FRAME REPRESENTATIONS IN E-LEARNING – APPLICATIONS AND NEW DEVELOPMENTS

Rositsa Doneva, Silvia Gaftandzhieva, George Totkov

University of Plovdiv "Paisii Hilendarski"
rosi@uni-plovdiv.bg, sissiy88@uni-plovdiv.bg, totkov@uni-plovdiv.bg
Bulgaria

Abstract: The use of frame-based knowledge representations in training methods has a long history. The paper presents a part of a study on the application of frame-based computer representations of knowledge for the needs of e-learning. It proposes an innovative modification of frame models, called accumulative frame model (AFM). The AFM is a development of the classical understanding of a frame model, and therefore has its all typical features, but beside the possibilities for knowledge representation, it adds to the model the means for knowledge accumulation also. This provides a particular flexibility in the implementation of processes for automated extraction and aggregation of data and knowledge for training needs. In addition, a model of a system of AFM is introduced, with the purpose of conceptual representation of knowledge in separate subject domains. The proposed models are approbated for conceptual modelling of a particular subject domain of study – the domain of computer programming.

Key words: Knowledge Representation, (Accumulative) Frame Models and Systems, Intelligent E-Learning Solutions

1. INTRODUCTION

The organization of the learning process should include technologies, methods and tools for intensive learning, which allow quality acquisition of communicative knowledge, skills and competencies in a short time [1]. A perspective direction in the teaching methodologies [2] is based on the use of so called frames (alias named in addition semantic nets, conceptual graphs, cognitive models, schemes, scenarios, etc.) for knowledge representation.

The use of frame-based learning methods allow students to acquire more knowledge without spending more time than with traditional educational technologies. Frames enable activation of students' cognitive abilities and skills for a systematization of the learning material.

The frame theory reflects the stereotyped nature of learning, knowledge organization and problem solving approaches [3] – the comprehension process is accompanied by a summarization and is stored in a structured form. The learning material, presented by the teacher through frames (schemas, tables, etc.), is properly structured (aggregated) and ordered information, which is expected to be taught to students [1] and that students can understand easier.

The paper presents a part of a study on the application of frames in e-learning as means of computer modelling of knowledge. The first two sections are devoted to the theoretical study of frame representations and the analysis of their applications in the training. The innovative modification of frame models, called accumulative frame model (AFM) is proposed. In addition, a model of a system of AFM is introduced, with the purpose of conceptual representation of knowledge in separate subject domains. The proposed models are approbated for conceptual modelling of a particular subject domain of study – the domain of computer programming in the context of a particular programming language (C ++) from the language syntax aspect.

2. FRAME REPRESENTATIONS IN LEARNING

The use of frame-based representations in learning has a long history. According to Perkins [4], by using frames educational institutions can help students to think better. Perkins [4] defines the frame as a representation designed to guide the thinking process, maintenance and organization of the learning process.

In traditional training, a frame-based methodology for presenting and studying learning material [3] is proposed. Frame structures suitable for knowledge systematization and problem solving are developed in a number of subject domains studied in secondary and higher education – e.g. Mathematics, Informatics, Physics, Chemistry, History, English, etc. The set of standard situations, scenarios, dialogues and structures of each particular subject domain is modelled by a frame system.

Frames are excellent means for promoting reading comprehension. Two main learning tasks can be given to the students – to read text and then to fill in a frame (to a blank copy of a pre-created frame or to a newly created frame) or to extract from a text additional information (notes) for an already completed frame. Those tasks can be performed individually or in a group. When working in groups, each group can fill frames for different text passages or different groups can look for information to fill different frames from the same text. The teacher’s primary role [5] is to check whether the frames are correctly filled, to add any missing essential information, and to model the creation of notes on the frame.

Ellis [5] proposes a wide range of ways in which frames (called graphical organizers) are used to deepen understanding of information related to key ideas and learning topics. Frames present abstract ideas and help students to learn the content in a thorough and meaningful way, focusing on the relation between the basic ideas and the essential details. Frames are flexible because they can be used to organize important information as well as a tool to facilitate the use of strategies for reading with understanding and effective writing and thinking strategies. Studies show [5] that routine framing can facilitate training in different subjects and develop reading, writing and analytical skills.

The use of frames in language training relies on the idea of language as a system of interconnected elements at different levels (phonetic, lexical, grammatical) and allows students to form a basic vocabulary, specific communicative knowledge, skills and competences for a limited time [1].

A frame model for identifying the causal relations in the consciousness of people in studying Dutch is presented in [6]. Causal relations are created in consciousness of native speakers in the form of frames, independent of the language structure. For creating the relevant frame system, models of syntactic frame and thematic frame of causal relations are investigated and introduced.

The importance and universality of the frame in the synthesis of knowledge elements in integral system, in the educational information transformation in the teaching content, in the transformation of verbal into non-verbal information, in the creation of innovative, symbolic and symbolic structural diagrams of its presentation to students are determined in [7].

Frames are used for knowledge representations in intelligent tutoring systems (based on knowledge about domain, teacher and students). For example, in the system TEx-Sys [8], designed for improving the process of learning and teaching in a chosen subject domain, the knowledge is represented through semantic networks with frames and production rules. The basic components of TEx-Sys semantic networks are nodes and links. The nodes are used for representation of knowledge about objects from the domain, while links show relations among them. Beside nodes and links, the system supports properties and frames (consisting of attributes and respective values), as well as property inheritance. Users (teachers and students) can generate semantic primitives for domain knowledge formalization and storing in the knowledge base.

For the need of e-learning, a frame-based method for automated generation of educational test questions (test units) of different types is proposed. The method is related to the accumulation and evaluation of answers to test units of open type. For this purpose, a new type of test unit called "Accumulative Test Unit" is introduced and studied [9, 10]. Later, the accumulative test unit system [11] is also proposed. The system can be used to develop conceptual descriptions and test banks (including test units of different types [12]) in different subject domains. The accumulative test unit can be considered as a specific frame-prototype with several slots. The first of slots is designed for the test unit formulation, and the next – for accumulation of evaluated answers. Thus, in the e-learning process, accumulative test units will produce frame-instances that can be used to create test banks.

A study conducted among medical students [13] shows that frames are a proper system for knowledge representation in LMS Moodle that allows students to have the highest results during exams. This is due to the fact that compared to conceptual maps and charts, frames allow the grouping and structuring of information, the focusing on concepts, and they require a higher level of concentration.

With the introduction of information technologies in education, teachers have an opportunity to create most advanced learning techniques which improve the assimilation of learning material and allow them to pay more attention to the individual and personal growth of students and to direct their creative development. According to some researchers [1], "frames underlie the structure of the e-books and they are necessary for self-education and the development of the ability for work independently. The use of a frame-based e-learning approach allows the teacher to direct students to text reproduction, text formation and text perception, i.e. teaches them to analyse the information received. Frames allow teachers to manipulate both declarative and procedural knowledge".

Frames are successfully applied for the creation of e-learning materials suitable for adaptive learning. Kostolányová K. and J. Šarmanová [14] use frames to represent united elementary parts within the curriculum, i.e. the frame is an elementary educational unit. The frame corresponds to the lowest level of numbered or otherwise marked paragraphs or a web page including multimedia elements. According to them the instruction is divided into units and frames with each frame containing sensory and depth variants. The sensory variants must be “with text (for the verbal type of students), with images, graphics and animations (for the visual type), with audio recordings and discussions (for the auditive type) or creative exercises, constructions, etc. (for the kinaesthetic type)”. The depth variants are produced according to the depth of the instructions. Learning materials are proposed to the students in the "universal depth". Students, unable to comprehend the instructions formulated in this depth, have available variants of the modified instruction (more detailed, from different point of view, etc.) and students, motivated by the given topic, have access to interesting facts and specifics of the given topic. Due to the fact that the instructions also have to respond to differences in the learners' personalities, the authors suggest adaptation of the instruction style of the frame to be done by dividing the frame into partial components – layers (parts of the frame that are homogeneous from the point of view of the learning process, incl. explanation, reinforcement, knowledge assessment, motivation, instruction management).

3. ACCUMULATIVE FRAME MODEL

The above short exposition of the analysis of the frame models application in education is a part of the study dedicated to the application of frame models for representation of knowledge and processes in the field of e-learning.

The main goal of the study is creating intelligent software e-learning solutions in different subject domains by using methods of frame representations and conceptual modelling [15].

On the basis of the analysis, an innovative modification of frame models, called **accumulative frame model** (AFM) is introduced, as a solution of the problem for conceptual modelling of e-learning tasks in a separate subject domain. AFM is used for representation of relatively independent, logically distinct units of knowledge with the possibility of multiple usage in different situations (incl. data extraction and aggregation).

The proposed AFM, introduced bellow, is a development of the classical understanding of a frame model, and therefore has all its typical features. But beside the possibilities for knowledge representation, it adds to the model and means for knowledge accumulation. This provides a particular flexibility in the implementation of processes for automated extraction and aggregation of data and knowledge for training needs.

AFM is a named structure that describes any standard situation (or object).

From the structural point of view (see Figure 1), AFM is made up of 'slots' that correspond to different elements/aspects of the situation. Each *slot* has a unique name (other than the names of the other AFM slots) and includes one or more facets representing knowledge for different characteristics of the relevant situational element.

Facets serve as a description of both *static knowledge*, such as: `value`, `default value`, `range`, and *dynamic knowledge*, through procedures associated with them – so-called procedural attachments (methods), or demons. Examples of procedural attachments are: `if_added (value)`, `if_removed`, `if_replaced`, `when_needed`, `help`, etc. An important role in the knowledge representation through AFM plays a special kind of methods, called "filling methods" or "fillers", which assign values to the frame slots (by: default value, data retrieval via attached procedures, etc.) on the basis of the current context and slot-specific heuristics. Demons are particular type of procedures that are run automatically whenever a particular event occurs (e.g. when a particular value changes).

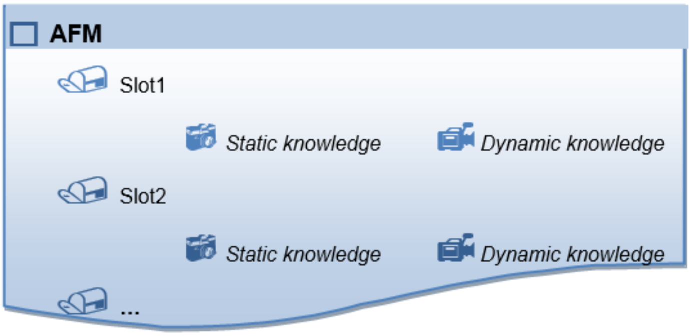

Figure 1. AFM structure

The slot value is of a certain data type, which can be elementary or composed. Examples of elementary types are: real, integer, symbolic, or range types, and for composite are: dates and periods, texts, images, different type files, lists, records, as well as AFM again or AFM slots. However, it should not be forgotten that the same value can be related to different type systems (e.g. data type, syntactic and semantic type of speech parts).

The frame structure is dynamic, i.e. allows adding new slots at any time.

The frame theory considers frame-prototypes and frame-instances. Frame-prototypes, also called classes, generic frames, templates, represent categories of situations/objects, while frame-instances represent specific situations/objects. Frame-instances have a special slot called `instance_of`.

From the point of view of the scope (Figure 2), AFM includes both *local knowledge* and *global knowledge* representation. The AFM slots mentioned above as examples for static and dynamic knowledge (`value`, `range`, `if_added`) serve to describe the local knowledge for the situation/object under consideration. Examples for description of global knowledge are slots related to the frame system to which the AFM belongs to, such as AFM predecessors and successors (typically included in the model, because frames can be inherited), or slots representing other types of relationships with other AFMs.

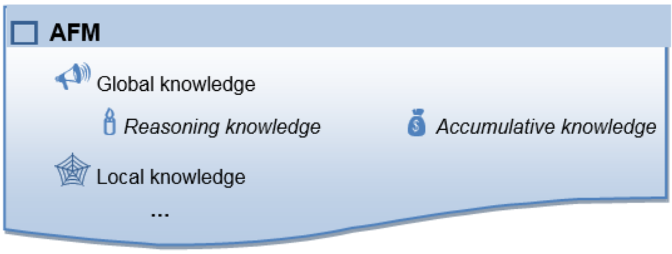

Figure 2. AFM scope

A fundamental part of the global knowledge for each AFM is so-called *reasoning knowledge* that assists in the extraction/understanding/inference of the information presented through the frame, including special inference methods. They manage a matching process that attempts to assign a value to each AFM slot and that is partially controlled by the relevant slot methods for execution and control of knowledge extraction (e.g. range checking, filler, etc.). For this purpose, it is necessary to specify the source of information/data (`inference_source`).

An innovative element of the proposed AFM is the possibility to include so-called *accumulative knowledge* as part of the global knowledge for the regarded situation/object, including tools for knowledge accumulation – accumulative methods. These methods, on their turn, manage an accumulation process of knowledge related to the situation/object under consideration, in the form of frame-instances, new AFM prototypes and instances, new relations, etc. by using the appropriate *interfaces* with selected sources of accumulative knowledge (`accumulative_source`). An important role for accumulative knowledge plays the knowledge about the related *subject domain*, as well as about the *context* and the *aspect*/goal of the representation, that is a part of the AFM global knowledge.

Accumulative knowledge is also propagated throughout the local level.

Collections of linked frames, typically in the same subject domain, are called frame systems. A **model of an AFM system** is introduced (Figure 3), with the purpose of conceptual knowledge representation in separate subject domains. It includes, once again, both *local knowledge* and *global knowledge*. The local ones concern, for example, the knowledge about the network of the included AFMs – *frames network* and about the types to which the values of the slots of the participating AFMs belong – *type systems* (incl. elementary and composite data types).

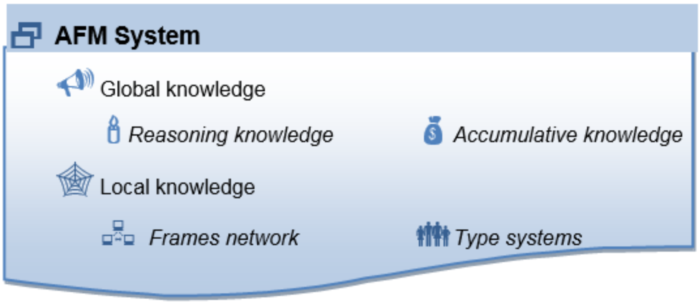

Figure 3. Model of AFM system

The global knowledge includes a mechanism for information extraction, i.e. an inference engine, in this case on the AFM system as a whole, which evaluates the slots of the individual AFMs (by inheriting the frame values via inheritance links, by calculation using dependences between frames, etc.). This mechanism (comprising reasoning knowledge) can be bottom-up (data-driven or event-driven) or top-down (driven by expectations).

The AFM systems also contain accumulative knowledge, including knowledge about the subject domain, the context and the aspect/purpose of the representation (which in some cases may be more general than the context and aspect of each individual AFM).

As a first step, **to check the suitability of the proposed models for conceptual modelling** and representations of knowledge for the needs of e-learning, they are approbated in a particular subject domain. For this purpose the *subject domain* “Programming” from the Computer Science area of study is chosen. Correspondingly, the AFM-based representations of knowledge are built in the *context* of “Learning programming with C ++ programming language” from the *aspect* of “Learning of the language syntax”.

The resulting AFM system is built up with the purpose to support student (self)assessment and testing activities during the e-learning process while studying the C ++ programming language syntax by:

- Maintenance of a database of test questions and examples on the topic;
- Testing student knowledge on the C ++ syntax constructions by accumulation mechanism (in automated manner) or by the teacher himself (manually) in dialogue with students;
- Gathering in the database new examples of the C ++ syntax constructions by inference and accumulation mechanisms (in automated manner) or by the teacher himself (manually);
- Gathering new test questions in the database by accumulation mechanism (in automated manner) or by the teacher himself (manually).

For example, the AFM system, developed for all topics of learning on C++ statements, consists of nineteen (19) AFMs. Figure 4 presents (in simplified manner for compactness purposes) one of the described AFMs, namely a frame-prototype modelling the knowledge for the simple assignment statement syntax in C ++ programming language.

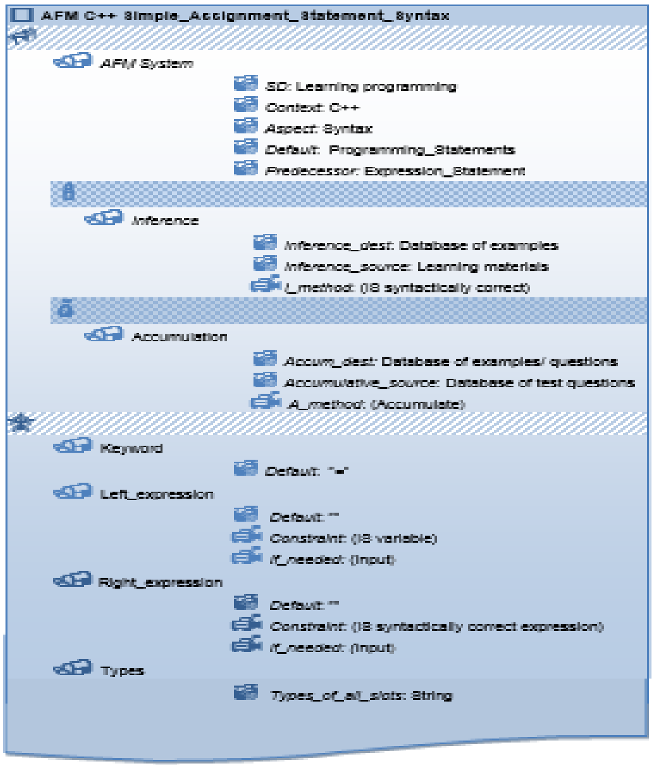

Figure 4. AFM, simple assignment statement

A big part of the knowledge (especially global knowledge) described in this AFM (`Simple_Assignment_Statement_Syntax`) is inherited directly from its predecessor (`Expression_Statement`) from the AFM system (`Programming_Statements`) to which it belongs to. In particular it inherits the description about:

- subject domain (`SD`), as well as about the context and the aspect of the representation;
- inference source and destination of data (`Inference_source` and `Inference_dest`) and partially about the matching process method (`I_method`);
- accumulation process, including about the source of accumulative knowledge (`Accumulative_source`), the destination of the accumulated data (`Accum_dest`) and the accumulative method (`A_method`);
- data types to which the values of the AFM slots belong (`Types_of_all_slots`).

4. CONCLUSIONS AND FUTURE WORK

The proposed innovative modification of frame models AFM and a model of a system of AFM are approbated for conceptual modelling of a particular subject domain "Programming" from the Computer Science area of study in traditional learning. The teacher tested the students' knowledge on the C++ syntax constructions in a dialogue with students during (self)assessment activities. Students had to fill frame-instances on the basis of the developed frame-prototypes, modelling the knowledge for C++ statements. The experiment proves that the proposed AFM activate students' cognitive abilities and skills for a systematization of the learning material and lead to higher results. The presentation of use case scenarios for learning programming language C++ and evaluation results are not among the purposes of the paper and will be presented in another paper.

Procedures for data extraction and aggregation are used for gathering of new examples of the C++ syntax constructions (frame-instances). On the basis of these examples new test questions were created and stored in the database. These test questions will be used for assessment of the students' knowledge.

In the short term, systems of AFM for other subject domains (related to informatics, information technologies, etc.) will be defined. On the basis of the defined AFM systems, algorithms for data extraction and aggregation for automating e-learning tasks will be created, including:

• an algorithm for automated bookmarking with AFM of text passages in learning materials (from different students in e-learning processes);

• an annotation algorithm (where AFM slots will get values);

• an algorithm for forming a system of frame-instances for subject domains;

• an algorithm for confirming or rejecting of the AFM application of specific situations/objects by filling slots;

• an algorithm for the accumulation of "case studies/examples" by creating a frame-instances base;

• an algorithm for the application of the pedagogical method "understanding by example" on the basis of frames-instances.

The further prospects for the development of the study are the possibilities for:

• automation of e-learning activities (including optimization - reducing costs and deadlines for performing different tasks as well as achieving a higher quality of learning activities and materials and greater objectivity, e.g. for evaluation);

• automated construction (design, generation) of AFM systems in the specific subject domain (e.g. as part of a learning process).

It is possible on the basis of the results achieved to be created models and developed intelligent systems to carry out more general institutional processes with dynamic extraction and aggregation of data from different information sources (internal and external to the institution).

ACKNOWLEDGEMENTS

The paper is partly supported within the project MU17-FF-023 "Accumulative frame models for extraction and aggregation of data for knowledge and processes in learning" of the Scientific Research Fund at the University of Plovdiv.

REFERENCES

[1] Kulgildinova T.A., Uaissova. Realization of frame-based technologies in the context of education in informatization, *Journal of Theoretic and Applied Information Technology*, ISSN: 1992-8645, Vol.89. No.1, pp. 254-260, 2016.

[2] Kolodochka T.N., Didactic possibilities of the frame technology. *School Technologies*, 3, pp. 27 – 30, 2003.

[3] Gurina R. et al., *Frejmovie opori*, NII Shkolnih tehnologii, Moscow, 2007 (in Russian).

[4] Perkins D., Thinking Frames, *Educational Leadership*, Vol.43, No.8, pp.4-10, 1986.

[5] Ellis Ed., *Framing Main Ideas and Essential Details to Promote Comprehension*, Edge Enterprises, 1998.

[6] Dalbergenova L. et al., Cognitive approach to the study of causal relations, *Procedia - Social and Behavioral Sciences*, Vol.143, pp.233 – 237, 2014.

[7] Novikova G., N. Tagiltseva, V. Ignatova, L. Vakhrusheva, L. Faleeva, A. Litvinov, Didactic frame compression principle in students training content, *Revista ESPACIOS*, ISSN 0798 1015, Vol. 39, No 05, pp. 21, 2018.

[8] Stankov S., Glavinić V. & Rosić M., On knowledge representation in an intelligent tutoring system, *Proceedings of INES'2000—International Conference on Intelligent Engineering Systems*, Portoroz, Slovenija, pp. 381-384, 2000.

[9] Kostadinova Hr., G. Totkov, D. Blagoev, Automated generation of metadata for learning objects, *4-th National Conference Education in the Information Society*, ISSN 1314-0752, pp. 44-52, 2011 (in Bulgarian).

[10] Sokolova M., G. Totkov, Accumulative Question Types in e-Learning Environment, *International Conference on Computer Systems and Technologies – CompSysTech'2007*, ISBN: 978-954-9641-50-9, 2007.

[12] Totkov G., M. Sokolova-Rajkova, Hr. Kostadinova. *Test in e-learning*, Rakursi Ltd., Plovdiv, ISBN 978-954-8852-42-5, 205 pages, 2014 (in Bulgarian).

[12] Minsky M., *A Framework for Representing Knowledge*, MIT, Cambridge, 1974.

[13] Fonseca O.H. Learning styles and knowledge representation systems in Ecaes (quality examinations for higher education) for medical students. *Revista Horizontes Pedagógicos*. ISSN-e 0123-8264, Vol. 17, No. 1, pp. 42-52, 2015.

[14] Kostolányová K., J. Šarmanová, Use of Adaptive Study Material in Education in E-learning Environment, *The Electronic Journal of e-Learning*, ISSN: EISSN-1479-4403, Vol. 12, No. 2, pp. 172-063, 2014.

[15] Totkov G., S. Gaftandzhieva, R. Doneva, Accumulative frame models in e-learning, *Scientific Works of the Union of Scientists in Bulgaria – Plovdiv, Series C. Technik and technologies*, ISSN 1311-9419, Vol. 15, pp. 17-20, 2017 (in Bulgarian).

Information about the authors:

Rositsa Doneva, PhD **–** Professor at the University of Plovdiv “Paisii Hilendarski”, ECIT Department. She has led/ taken part in more than 50 national and international projects in the area of computer science, electronic and distance learning, applications of IT in education, etc. Prof. Doneva is the author of over 110 scientific publications in the field of Intelligent Systems, Conceptual Modelling, quality assurance (of HE, e-Learning, Projects, etc.), OOP, e-Learning, m-Learning, etc. and 40 textbooks and learning materials with over 300 citations.

Silvia Gaftandzhieva, PhD – Assistant Professor at the University of Plovdiv “Paisii Hilendarski”, Faculty of Mathematics and Informatics, Department of Computer Science. Her research areas include e-learning and distance learning, automated evaluation of quality in higher education, distance learning. She is an author of 30 scientific publications in the field of quality assurance (of HE, e-Learning, Projects, etc.), e-Learning, m-Learning, etc. with over 70 citations.

George Totkov, D.Sc. **-** Prof. at Department of Computer Science, University of Plovdiv “Paisii Hilendarski”. Prof. Totkov’s main scientific interests are in the sphere of computer science (e-learning, computer linguistics, information modelling, etc.) and computational mathematics (approximation, mathematical statistics, etc.). He is the author of more than 200 publications with over 600 citations. He has been a leader of or taken part in more than 50 national and international projects on the mentioned research fields.

Manuscript received on 22 February 2018