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AUSTRIAN – UKRAINIAN PROJECT CENREC AS EXAMPLE OF INFORMATION SUPPORT OF ACTIVITY OF INTERNATIONAL SCIENTIFIC COMMUNITY.

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In the paper the problem of informational support and international scientific activity and cooperation of a few research groups working in the same scientific area is considered. Each such group includes scientific adviser, collaborators, postgraduate and master students. The problem consists in effective support of its collaboration. As an example of support environment of joint scientific activity we consider the portal CENREC, developing in the frame of joint project of research institute of symbolic computations of J. Kepler University (Linz, Austria) http://risc.uni-linz.ac.at/ and research institute of information technologies of Kherson State University (Ukraine). The project was initiated by authors in 2008. Since 2009 the project is supported by ministers of science and education of Austria and Ukraine.

Key words: *scientific activity, international scientific cooperation, Information and Communication Technologies.*

Introduction

Development of modern informational-communicational means for supporting of scientific and educational activity is one of key technological problems for improving of effectiveness of processes of scientific and educational activity. In [18] the approach to solve this problem, based on specificity of organization forms of educational process depending on the qualification level of educational institution and students is considered.

One of the highest levels in hierarchy of educational institutions is the level of postgraduate and master programs. The postgraduate and master students are future specialists of higher qualification.

The specialist of higher qualification must be qualified for job, requiring the research and leader competences, analytical skills of process and phenomena and abilities to make necessary decisions. As a rule, this specialist has already selected the research issue and scientific advisor. He works in the staff of research group and trains by himself.

The most important role plays the integration of this specialist in the international scientific community. All these specific requirements should be transformed into users' requirements to correspond software – integrated environment supported this kind of education.

This specific proposal of users requirements addresses the following objectives within the scope of Austrian-Ukrainian scientific cooperation: ***Information technology.*** It is based on an activity that is (on the Austrian side) funded by an *FWF project P20164-N18* since October 2007 and on a subsequently developed informal cooperation with the Ukrainian side. By this joint work, already first results have emerged (http://cenrec.risc.uni-linz.ac.at). The purpose of this proposal is to further strengthen this cooperation by receiving support for (currently not yet funded) regular mutual visits of the project participants. Since many of the participants are students, this also raises the possibility for pursuing commonly supervised (diploma and potentially also PhD) theses.

1. Research project CENREC: requirements for content

The main goal of the project CENREC will be to create a Web portal for a virtual **CE**ntre for **N**onlinear **RE**sonance **C**omputations (**CENREC**) as an international open-source information

resource in one of the most important and vastly developing area of modern nonlinear dynamics (ND) – nonlinear resonances. **CENREC** will contain the following:

1. A MediaWiki-based hypertext encyclopedia provides a survey on the main subjects of the field with cross-linked articles that include references to the electronic bibliography and to executable software.

2. An electronically indexed and searchable bibliography which collects literature in the field in the form of bibliographic data, abstracts, links to electronic documents (if freely available) respectively links to the corresponding entries in the digital libraries of the respective publishers.

3. A collection of executable symbolic methods accessible via web interfaces that allow users of the portal to submit via conventional web browsers input data and retrieve result data as text and/or graphics.

4. An international ND Forum to maintain contacts with the ND groups, running regular advertisements by Email, on the Internet, etc. that will provide high quality content and good promotion of the Web portal.

A preliminary version of the **CENREC** structure can be found at: http://cenrec.risc.uni-linz.ac.at/portal/.

International cooperation with groups of Prof. S. Nazarenko (Warwick Math. School, University of Warwick, UK), and Prof. I. Procaccia (Weizmann Institute for Sciences, Rehovot, Israel) is on the way; links:

http://www2.warwick.ac.uk/fac/sci/maths/people/staff/Sergey_Nazarenko/

http://www.weizmann.ac.il/chemphys/cfprocac/home.html.

Cooperation with other international groups on nonlinear dynamics is planned.

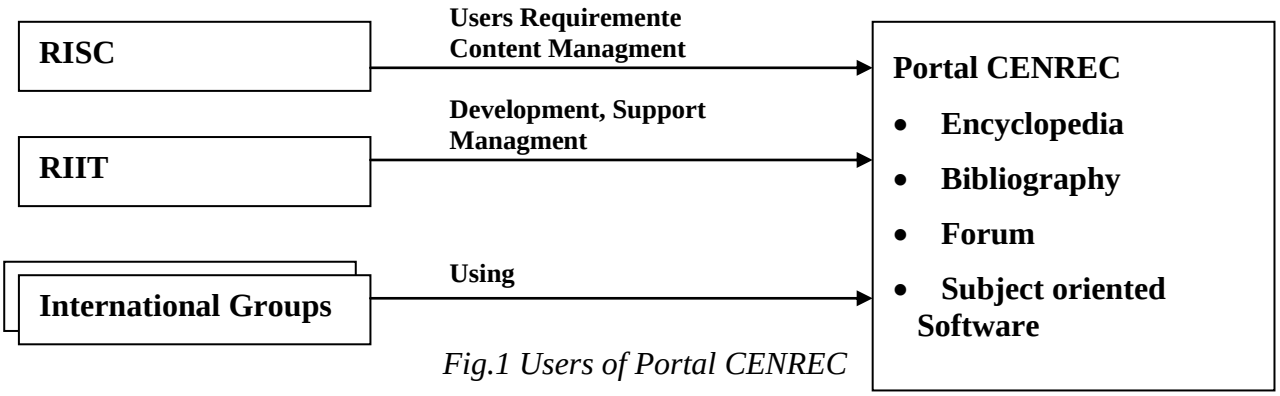

Fig.1 Users of Portal CENREC

1.1. Scientific background of Subject Domain

Resonance is a common thread which runs through almost every branch of physics, without resonance we wouldn't have radio, television, music, etc. Resonance causes an object to oscillate, sometimes the oscillation is easy to see (vibration in a guitar string), but sometimes this is impossible without measuring instruments (electrons in an electrical circuit). While linear resonances in different physical systems are comparatively well studied, to compute characteristics of nonlinear resonances and to predict their properties is quite a nontrivial problem, even in the one-dimensional case. Thus, the notorious Fermi-Pasta-Ulam numerical experiments with a nonlinear 1D-string (carried out more then 50 years ago) are still not fully understood. Nonlinear waves in continuous 2D-media like ocean, space, atmosphere, plasma, etc. are well studied in the frame of statistical wave turbulence theory (WTT) and provide a sound basis for qualitative and sometimes also quantitative analysis of corresponding physical systems, provided that discrete nonlinear resonances are explicitly excluded from the consideration.

In the last decades it has become increasingly clear, that in the majority of the laboratory experiments and numerical simulations of nonlinear dispersive wave systems, the discreteness of the wave-number space remains an important factor which causes the system to behave completely differently from the predictions of the classical WTT based on the continuous (infinite-box) limit.

The most surprising fact is that some regularity, characteristic of small number of modes, often persists in much larger and even infinite wave sets, and sometimes such regular motions happily coexist with emerging chaotic behavior. In the other words, resonant interactions among a relatively few selected discrete modes remain at least as important as statistical evolution of the remaining vast majority of the modes. Although the theory of nonlinear resonances has been intensively developed over the last few decades, the results are scattered in numerous papers treating specific application areas and using specific terminologies unknown even to physicists and mathematicians working in nearby areas. On the other hand, many existing results are completely algorithmic and can be used as a base for developing some symbolic programming packages dealing with the problems of nonlinear dynamics as well as in numerous applications demanding a deep knowledge of differential equations. The present online mathematical encyclopedias (Wikipedia, Mathworld) have practically no coverage of this area. In addition they do not possess the most important property for a user – interactivity, i.e. there is no suitable software and other services; all this will make **CENREC** portal a unique learning and development environment.

1.2. Project objectives

The main goals of the project **CENREC** are to

I. Create an integrated learning environment to support university courses on the various aspects of nonlinear dynamics (ND); in particular, the special course "Nonlinear resonances: theory, computations, applications" held at RISC since 2006;

II. Establish **CENREC** as a central resource for the international community in the novel and fast developing area of nonlinear resonances;

III. Attract a critical mass of contributors to ensure a dynamic, volunteer-based Web-portal in the long term.

The heterogeneous nature of the various scientific problems to be solved makes the project **CENREC** a very challenging task indeed. **The first group of problems** is connected with developing the unified theory of nonlinear resonances, elaborating the standard terminology in the area, classifying the resonant systems due to the form of their dynamical systems, pointing out important application areas of this theory, selecting significant examples (both from educational and scientific point of view) to demonstrate possibilities of the existing methods and software, etc. **The second group of problems** has to do with the design and implementation of symbolic algorithms as a user-friendly program package embedded into a specially developed open Web-platform, based on the corresponding scientific infrastructure. **Open Web-platform based systems** form a vital infrastructural tool in areas of modern academic and commercial research, with important applications in mathematics, physics, computer science, engineering and other technical disciplines. The project will improve the international technical and informational cooperation between educational institutions, academic researchers and application groups in the area of nonlinear resonances. RISC is an internationally renowned scientific institution in the field of symbolic computation field and also the place where this research area was first recognized as a separate branch of nonlinear science, corresponding mathematical methods were developed and implemented into symbolical program packages. RIIT is a prominent Ukrainian establishment in the area of educational software tools approved by Ukrainian Ministry of Education and Science and used all over the country. The collaboration of these two institutions will help to bring together the competences needed for achieving the main goals of the project **CENREC**.

1.3. Brief description of the project subjects

Part 1: portal content

A classification of nonlinear resonances

The classification will be based on 1) the form of dispersion function, and 2) the order of nonlinearity in the corresponding evolutionary dispersive PDEs. Outgoing from this classification we are endeavoring to describe classes of nonlinear PDEs with similar structure of resonance sets thus developing further the methods of [7], [8]. To compute resonance sets we are going to extend the *q*-class method [2] to PDEs with nonlinearity of order more than 3. We are going to expand the construction of all non-isomorphic clusters of the topological structure of a resonance set [7] to the

4-term resonance systems. This classification, together with a few dozen of expertly chosen physically relevant examples [1], [6], [8], will form the kernel of the future encyclopedia.

Symbolical software

Originally, methods to compute nonlinear resonances have been implemented numerically [3], [4], [5]. These methods enable computation of resonance sets only while we are interested in the coefficients of dynamical systems and, eventually, in the rational parameterizations of resonance manifolds which can only be achieved symbolically. Therefore we need symbolical program packages to that effect. First steps in this direction [7], [9] show (implementation has been done in Mathematica) that the *q*-class method is fast enough to compute the desired solutions in physically relevant domains in reasonable time. On the other hand, as it has been demonstrated in [9], some bugs in Mathematica do not allow computing dynamical coefficients symbolically. Concerning parameterization, a few days of computation in Mathematica for one specific example did not yield any results. The same problem treated with Maple produced only trivial solution and with Singular – some weird partial parameterization. We are going to try the employment of the original APS package developed by our Ukrainian partners [9], [11] to this end.

Part 2: Content management

A Web-based infrastructure is developed that provides easy to use, portable, and in particular location-independent access to the **CENREC**. For the typical user, the access interface is simply a Web browser which connects to a Web portal that on the one hand displays encyclopedia, bibliography, data sets, and various online services. The user may invoke some of these services on the equation and then gets its result displayed. However, this portal is actually only the frontend of a complex Web service infrastructure which consists of the following components:

A language for building Web interfaces to mathematical software

The goal of this work is to build a generic framework for publishing mathematical software (written in systems like Mathematica, or APS, or in a general-purpose programming language) as web applications with which humans interact by conventional browsers. The core of this framework is a simple XML-based language; this language describes the dataflow of an application which consists of invocations of computer algebra methods and interactions with the user (input through web forms and output as web pages with embedded text, MathML formulas, or generated images). The language shall be compiled to say PHP-enhanced HTML pages that implement the user interface and invoke mathematical software to perform the actual computations. A comfortable programming and publishing framework that makes it comparatively easy for a mathematician to develop a new solution method in one of the major mathematical software systems, wrap it as a web service and describe it for the use in **CENREC**. Theoretical approach presented in [10], [11] will be used; an example of its application can be found here:

http://apache2.risc.uni-linz.ac.at/schreiner/DiscreteWaveTurbulence/)

Formal specification and verification of the software

To achieve the goals of the project, various problems of formal specification and verification of the software, especially third-party software, should be solved.

General analysis

The computer algebra system APS, developed by Ukrainian collaborators, has to be expanded to include expansions, morphisms and inherited multi-sorted algebras according to the specifics of the chosen subject domain (nonlinear resonances). Added operations and relations pose new demands concerning synthesis, verification and optimization of algebraic program-interpreter for this new subject domain. This will be realized in terms of data types, operations and relations corresponding to the new subject domain (for theoretical background see [8]).

Static analysis

Static analysis of the software will be performed using specifics of the chosen subject domain, along the following lines. As our subject domain – nonlinear resonances – is part of physics, some *preliminary* physically relevant restrictions, if not satisfied, will demonstrate immediately possible programming errors. The list of preliminary examinations includes (but is not exhausted by them) (a) dimensions of the physical variables (say, time can not have dimension 2),

(b) physically meaningful domains of parameter definition (say, length can not be a complex number), (c) physical laws have to be satisfied (say, energy must be conserved in the non-dissipative resonant system), (d) etc.

Equations data base

An XML database with a high-level Java API for storing known equations and their intrinsic properties, descriptions of solution methods and their domain of applicability (e.g. equations known to be handled by the method or explicit constraints on equation properties), and interface descriptions of services implementing these methods. Equations are represented in the portable and easy to process XML encoding of the OpenMath format; descriptions of solution methods are represented as XML files that can be flexibly transformed and presented; descriptions of service interfaces are represented as WSDL (Web Service Description Language) files which contain all information to contact appropriate solution services.

Web services encapsulating the solution methods

These services provide to clients a uniform communication interface on the basis of the SOAP protocol; they accept equations represented as OM objects, convert them into the internal format of the solution method (using a so-called OM "phrasebook" for conversion to the representation format of the software system in which the method is implemented), invoke the method, retrieve its result, convert it into the OM representation, and return a message to the service client. A classification service with a high-level Java API receives an equation and analyzes it, based on the ideas sketched in the previous sections, for its properties, investigates the database of known solution methods, and returns references to those methods that seem most relevant for this type of equation. The classification service (and also the database) must be structured in a modular way such that it can be easily extended by new kinds of intrinsic properties and corresponding classifications.

A Web portal

A Web portal renders, as explained above, on the fly the information stored in the database, and provides convenient interfaces to the various available services. The average user has access to the **CENREC** via a standard Web browser as the user interface without the necessity of having any software locally installed. However, by the use of public Web protocols and supported by the provision of a high-level Java API, also any third-party software can directly access the **CENREC** (i.e., without going through the human-friendly browser interface). The development of portals components should keep the specific requirements in mind and lay at least some initial steps towards this goal. The main theoretical basics of this approach and descriptions of implemented projects see in [9]-[15].

The development of the web-based infrastructure will be (apart from the use of some commercial computer algebra systems to implement solution methods) be entirely based on open source software, such as Tomcat (a Java servlet engine for implementing Web-based dynamic content), Axis (a SOAP engine for implementing Web services), Cocoon (a framework for generating Web documents from XML), Xindice (an XML database), and the RIACA OpenMath library (a Java API for OpenMath which also provides phrasebooks for various mathematical software systems). Likewise, the software developed in this project will be made available as open source. **The advantage of OpenMath (OM)** is that it does not mix semantics with presentation (as MathML) and it is also extensible by "content dictionaries" of new symbols, while MathML has a fixed set of symbols. There exist open source OM "phrasebooks" for conversion of OM to/from the syntax of various mathematical systems. Special Tex-like format will be defined based on Tex-like syntax and text then will be fed to a translator which generates the internal OM representation. Using e.g. HyperLatex, documents of this form can be converted to HTML pages and above sections can be forwarded to Java applets embedded into the Webpage page. The Java applet could parse the equation, generate the internal representation and connect to a server that processes the equation. **All mathematical computing will be done at the remote server**: the Java applet at the client will connect to a server which in turn is connected to some Mathematica/APS installation.

Part 3: Portal as international resource

Our goal is to establish CENREC as an international resource for the ND community. CENREC will become a web portal which researchers visit regularly to interact, to obtain information, to promote the field. Our strategy to achieve this goal is based on three points: 1. higher usability through better technology; 2. attractive a high quality initial content and good promotion; and 3. innovative new ideas (as outlined below):

(a) Our content management system will implement adding, browsing a searching for worldwide events and conferences, international list of groups a scientists in the field, research news, etc.

(b) To form a governors board of CENREC consisting of the well-known and internationally distributed specialists in ND and information technologies in order to maintain the scientific content and web-performance on the highest level. Preliminary list: Kartashova, Schreiner (Austria), Nazarenko (UK), Procaccia (Israel)

(c) Integration of the CENREC content with other web pages. We plan a close cooperation with a few most notorious interdisciplinary centers of nonlinear dynamics in Europe and USA, first of all, with http://www.amsta.leeds.ac.uk/cnls/ (Leeds, UK),

http://www.lboro.ac.uk/departments/ma/research/cnlma/ (Loughborough, UK),

http://www.cns.gatech.edu/ (Atlanta, Georgia, USA).

(d) To organize the system of grants for young research students to write essays and/or research projects on specific issues of the field. These essays can become part of the encyclopedia, subject to the governor board decision. A Call for suggestions will be send to the partner ND-centers and also to the universities with high quality teaching in ND and information technologies. The governors will also organize the information about a Call being published in a few internationally notorious journals. Grants will be financed by FWF Project under the contract P20164-N18 (project coordinator – E. Kartashova).

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