is determined by the direct comparison of the two statements (the *conflicting sides*) that differ one from another by just a definite number of symbols '$\neg$' or '~'. For example: A and $\neg$A; B and not B (using $\neg$ equivalent to 'not'), etc.

In the case of implicit (or hidden) negation between two statements, A and B can be recognized only by an analysis of preset models of the type of (2).

$$\{U\}[\eta: A, B] \quad (2)$$

where η is a type of negation, U is a statement with a validity including the validities of the concepts A and B, and it is possible that more than two conflicting sides may be present. It is accepted below that the contents in the figure in brackets U is called *an unifying feature*. In this way, it is possible to formalize not only the features that separate the conflicting sides but also the unifying concepts joining the sides. For example, the intelligent detection may be either automated or of a human-machine type but the conflict cannot be recognized without the investigation of the following model.

$$\{\text{detection procedures}\}[\neg: \text{automatic, interactive}].$$

The formula (1) formalizes a model of the conflict the sides of which unconditionally negate each another. In the majority of the situations, the sides participate in the conflict only under definite conditions: $\chi_1, \chi_2, \ldots \chi_z$.

$$\{U\}[\eta: A_1, A_2, \ldots A_p] <\chi\sim_1 * \chi\sim_2 * \ldots * \chi\sim_z>. \quad (3)$$

where $\chi\sim$ is a literal of χ, i.e. $\chi\sim \equiv\chi$ or $\chi\sim \equiv\eta\chi$, * is the logical operation of conjunction, disjunction or implication.

The present research allows a transition from models of contradictions to ontologies [9] in order to develop new methods for revealing and resolving contradictions, and also to expand the basis for cooperation with the Semantic Web community and with other research groups. This is the way to consider the suggested models from (2) or (3) as one of the forms of static ontologies.

The following factors have been investigated:

T – time factor: non-simultaneous events do not bear a contradiction.

M – place factor: events that have taken place not at the same place, do not bear a contradiction. In this case, the concept of place may be expanded up to a coincidence or to differences in possible worlds.

N – a disproportion of concepts emits a contradiction. For example, if one of the parts of the contradiction is a small object and the investigated object is very large, then and only then it is the case of a contradiction.

O – identical object. If the parts of the contradiction are referred to different objects, then there is no contradiction.

P – the feature should be the same. If the parts of the contradiction are referred to different features, then there is no contradiction.

S – simplification factor. If the logic of user actions is executed in a sophisticated manner, then there is a contradiction.

W – mode factor. For example, if the algorithms are applied in different modes, then there is no contradiction.

MO – contradiction to the model. The contradiction exists if and only if (*iff*) at least one of the measured parameters does not correspond to the meaning from the model. For example, the traffic is bigger than the maximal value from the model.

Example. We must isolate errors that are done due to lack of attention from tendentious faults. In this case we introduce the following model (4):

$$\{\ user : faults\ \}[\sim: accidental,\ tendentious\ ]\ \langle T,\neg M,O;\neg S\rangle \qquad (4)$$

It is possible that the same person does sometimes accidental errors and in other cases tendentious faults; these failures must not be simultaneous on different places and must not be done by same person. On the other hand, if there are multiple errors (e.g. more than three) in short intervals of time (e.g. 10 minutes), for example, during authentications or in various subprograms of the security software, then we have a case of a violation, nor a series of accidental errors. In this way, it is possible to apply comparisons, juxtapositions and other logical operations to form security policies thereof.

Recently we shifted conflict or contradiction models with ontologies that give us the possibility to apply new resolution methods. For pity, the common game theoretic form of conflict detection and resolution is usually heuristic-driven and too complex. We concentrate on the ultimate conflict resolution forms using contradictions. For the sake of brevity, the resolution groups of methods are described schematically.

The conflict recognition is followed by its resolution. The schemes of different groups of resolution methods have been presented in Fig. 9 to Fig. 12.

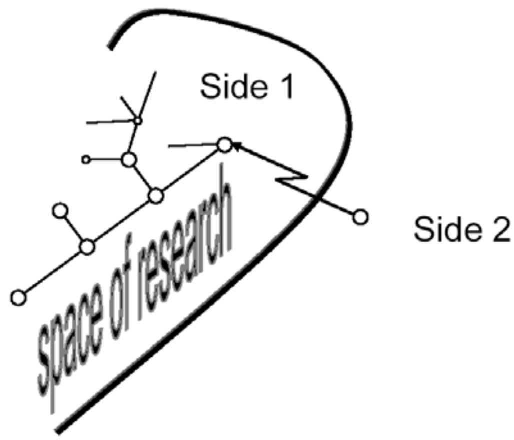

Fig. 9.Avoidable (postponed) conflicts when Side 2 is outside of the research space.

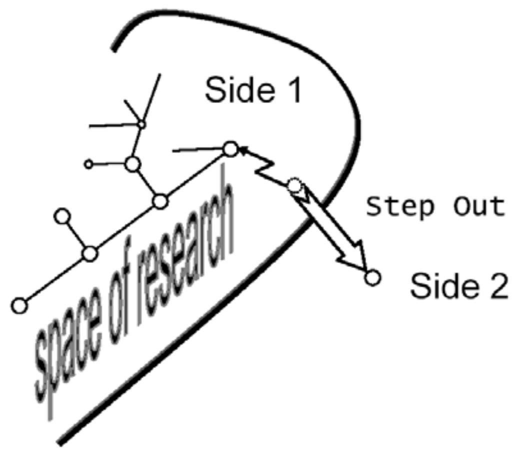

Fig. 10**.** Conflict resolution by stepping out of the research space (postponed or resolved conflicts).

In situations from Fig. 9, one of the conflicting sides does not belong to the considered research space. Hence, the conflict may be not be immediately resolved, only a conflict warning is to be issued in the future. Let's say, if we are looking for an intrusion attack, and side 2 matches printing problems, then the system could avoid the resolution of this problem. This conflict is not necessary to be resolved automatically, experts may resolve it later using the saved information. In Fig. 10, a situation is depicted where the conflict is resolvable by stepping out from the conflict area. This type of resolution is frequently used in multi-agent systems where conflicting sides step back to the pre-conflict positions and one or both try to avoid the conflict area. In this case a warning on the conflict situation has been issued.

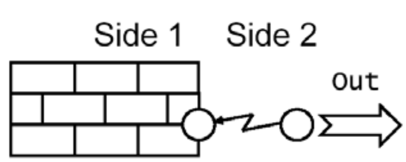

Fig. 11. Automatically resolvable conflicts.

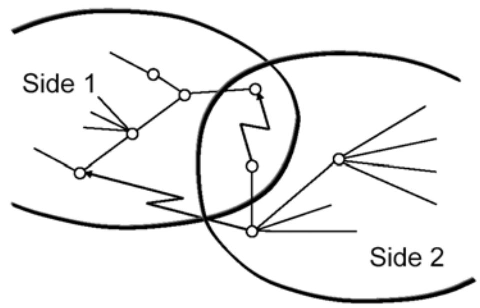

Fig. 12.Conflicts resolvable using human-machine interaction.

The situation from Fig. 11 is automatically resolvable without issuing a warning message. Both sides have different priorities, say side 1 is introduced by a security expert, and side 2 is introduced by a non-specialist. In this case, side 2 has been removed immediately. A situation is depicted on Fig. 12 where both sides have been derived by an inference machine, say by using deduction. In this case, the origin for the conflict could be traced, and the process is using different human-machine interaction methods.

Knowledge bases (KBs) are improved after isolating and resolving contradictions in the following way. One set is replaced by another while other knowledge is supplemented or specified. The indicated processes are not directed by the elaborator or by the user. The system functions autonomously and it requires only a preliminary input of models and the periodical updates of strategies for resolving contradictions. Competitions to the stated method may be methods for machine supervised – or unsupervised – learning. During supervised learning, for example by using artificial neural networks, training is a long, complicated, and expensive process, and the results from the applications outside the investigated matter are unreliable. The 'blind' reproduction of teacher's actions is not effective and it has no good prospects except in cases when it is combined with other unsupervised methods. In cases of unsupervised training via artificial neural networks the system is overloaded by heuristic information and algorithms for processing heuristics, and it cannot be treated as autonomous. The presented method contains autonomous unsupervised learning based on the doubt-about-everything principle or on the doubt-about-a-subset-of-knowledge principle. The contradiction-detecting procedure can be resident; it is convenient to use computer resources except for peak hours of operation.

The unsupervised procedure consists of three basic steps. During the first step, the contradiction is detected using models from (2) to (4). During the second step, the contradiction is resolved using one of the resolution schemes presented above, depending on the type of conflict situation. As a result from the undertaken actions, after the second stage the set *K* is transformed into *K'* where it is possible to eliminate from *K* the subset of incorrect knowledge $W \subseteq K$, to correct the subset of knowledge with an incomplete description of the object domain $I \subseteq K$, to add a subset of new knowledge for specification $U \subseteq K$. The latter of cited subsets includes postponed problems, knowledge with a possible discrepancy of the expert estimates (problematic knowledge), and other knowledge for future research which is detected based on the heuristic information.

In cases of ontologies, metaknowledge or other sophisticated forms of management strategies, the elimination of knowledge and the completion of KBs becomes a non-trivial problem. For this reason the concepts of orchestration and choreography of ontologies are introduced in the Semantic Web and especially for WSMO [10,11]. The elimination of at least one of the relations inside the knowledge can lead to discrepancies in one or in several subsets of knowledge in *K*. That is why after the presented second stage, and on the third stage, a check-up of relations is performed including elimination of modified knowledge and the new knowledge from subsets *W*, *N*, *I*, *U* are tested for non-discrepancies via an above described procedure. After the successful finish of the process a new set of knowledge *K'* is formed that is more qualitative than that in *K*; according to this criterion it is a result from a machine unsupervised learning managed by models of contradictions defined a priori and by the managing strategies with or without the use of metaknowledge.

3. Applications

The presented system source codes are written in different languages: C++, VB, and Prolog. It is convenient to use the applications in freeware like RDF, OWL, Ontoclean or Protégé. Many of the described procedures rely on the usage of different models/ ontologies in addition to the domain knowledge thus the latter are metaknowledge forms. In knowledge-poor environment the human-machine interactions have a great role, and the metaknowledge helps make the dialog more effective and less boring to the human. The dialog forms are divided in 5 categories from 1='informative' to 5='silent' system. Knowledge and metaknowledge fusions are always documented: where the knowledge comes from, etc. This is the main presented principle: every part of knowledge is useful and if the system is well organized, it will help us resolve some difficult situations.

We rely on nonsymmetrical reply 'surprise and win',

4. Conclusion

The main conclusion is that to overcome the shortcomings, methods and applications are considered concerning the logical parts of knowledge discovery and data mining. Special attention is paid to methods for identification and resolution of conflicts, and to machine (self-) learning based on them. The role of the above methods for the security bots and agents is discussed.

Analysis is represented for technologies used for machine learning in intelligent agents, and for sending information by sense, and for understanding the semantics of the information. Common disadvantages for different existing groups of contemporary applications are revealed.

Same methods in different combinations are effectively used to enhance security administrator possibilities or in contemporary e-learning systems in the field of Information/National Security [12]. Applications outside the field of information security have been made since a long time, but their explanation goes out of the field of the considered research.

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Author information

Vladimir S. Jotsov (В.С. Йоцов): e-mail: bgimcssmc@gmail.com

State University of Library Studies and Information Technologies (SULSIT);

Intsitute of Information Technologies of the Bulgarian Academy of Sciences (IIT-BAS);P. O. Box 161, Sofia 1113, BULGARIA, EU;