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Robert Burduk
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Preface

The goal of the CORES series of conferences is the development of theories, algorithms, and applications of pattern recognition methods. These conferences have always served as very useful forum where researchers, practitioners, and students working in different areas of pattern recognition can meet to come together and help each other keeping up with this active field of research. This book is collection of 87 carefully selected works which have been carefully reviewed by the experts from the domain and accepted for presentation during the 8^{th} International Conference on Computer Recognition Systems CORES 2013. We hope that the book can become the valuable source of information on contemporary research trends and most popular areas of application.

The papers are grouped into eight sections on the basis of the main topics they dealt with:

1. Features, learning, and classifiers consists of the works concerning new classification and machine learning methods;
2. Biometrics presents innovative theories, methodologies, and applications in the biometry;
3. Data Stream Classification and Big Data Analytics section concentrates on both data stream classification and massive data analytics issues;
4. Image processing and computer vision is devoted to the problems of image processing and analysis;
5. Medical applications presents chosen applications of intelligent methods into medical decision support software.
6. Miscellaneous applications describes several applications of the computer pattern recognition systems in the real decision problems.
7. Pattern recognition and image processing in robotics which presents pattern recognition and image processing algorithms aimed specifically at applications in robotics
8. Speech and word recognition, which consists of papers focused on speech recognition, automatic text processing and analysis.

Editors would like to express their deep thanks to authors for their valuable submissions and all reviewers for their hard work. Especially we would like to thank Prof. Piotr Porwik and his team from University of Silesia who organized special session devoted to Biometrics, Prof. Jerzy Stefanowski from Poznan University of Technology who helped us to organize special session on Data Stream Classification and Big Data Analytics, Prof. Andrzej Kasiński, Prof. Piotr Skrzypczyński and their team from Poznan University of Technology for their effort to organize special session on Pattern recognition and image processing in robotics. We believe that this book could be a reference tool for scientists who deal with the problems of designing computer pattern recognition systems.

CORES 2013 enjoyed outstanding keynote speeches by distinguished guest speakers:

Prof. Wodzisław Duch - Nicolaus Copernicus University,
Prof. Janusz Kacprzyk - Systems Research Institute, Polish Academy of Sciences,
Prof. Juliusz Lech Kulikowski - M. Nalecz Institute of Biocybernetics and Biomedical Engineering PAS,
Prof. Dariusz Plewczyński - University of Warsaw, Interdisciplinary Centre for Mathematical and Computational Modelling.
Although the last, not least we would like to give special thanks to local organizing team (Robert Burduk, Piotr Cal, Kondrad Jackowski, Bartosz Krawczyk, Maciej Krysmann, Bartosz Kurlej, Piotr Sobolewski, Marcin Zmyślony, Andrzej Żołnierek) who did a great job.

We would like to fully acknowledge support from the Wrocław University of Technology, especially from Dean of Faculty of Electronics, Chairs of Department of Systems and Computer Networks, and The Polish Association for Image Processing which has also supported this event.

Wroclaw,
May 2013

Robert Burduk
Konrad Jackowski
Marek Kurzyński
Michał Woźniak
Andrzej Żołnierek

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Part I
Features, Learning, and Classifiers

Toward Computer-Aided Interpretation of Situations

Juliusz L. Kulikowski

Abstract. The problem of interpretation of situations as a widely extended and important component of living beings' behavior in real world is considered. A scheme of interpretation of situations in natural living beings is presented and a general scheme of inspired by the nature artificial situations interpreting system is proposed. Basic constraints imposed on computer-based situations interpreting systems are described. It is shown that the computer-based situations interpreting systems are an extension of pattern recognition systems and the differences between them are characterized. The role of domain ontologies and of ontological models in computer-based situations interpreting systems design is shown and it is illustrated by examples.

1 Introduction

70 years since the publication by W.S. Mc Culloch and W.H. Pitts of their concept of a *mathematical model of neuron* in 2013 will be passed. Their significant publication initiated an increasing interest of scientists and of engineers to construct mechanisms simulating functional abilities of a natural nervous system. A next important step in this direction was made by F. Rosenblatt in the late 50ths of the past century by publication of his concept of *perceptron* - a first *artificial neural network* recognizing simple graphical patterns. This was a starting point of *pattern recognition* as a new scientific discipline which for the following years resulted in numerous new concepts, original computer programs and many thousands of considerable papers. Since that time, pattern recognition evolves in two competing streams of works: the first one based on artificial neural networks (ANN)

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and the second one using various algorithmic (statistical, functional, algebraic, formal linguistic, etc.) approaches to classification and recognition of patterns. In fact, the first approach, which originally tried to construct pattern recognition systems in hardware, finally realize them in the form of computer programs simulating artificial neural networks. Therefore, both approaches in some sense are "algorithmic", the main difference among them consisting in the sources inspiring with the concepts of algorithms: modeling of neural networks or modeling of formally defined classes of objects' similarity. Against original expectations, artificial neural networks rather few contributed to our understanding of the natural thinking mechanisms. This is rather the progress of neuropsychology and neurophysiology which for the last decades provided new concepts which may be useful in improving and extending the intelligent computer-aided data processing methods and algorithms. In particular, a lot of highly effective pattern recognition methods and computer programs in application to detection and recognition of simple printed or hand-written characters, voice signals, defects of machine details, diseases symptoms, biological cells, finger-print minutiae, etc. became available and are presently widely used. On the other hand, the problems of computer-aided image understanding on advanced semantic level, interpretation of observable situations connected with their pragmatic evaluation, early natural disasters prognoses, effective recognition of admissible ways to reach a goal in unclear circumstances, etc. still remain to be solved, despite the fact that our natural mind less or more effectively solves them everyday. Let us remark that the above-mentioned problems go beyond the limits of the conventional pattern recognition ones, however, they still concern recognition in a more general sense: assigning of some widely defined "objects" to fuzzy similarity classes in connection with their semantic and/or pragmatic assessment. Moreover, till now, no effective results of image, scene or situation analysis by artificial neural networks in the above-mentioned, wide sense have been achieved. This is clear because architecture of no artificial neural network (see, e.g. [1], [2], [3]), sophisticated as might it be, reminds the real functional structure of a natural brain (see, for a comparison [4], [5]). This does not mean that the state of ANN will not be evolving; nevertheless, it seems that in the nearest future more effective methods of composite objects recognition and interpretation will be provided by the approaches based on formal models. This expectation follows from the fact that a lot of computer-aided decision-making systems already exist; however, the role of computers in this type of systems is usually reduced to acquisition, primary processing, partial analysis, presentation and/or storage of data for final decision making by a human user. The user is faced with a deontological problem [6]:

If it is known that a situation A arose then undertake an action B in order to reach a more desirable situation C.

In this context, our problem consists in designing algorithms stating that a situation A really arose; this is a general objective of the *situation interpretation* theory and practice. At a first glance, it might seem that *pattern recognition* is a discipline solving the above-mentioned problem satisfactorily. E.g., if in a given histological specimen cancer cells have been recognized then usually it follows from this that some therapeutic actions should be undertaken in order to cure the patient. However, the cancer cells are in this case no more but a component of a more general situation: they have been detected in an inner organ of a patient of a given gender, age, etc. whose less or more extended and accurate case record is known. All this information constitutes a situation a medical doctor has to deal with. Therefore, *pattern recognition* can be considered as a particular case of *situation interpretation*. Nevertheless, the notions of *situation* and *interpretation* remain to be more strictly defined. In this paper an attempt to the formulation of *situation interpretation* (SI) backgrounds as well as some suggestions concerning the computer-aided SI systems design are presented. We try to show that basic notions of SI can be founded on well known mathematical concepts on which ontological models are based while practical solution of SI can be inspired by the natural cognitive processes created by the evolutionary processes.

2 Basic Notions

2.1 Natural Interpretation of Situations

There are two basic approaches to definition of the notion of *situation*. In a widely used sense **situation is a passing state of a selected fragment of reality**. Reality can thus by a subject be considered as a stream of surrounding her/him or it, arising, evolving, affecting some other ones or being by some other ones affected and finally disappearing situations. Any living being deals with various situations as an observer, their active subject, object, commentator, etc. However, situations are not the components the reality consists of; they rather are the components of perception of the reality by living beings. The same objects or fragments of real processes can by different subjects be considered as elements of different situations. This follows from a general, in fact - subjective way a living being learns to perceive and to discriminate the situations. E.g., the same state considered by a subject in the context of some preceding and some following states can be assessed as "desired" or "undesired" and as such it will be differently interpreted. The way of situations recognition by simple living beings is illustrated in Fig. 1.

They reach their ability to perceive situations by perception of various temporary signals coming from the real world, primary assessment of their value as "more" or "less" agreeable, remembering, collecting according to some similarity features, discriminating their components, associating according to their time- and/or space-co-occurrence and assigning to them specific reactions in the form of signals or behaviors expressing subjects' emotions caused by the situations. According to our present knowledge about natural brain functions, most of the above-mentioned operations using memory takes place in an anatomic part of the brain, belonging to its temporal lobe, called a hippocampus. Emotional values to the impressions are assigned in adjacent to it amygdale body. The emotionally marked reactions to many

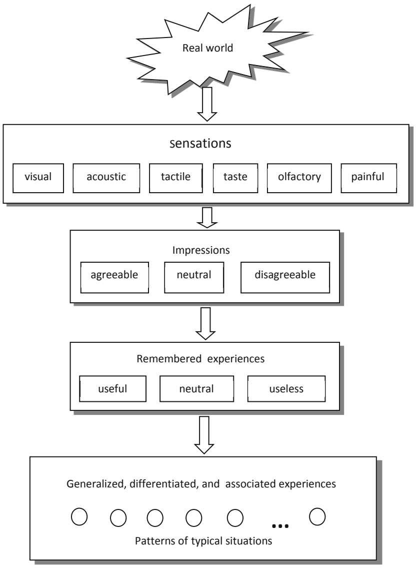

Fig. 1 A natural way to recognize situations in simple living beings

times in similar situations repeated impressions become established as germs of a code used to communicate about the situations by the members of a social group of living subjects. Therefore, recognition of situations even in simple living beings is closely connected with assessment of their importance for the recognizing subjects. Otherwise speaking, it contains some aspects of their "interpretation" even if not expressed in terms of any advanced language.

In more developed living beings the natural way of situations interpretation is in general similar, however, some differences should also be remarked:

- Instead of simple, sensations some formerly established sub-situations can be used as a basis to construct the concepts of higher-level situations;
- The scale of situations' practical importance assessment becomes more sophisticated, also in a multi-aspect sense;
- Linguistic terms are assigned to typical situations;
- Elements of classification of the situations may be used;
- Situations are assessed also from a point of view of their relations to other: past, existing, expected or possible situations.

In a large sense, **interpretation of situation** means a natural cognitive process consisting of:

- acquisition of observations;
- primary situation recognition;

- situation's position localization in a more general system of concepts;
- establishing of relations between the given and other (past, present, future possible, etc.) situations.

As a result, this leads to an ability to avoid emergency, to find food, to contact other social partners or to make another decision of vital importance.

A scheme of advanced natural situations interpretation is shown in Fig. 2. In fact, the scheme is rather hypothetical, because till now it is rather few known about the natural processes and mechanisms of situations interpretation in primates. However, a progress in modern brain imaging modalities (e.g. functional magnetic resonance, f-MRI [6], diffusion tensor imaging, DTI [7]) opens new possibilities in this research area.

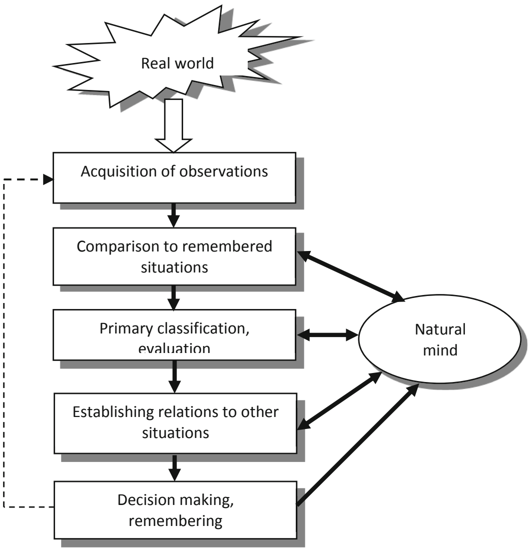

Fig. 2 Advanced natural interpretation of situations

2.2 Formal Model of Situation Interpretation

A general architecture of a computer-based situations interpretation (SI) systems can be inspired by the scheme shown in Fig. 2, excepting that the "natural mind" should be replaced with computer-based knowledge base and logical engines. However, a strong simulation of the natural way of learning the recognition and interpretation of situations for certain reasons seems to be unrealistic. First, because of a long, hundreds thousands years counting duration-time of the natural evolutionary processes. Second, because our knowledge about the natural mechanisms of everyday experiences acquisition, association, generalization, evaluation, storage and reminding is still now incomplete. Therefore, the computer-based SI system cannot be modeled on the natural one; they rather should be based on an abstract idea of ontology which in the last years in information processing systems design became popular [8], [9].

A general ontology is usually defined as a part of metaphysics concerning the nature and theory of existence. In computer applications an idea of domain ontologies defined as "a common understanding of some domain" [8] or as "an abstract view of the world we are modeling, describing the concepts and their relationships" [9] became more useful. Any domain ontology defines a hierarchy of its concepts representing objects, attributes, states, actions etc. used to the description of the given part of reality. In [10] a domain ontology decomposition into an ensemble of ontological models was proposed:

$$O = \{OM_1, OM_2, \ldots, OM_I; Q, A\} \tag{1}$$

where any ontological model is defined as a quadruple:

$$OM_i = \{C_i, R_i, T_i, A_i\},\ i = 1, 2, \ldots, I. \tag{2}$$

Above, C_i denotes a non-empty family of concepts (objects, attributes, actions, etc.) the OM is based on; R_i is a family of relations described on selected subsets of C_i. Among the relations in R_i a multi-aspect taxonomy Ξ_i of the concepts is distinguished, a concept $T_i \in C_i$ being its top-level element, the highest concept of the OM_i.

Basic formal properties of the ontology as well as of its ontological models follow from the corresponding sets of axioms A and A_i-s. In particular, the axioms of the algebra of sets, of relations and of their extensions theory, of fuzzy sets, of probability theory, etc. if used as bases of the given OMs' definitions should be considered as components of their formal description.

A general structure of the ontology is described by a super-relation Q between the OMs. In particular, clustering of OMs into categories corresponding to various aspects of the domain reality suits to putting an ontology in a clearer order. Despite the fact that in practice, the axioms in the description of the ontological models are very often neglected, they should be strongly respected if an ontology is to be correctly designed.

Sequences of elements of C_i satisfying a given relation $\rho \in R_i$ are called *syndromes* of ρ . Similarity relations describe particular types of concepts called *patterns*. *OMs* consisting of similarity relations and of some based on them higher-order relations describe a particular type of syndromes called *scenes*. Otherwise speaking, a scene is a composition of objects representing some patterns. As such, it can be described in terms of concepts of a domain ontology.

Sets of syndromes commonly satisfying the relations of a given *OM*, more generally, will be called *situations* of the model. Observed scenes are thus particular cases of observed situations; recognition of scenes or of patterns is a particular case of **situation recognition**. However, **interpretation of situation** consists of:

- situation recognition,
- its pragmatic aspects assessment,
- its logical extension.

The last term denotes detection within the given domain ontology other *OMs* whose syndromes may be logically consistent with the analyzed situation. Logical extension makes thus possible answering questions not only directly concerning the analyzed situation but also some questions concerning its possible connections with other situations.

Not all domain ontologies and ontological models can be used to situations interpretation. For this purpose, they should contain a *mechanism V* of the situations' *pragmatic aspects assessment*. It should provide a possibility to compare any syndromes from the point of view of their significance, utility, emergency level, etc. for the observer. In the simplest case it can take the form of a binary scale (e.g., "*important*", "*not important*"). Therefore, an *OM* admitting pragmatic evaluation of situations takes the form of a quintuple:

$$EOM_j = [C_j, R_j, T_j, V_j, A_j],\ j \in [1, 2, \ldots, I], \tag{3}$$

(C_j, R_j, T_j, A_j denoting the same objects as in (2)). This type of *OMs* can be called *evaluated ontological models*.

The above-presented elements of formalism lead to a hierarchy of real world representing models suitable to be used in a computer-based *SI* system, consisting of:

- *a general ontology*;
- *domain ontologies*;
- a *hierarchy of ontological models* describing the inner structure of the domain ontology as a composition of ontological models;
- *ontological models* (OM, EOM) describing selected aspects or states that in a given domain may occur and can be observed;
- *relations, super-relations or hyper-relations* of any type specifying the ontological models;
- *situations* described by the ontological models;
- *formal patterns* specifying the *similarity classes, structures* satisfying *ordering relations* and *syndromes* satisfying other types of relations, super-relations and/or hyper-relations;
- *sets of objects, values of attributes, alphabets* etc. on which the patterns, formal structures, symbolic expressions, etc. are defined.

The multi-level structure of models and their components is shown in Fig. 3.

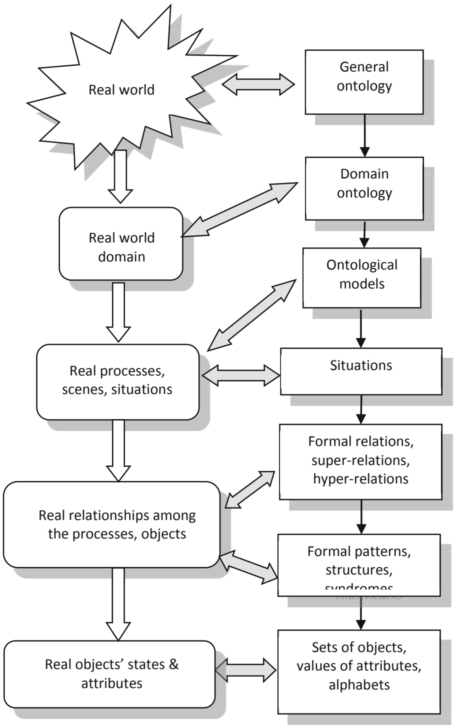

Fig. 3 Relationships between real world and its formal models

3 Evaluated Ontological Models

3.1 General Remarks and Constraints

From a practical point of view, *EOMs* are a form of acceptable by computers description of the situations that in a given application domain may arise. A repertoire of formal tools suitable to construction of *EOMs* is thus limited to those expressible by computer languages or data structures, Some sophisticated mathematical notions like: a *family of all subsets of a continuous set* or *a set of all transcendental numbers between 0 and 1*, etc. cannot in computer systems exactly be represented. Therefore, *OMs* or *EOMs* on this type of incalculable notions cannot be based. As a consequence, not all real situations can by ontological models be described.

More generally, it seems impossible to recognize and to interpret situations in the case of:

- real situations not expressible in correctly defined and calculable formal terms;
- inadequacy of the concepts of a domain ontology to real input (observation) data;

- lack of effective algorithms of processing on formal terms the ontological models are based on;
- lack of adequately chosen methods of situations similarity and pragmatic aspects assessment.

As examples of real situations that for the above-listed reasons (till now) cannot by a computer-based *SI* system be analyzed the following situations can be mentioned:

- connected with subjective psychical impressions or consciously non-controlled emotions (e.g. impression of fear evoked by a thriller emitted in tv, people's excitement caused by a street accident, etc.);
- described by logically incompact datasets (e.g. a total welfare level which in different countries is evaluated by different methods);
- concerning real life domains not described by strongly defined or measurable terms (e.g. ambience at a board meeting);

etc. Despite the above-mentioned limitations, an area of real *SI* problems possible to be solved by using available mathematical tools remains still large.

Design of an *EOM* for a given *SI* purpose can be facilitated by a preliminary answering the following questions:

- Concerning the domain:
  - What is the name of the area of interest;
  - Does it exist a domain ontology for it? (if not, start to construct it);
- Concerning a general structure of the domain:
  - What is the name of the specific sub-area of interest;
  - Does it exist a sub-ontology for it?
- Concerning the ontological model:
  - What is the name of the situation of interest within the ontology or sub-ontology;
  - Does it exist an ontological model for it?
- Concerning an "anatomy" of the situational ontological model:
  - What are the active and/or passive objects participating in the situation?
  - What are the attributes of the objects?
  - What are the types of substantial relations among the objects?
  - Are there any typical examples of instances of the relations?
  - What are the criteria for other objects' approval as instances of the relations?
  - What features of the relations' instances should be taken into account for their pragmatic value assessment?
  - What are the relations whose instances' time-evolution for pragmatic value assessment should be taken into consideration?
- Concerning the super-relations within the domain:

– Are there any other types of situations that in some way may be associated to the given one (e.g. coexisting in time, influencing one the other one, etc.)? Name them.
– Are the other types of situations described by ontological models?
– Is it formally possible to define a super-relation on the basis of the associated relations?
– What pragmatic values can be assigned to the instances of the super-relation as a function of pragmatic values of its components?

3.2 Categorization

Besides the above-mentioned super-relations described on some combinations of relations, the last can be categorized according to some criteria following from a general domain structure. E.g., within a domain *Health* service the following categories of *OMs* can be specified:

- topographical: *Warsaw City, South region, Country,* etc.;
- functional: *Diagnosis, Treatment, Education, Prevention,* etc.;
- medical: *Internal diseases, Psychiatry, Oncology*, etc.;
- organizational: *Hospitals, Outpatients clinics, Ambulance stations*, etc.

Evidently, the taxonomy of OMs may be horizontally or vertically-down extended, e.g.:

Warsaw Center Home visit rounds, Influenza, Private outpatient clinics.

This may associate by a super-relation an OM satisfying the above-given criteria: modeling all *Private outpatient clinics* in *Warsaw City* offering *home visits* in the case of *influenza*.

Categorization of *OMs* makes also possible recognition of "higher level" situations like: "*Abnormal number of patients registered on Monday in all public health service centers of Warsaw City with the symptoms of influenza*" and assigning to them pragmatic values like: *important* or *alarming*. This is possible if in the *OM* among the relations describing all types of *Health service centers* there are the ones representing an ontological concept *State of services* described by the following lower-level concepts (objects, attributes):

(Health service center), Home visit ♯, Date, Case (medical diagnosis)

On the basis of all relations of this type in all *OMs* describing *Health service centers* in *Warsaw City* it can be constructed a super-relation defined as an extended algebraic sum [12] of sub-relations obtained by fixing the data:

Date := Monday, Case := influenza.

Such a super-relation will be satisfied by all syndromes of the form:

$*$, $*$, *Monday, influenza*

where the unknown values of *Health service center* and *Home visit* $\sharp$ have been denoted by $*$).

3.3 Pragmatic Value Assessment

From a formal point of view, a mechanism of situations' pragmatic value evaluation is a sort of a *weak semi-ordering relation V* imposed on the situations of a given *OM*. Before it to be defined, let us remind the notion of a *strong similarity* as a reflexive, symmetrical and transitive relation $\approx$ [13]. Then, if it is given a set of situations admitted by the *OM* and ω', ω'', ω''' are some particular situations then V should satisfy the following conditions:

- V is satisfied by any pair $[\omega', \omega']$ (reflexivity);
- If V is satisfied by an $[\omega', \omega'']$ then it is also satisfied by $[\omega'', \omega']$ if and only if $\omega' \approx \omega''$ holds (weak asymmetry);
- If V is satisfied by an $[\omega', \omega'']$ and by $[\omega'', \omega''']$ then it is also satisfied by $[\omega', \omega''']$ (transitivity).

We call *equivalence classes* the sets of objects mutually equivalent in the sense of the (mentioned in the definition) strong similarity ($\approx$) relation.

The mechanisms of pragmatic value evaluation into two groups can be divided:

- Single-aspect evaluation (*SAE*) mechanisms,
- Multi-aspect evaluation (*MAE*) mechanisms.

SAE mechanisms can directly be based on the above-given definition of weak semi-ordering relations. They may suit to evaluate such situations' properties as *importance, usefulness, level of interest, emergency level,* etc. However, they may take the forms of:

a. strong (linear) ordering;
b. semi-ordering;
c. partial semi-ordering

Strong linear ordering means that for any different situations ω', ω'' the relation V is satisfied either by $[\omega', \omega'']$ or by $[\omega'', \omega']$; however, the equivalence classes may contain no more but one element. In "standard" (denoted b)) and partial (denoted c))semi-ordering multi-element equivalence classes are admissible. However, partial semi-ordering admits also that for certain pairs of situations the relation V is neither by [ω', ω''] nor by [ω'', ω'] satisfied. This is illustrated in Fig.4 a, b, c, where circles represent situations, arrows - increasing pragmatic values and multi-element equivalence classes are by dotted contours denoted.

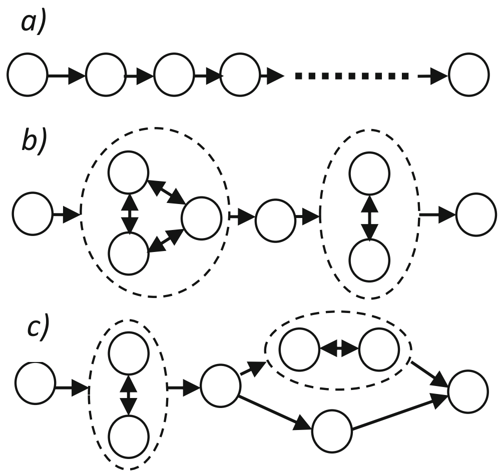

Fig. 4 Types of pragmatic values ordering: a) strong (linear), b) semi- ordering, c) partial semi-ordering

In the cases a) and b) numerical or nominal scales of pragmatic values can be used while in the case c) pragmatic values by their relative comparison only can be assessed.

MAE mechanisms on the basis of particular *SAE* mechanisms can be defined. One of the simplest ways to reach this is introducing a higher-level lexicographic order between the *SAEs*. For this purpose, let the set of particular *SAEs* be linearly ordered as $[SAE^{(1)}, SAE^{(2)}, \ldots, SAE^{(k)}]$. Then, for a given pair of situations $\{\omega', \omega''\}$ to be compared their order is first established in $SAE^{(1)}$. If they belong to different equivalence classes then the corresponding order is to them assigned and the procedure is finished. Otherwise, if they belong to the same equivalence class, their order is established according to the $SAE^{(2)}$ rule, etc., up to reaching $SAE^{(k)}$.

4 Interpretation of Situations

4.1 Recognition of Situation

Let $\boldsymbol{u}$ denote a sequence (ordered set) of results of observations in a certain application area. The elements of $\boldsymbol{u}$ may be of **various physical and/or formal nature**.

Recognition of a represented by $\boldsymbol{u}$ situation consists in **finding in a corresponding domain ontology a model** OM_i whose relations are by $\boldsymbol{u}$ (or by its subsets) fulfilled. Apparently, it reminds a typical pattern recognition problem in which the role of *OMs* is played by some predefined patterns [14]. However, the differences between situations and pattern recognition are substantial:

- the universe $\boldsymbol{U}$ of all possible observations usually does not constitute any homogenous, well-defined mathematical space;
- the observations $\boldsymbol{u}$, $\boldsymbol{u} \in \boldsymbol{U}$, should fulfill several relations of various nature;
- relations can be characterized analytically, by examples or by logical tests [15];
- the number of relations in different *OMs* may be different;
- situation recognition is a multi-step decision process controlled by pragmatic assessment of the results reached at the preceding steps.

Recognition of a situation needs a preliminary analysis of $\boldsymbol{U}$ from a point of view of its **formal and semantic consistency** with the concepts defined in the domain ontology. The mentioned in Sec. 3 basic constraints imposed on *OMs* should also be obeyed. Moreover, in the case of *OMs* based on random or fuzzy relations the fact that they are by $\boldsymbol{u}$ fulfilled can be expressed not only in a binary ("yes", "no") logical scale but sometimes also in a continuous numerical scale of probability or of a membership measure. It thus arises a problem, **how to define a total measure of the fact that a given *OM* is by *u* fulfilled as a function of various particular measures of the corresponding *OMs* relations being by *u* fulfilled**.

The problem can be solved by imposing some constraints on the form of a fulfilling measure $\varphi_\rho(\boldsymbol{u})$ of a relation being fulfilled by the syndrome $\boldsymbol{u}$. It will be assumed that in general $\varphi_\rho(\boldsymbol{u})$ is a function satisfying the conditions:

1. $0 \leq \varphi_\rho(\boldsymbol{u}) \leq 1$
2. $\varphi_\rho(\boldsymbol{u}) = 0$ if $\boldsymbol{u}$ does not satisfy ρ (also, if ρ is an empty relation);
3. for any $\boldsymbol{u}$ if $\rho' \subseteq \rho''$ then $\varphi_{\rho'}(\boldsymbol{u}) \leq \varphi_{\rho''}(\boldsymbol{u})$

The following types of measures can be taken into consideration:

1. based on discrete scales 0 - does not satisfy, $1, 2, \ldots, k$ - certainly satisfies; $k = 1$ (binary), $k = 2$ (ternary), etc.;
2. based on a continuous scale $[0, 1]$.

Then, if $\varphi_0(\boldsymbol{u})$ denotes a total measure and $\varphi_n(\boldsymbol{u})$, $n = 1, 2, \ldots, N$, the measures of particular relations being satisfied by $\boldsymbol{u}$, it can be assumed that:

$$\varphi_0(\boldsymbol{u}) = \varphi_1(\boldsymbol{u}) \cdot \varphi_2(\boldsymbol{u}) \cdot \ldots \cdot \varphi_N(\boldsymbol{u}). \tag{4}$$

Example 1 It is given an observation:

Date / Hour / Name / Address / Age / Sex / Diagnosis / State
21.03 / 18.00 / N.N. / aaa / 67 / male / apoplexy / suspected

A doctor called to the urgent case needs a remote medical consultation of this case with a neurological specialist. For this purpose, he should introduce his observation data to a *Medical service OM* containing the relations:

Medical center, Center's address, Center's e-mail;
Center's departments, Center's departments' phones;
Center's department's specialists;
Center's department's duty schedule.

This makes possible to establish a relation:

Date / Hour / Diagnosis / State / Medical center / Center neurological department / Center neurological department's phone / Neurological specialist on duty.

Finally, this leads to recognition of a situation like:

21.03 / 18.00 / N.N. / aaa / 67 / male / apoplexy / suspected / Medical center XX / Neurological department / Phone number zzz / Neurological specialist dr YY /.

4.2 Interpretation of Situation

The above-presented example might suggest that *SI* is a simple one-step decision process. In fact, it is an iterative process consisting of several steps, as it has been mentioned in Sec. 2.2. This can be illustrated by a next example.

Example 2
Let us take into consideration a computer-aided street-traffic monitoring system. Its tv camera has caught a series of shot pictures illustrated schematically in Fig.5.

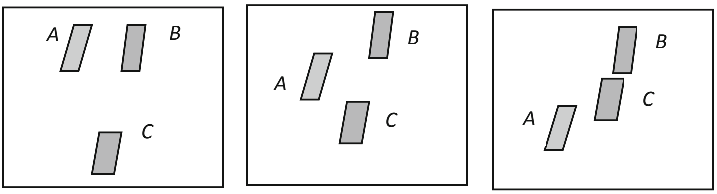

Fig. 5 Three consecutive shot pictures of a street-traffic film

Let us assume that three objects (denoted *A*, *B*, *C*) have been detected in the pictures. A preliminary comparison of the pictures leads to finding that:

A is approaching, B is steady, C is going away

The aim of the *SI* system is to detect and to record traffic accidents. The interpretation process may run as shown in Fig6.

In the above-described process a following qualitative linear scale of values has been used:

Not important $\rightarrow$ *Possibly important* $\rightarrow$ *Suspected* $\rightarrow$ *Important* $\rightarrow$ *Highly important*

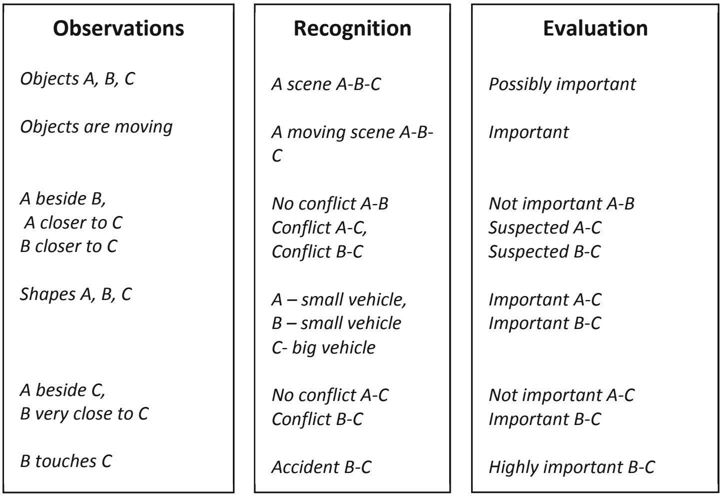

Fig. 6 Street traffic monitoring process

The *SI* process contains several pattern recognition acts: recognition of a *scene* (general), *moving scene*, *conflict*, *vehicle*, *accident*, etc. The mentioned here types of recognized objects as some ontological concepts are described by corresponding *OMs*. For example, the concept of *accident* can be defined by a hyper-relation H_Q described on a set Q consisting of at least two *objects* localized in a metric space and constructed as follows:

1. It is taken into account a Cartesian product $Q \times Q$;
2. It is defined a relation $r \subset Q \times Q$ as a set of all pairs of different elements of Q;
3. It is defined a table D_t of *metric distances* between the pairs of elements of r;
4. There are taken into consideration the tables D_{t1}, D_{t2}, D_{t3} for three consecutive time-instants $t_1 < t_2 < t_3$;
5. H_Q is fulfilled if for at least one pair of objects $q', q'' \in Q$ their metric distances satisfy the relation:

$$0 < dt_1(q', q'') > dt_2(q', q'') > dt_3(q', q'') = 0. \quad (5)$$

5 Conclusion

Interpretation of situations is a substantial component of living beings' behavior in real world. It consists of recognition of arising situations, their pragmatic assessment and establishing their relations to other situations. Similar type of decision making processes can be modeled in computer systems. Computer-based *SI* systems cannot